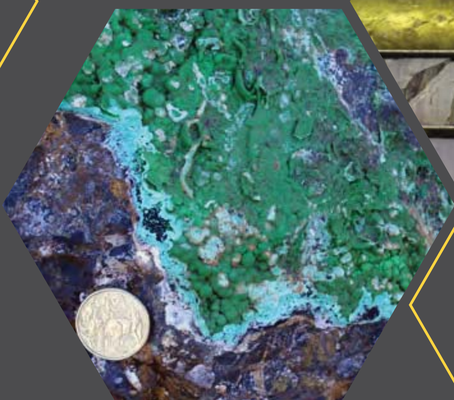
Department of Natural Resources and Mines
Geological Survey of Queensland



Queensland Minerals 2014

A summary of major mineral resources, mines and prospects

Compiled by Friedrich von Gnielinski

Queensland Government

Queensland Minerals

A summary of major mineral resources, mines and projects

2014

Compiled by Friedrich von Gnielinski

Acknowledgements:

The author wishes to acknowledge the assistance of Ian Withnall and Len Cranfield in the preparation of the Geological Framework section of this report. Ralph McIver and Graham Pope have assisted with the preparation of the Oil Shale section.

The author also wishes to acknowledge the research support from David Wallis, Courteney Dhnaram, Dominic Brown and Vladimir Lisitsin.

The desktop publishing work by Sharon Beeston and artwork by Liam Hogan in the presentation of this report is also acknowledged.

Disclaimer: All reasonable care has been taken in the preparation of this document. No responsibility is held by the Department of Natural Resource and Mines for any errors or omissions.

Address for correspondence:

Geological Survey of Queensland
Department of Natural Resources and Mines
PO Box 15216 City East 4002
Telephone: (07) 3006 4666; International +61 7 3006 4666
Email: geological_info@dnrm.qld.gov.au
Internet: www.dnrm.qld.gov.au

© State of Queensland (Department of Natural Resource and Mines) 2015

The Queensland Government supports and encourages the dissemination and exchange of its information. The copyright in this publication is licensed under a Creative Commons Attribution 3.0 Australia (CC BY) licence.

Under this licence you are free, without having to seek permission from DNRM, to use this publication in accordance with the licence terms.

You must keep intact the copyright notice and attribute the State of Queensland, Department of Natural Resource and Mines as the source of the publication.

For more information on this licence visit
http://creativecommons.org/licenses/by/3.0/au/deed.en

Cover photographs: (Clockwise from top left) Copper ore trucked at the Great Australia Mine; Bajool marble quarry — dolerite dyke intruding white marble; Andoom product conveyor; Andoom product conveyor and load-out bin loading bauxite on trains to Weipa Port; Copper chalcopyrite mineralisation in exploration core; Copper phosphate, Lorena Mine.

ISSN 1443 8747
ISBN 978-1-922067-61-6
Issued: February 2015

Reference: von GNIELINSKI, F., (Compiler) 2015: *Queensland Minerals 2014, a summary of major mineral resources, mines and projects*. Department of Natural Resources and Mines, Queensland.

Contents

Preamble . . . 1
Introduction . . . 1
Infrastructure . . . 2
Air Travel . . . 2
Road . . . 2
Rail . . . 2
Ports . . . 3
Water . . . 6
Energy . . . 6
Smelters/Refineries . . . 7
Geological framework . . . 11
North Australian Craton . . . 11
Mount Isa Province . . . 11
McArthur Basin . . . 15
South Nicholson Basin . . . 15
Etheridge Province . . . 15
Savannah Province . . . 16
Croydon Province . . . 16
Neoproterozoic – Early Paleozoic . . . 16
Georgina Basin . . . 16
Tasman Orogenic Zone . . . 16
Thomson Orogen . . . 17
Charters Towers Province (formerly Cape River Province) . . . 17
Mount Windsor Subprovince (formerly Thalanga Province) . . . 17
Greenvale Province (formerly part of the Cape River Province) . . . 17
Barnard Province . . . 18
Anakie Province . . . 18
Iron Range Province . . . 18
Mossman Orogen . . . 20
Hodgkinson Province . . . 20
Broken River Province . . . 20
Macrossan Province . . . 21
Pama Province . . . 21
Kennedy Province . . . 21
New England Orogen . . . 22
Silverwood Province and older blocks within the Yarrol Province . . . 22
Wandilla, Texas, Yarrol and Connors–Auburn Provinces and Gogango Overfolded Zone . . . 22
Gympie Province . . . 23
Southeast Queensland Volcanic and Plutonic Province . . . 24
Intracratonic basins . . . 24
Great Australian Basin . . . 25
Cainozoic sediments, volcanics and weathering . . . 25
References . . . 26
Overview of mineral commodities for Queensland . . . 33
Metalliferous Minerals . . . 33
Antimony . . . 33
Bauxite . . . 37
Base Metals: Copper . . . 42
Base Metals: Silver–Lead–Zinc . . . 74
Gallium . . . 91
Gold . . . 91
Indium . . . 116

Ironstone and magnetite 117
Lithium, tantalum and niobium 122
Mercury 122
Molybdenum and rhenium 122
Nickel, cobalt and scandium 128
Tin 133
Tungsten 140
Uranium 145
Vanadium 151
Yttrium, heavy and light Rare Earth Elements (REE) 153
Gemstones 156
Chrysoprase 156
Opal 157
Sapphire 158
Industrial minerals 160
Bentonite 160
Diatomite 163
Dolomite and earthy lime 167
Fluorite 169
Kaolin 169
Limestone and marble 173
Magnesite 181
Palygorskite 184
Perlite 184
Phosphate 188
Salt 191
Silica and foundry sands 192
Sodium bicarbonate 196
Structural clay and shale 197
Rutile, ilmenite and zircon 198
Wollastonite 202
Zeolite 203
Oil shale (updated by R. McIver & G. Pope) 204

Figures

1. Structural framework map of Queensland (Jell, 2013) 12
2. Solid geology map of the Mount Isa Province (Jell, 2013) 13
3. General geology of the southern Anakie Inlier (after Withnall & others, 1995) 19

Photographs

Photograph 1: QR's interconnected coal rail network links more than 30 mines with six export coal terminals. 2
Photograph 2: Port of Brisbane. 3
Photograph 3: Hay Point port facilities. 4
Photograph 4: Port of Weipa.. 4
Photograph 5: Port of Townsville. 5
Photograph 6: Port of Gladstone. 5
Photograph 7: Port of Cape Flattery. 5
Photograph 8: Stanwell Power Station. 6
Photograph 9: Queensland Alumina Refinery – Gladstone. 7
Photograph 10: The town of Mount Isa with the prominent Copper ISASMELT chimney and the lead ISASMELT chimney. 8
Photograph 11: Mount Isa copper smelter. 8
Photograph 12: Mount Isa copper anode wheel at the copper smelter.. 9
Photograph 13: Sun Metals Zinc Smelter — Townsville; roasting plant.. 10

Photograph 14: Aerial view of Yabulu Nickel Refinery around 2005 (now renamed to Palmer Nickel and Cobalt Refinery) 10
Photograph 15: Yabulu Cobalt Refinery (now renamed to Palmer Nickel and Cobalt Refinery). 10
Photograph 16: Old St George Antimony workings around Mitchell River.. 35
Photograph 17: Tunnel Hill mine. 36
Photograph 18: Antimony (stibnite) mineralisation from the Tunnel Hill mine, within the Northcote gold and antimony fields. 36
Photograph 19: Pisolitic bauxite from Weipa, Cape York. 39
Photograph 20: Andoom bauxite processing plant, (left) dump bridge hopper feeding bauxite into a scrubber and trammel; (centre) Andoom fines separation plant; (right) product conveyor and load out bin for train transport to Port of Weipa. 40
Photograph 21: Pisolitic bauxite from Binjour. 41
Photograph 22: Massive copper mineralisation (mostly chalcopyrite) from the 3000 ore body at Mount Isa Copper Mine. 46
Photograph 23: The Enterprise copper mineralisation within the 3000 ore body, over 1 mile below surface, Mount Isa Copper Mine 46
Photograph 24: (left) Chalcopyrite mineralisation in brecciated metasediments from the Mammoth underground mine; (right) massive chalcopyrite breccia from the Mammoth underground mine. 48
Photograph 25: The Esperanza open cut, currently used as mine water storage (panorama view). 48
Photograph 26: (left) Lady Annie electrowinning cathode production plant; (right) copper product ready for shipment. 49
Photograph 27: Lady Annie open cut.. 49
Photograph 28: Cuprite and secondary malachite mineralisation from the oxide zone at Lady Annie. 50
Photograph 29: Transition zone copper mineralisation from Mount Kelly – Flying Horse. 50
Photograph 30: Mount Oxide open cut. 51
Photograph 31: Cuprite and malachite mineralisation from Mount Oxide. 51
Photograph 32: Copper Bush (Polycarpia Glabra), a distinctive low bush which grows in clumps in areas were other plants appear absent. Its presence indicates ›300ppm Cu in soil and rock.. 52
Photograph 33: (left) Old workings in the Einasleigh area; (right) copper malachite gossan from the Einasleigh copper workings. . 52
Photograph 34: Mine truck at Ernest Henry mine. 53
Photograph 35: Copper magnetite mineralisation at Ernest Henry. 54
Photograph 36: (left) Osborne plant with headframe and conveyor belts; (right) Osborne copper mineralisation. 54
Photograph 37: Osborne open cut with underground portal at the base of the pit. 54
Photograph 38: Starra 257 open cut showing steeply dipping massive hematite bands within the Starra Line stratigraphy. Laminated hematite quartz ironstone and fine hematite mica schist are the main rock types. 55
Photograph 39: (left) Mount Elliott historical plant and workings; (right) Mount Elliott open cut.. 56
Photograph 40: Sulphide mineralisation in coarse gabbro. 56
Photograph 41: Iron-oxide copper–gold–uranium mineralisation from Amethyst Castle copper prospect. 57
Photograph 42: (left) Historical Hampden-Kuridala workings; (right) leached sulphide mineralisation and comb quartz from Hampden-Kuridala workings. 57
Photograph 43: Copper mineralisation from the Eloise underground mine. 58
Photograph 44: (left) Native copper mineralisation from the Las Minerale deposit; (right) chalcocite mineralisation from the Las Minerale deposit.. 58
Photograph 45: Historical open cut at Wilgar prospect. 59
Photograph 46: Sulphide (chalcopyrite) mineralisation from the Trekelano open cut.. 59
Photograph 47: The E1 open cut at Mount Margaret. 60
Photograph 48: Copper and magnetite mineralisation from Mount Margaret (E1).. 60
Photograph 49: Copper mineralisation at the Little Eva prospect. (Note sample in right hand photograph, placed on outcrop expression identified by presence of Copper Bush plant). 61
Photograph 50: Great Australia open cut. 62
Photograph 51: Chrysocolla, cuprite and quartz mineralisation from the oxidised zone at Great Australia mine. 62

Photograph 52: Sulphide (chalcopyrite) mineralisation from Great Australia mine. 63
Photograph 53: Taipan open cut. 63
Photograph 54: Drill core from Elaine Dorothy; a very-coarse pyroxenite with chalcopyrite and pyrrhotite mineralisation. 65
Photograph 55: Drill core from Elaine Dorothy; well-banded calc-silicate with chalcopyrite vein mineralisation. 65
Photograph 56: Massive sulphide (pyrite, chalcopyrite) mineralisation from Highway-Reward mine. 66
Photograph 57: Highway-Reward open cut. 67
Photograph 58: Panorama view of the Surveyor open cut with underground portal and waste dump refill on right of view. 67
Photograph 59: Ore carted out of Dry River South pit. 67
Photograph 60: (left) Balcooma copper underground portal; (right) Balcooma underground massive copper mineralisation (mostly chalcopyrite). 68
Photograph 61: Mount Morgan historical plant and open cuts; from left: open cut, historical chimney, sulphide mineralisation and overall view. 68
Photograph 62: Copper mineralised vein system from the Kiwi Prospect at Booubyjan. 69
Photograph 63: Copper mineralisation in drill core (KAKD1, 98m) from the Kiwi Prospect, Booubyjan 69
Photograph 64: Milled breccia with polymictic clasts of granite and granodiorite in fine molybdenum-rich matrix Wingfield Granodiorite of the Rawbelle Batholith, Whitewash South prospect. 70
Photograph 65: “Miesels” porphyry with molybdenum rosettes and chalcopyrite veinlets within the Wingfield Granodiorite of the Rawbelle Batholith, Gordons prospect, Whitewash Project. 70
Photograph 66: Porphyry with molybdenum rosettes and some chalcopyrite within the Wingfield Granodiorite of the Rawbelle Batholith, Gordons prospect, Whitewash Project. 70
Photograph 67: Biotite porphyry with disseminated copper and molybdenum and fine quartz veinlets in Wingfield Granodiorite of the Rawbelle Batholith, John Hill prospect. 71
Photograph 68: Secondary malachite mineralisation in brecciated metasediments from Baal Gammon. 72
Photograph 69: Sulphide mineralisation (mostly chalcopyrite) from Baal Gammon. 72
Photograph 70: Tartana oxidised copper ore (malachite and azurite). 73
Photograph 71: Tartana Copper Mine 73
Photograph 72: Panorama view of the Black Star open cut with the Mount Isa mine infrastructure in the background. 77
Photograph 73: Aerial view of the Mount Isa mine, showing the copper and lead zinc smelter operations (image courtesy DNRM).. 78
Photograph 74: Headframe of George Fischer Mine. 78
Photograph 75: Underground entry to the George Fischer Mine with access to the North and South deposits. 78
Photograph 76: Folded sphalerite and galena bands in metasediments in the George Fischer underground mine. 79
Photograph 77: Banded sphalerite and galena mineralisation in metasediments from George Fischer mine. 79
Photograph 78: Aerial photograph of the Century operations 80
Photograph 79: Century zinc-lead-silver plant operations. 80
Photograph 80: Dugald River underground development portal. 81
Photograph 81: (top) Exploration drilling at Dugald River; (bottom) high grade massive breccia and slaty breccia hosted zinc-lead-silver mineralisation from Dugald River 81
Photograph 82: Stratiform lead and zinc mineralisation from Cannington underground mine. 83
Photograph 83: Lead (galena) mineralisation from Cannington underground mine. 83
Photograph 84: Manganese (zinc) gossan at Pegmont. 83
Photograph 85: Thalanga processing plant viewed from the ROM pad near the primary crusher. 84
Photograph 86: Vomacka open cut. 84
Photograph 87: The West 45 underground portal. 85
Photograph 88: Early exploration drilling in the Balcooma area, around 2003. 85
Photograph 89: Mount Garnet open cut operations, around 2009. 86
Photograph 90: Skarn breccia with zinc-rich polymetallic mineralisation from Mungana mine. 87

Photograph 91: Drilling the underground zinc ore body at Mungana mine. 87

Photograph 92: Portal of Mungana underground zinc mine.. 88

Photograph 93: Silicified breccia with minor sulphides from King Vol drilling. 88

Photograph 94: Silver mineralisation from Silver Spur.. 89

Photograph 95: Massive copper mineralisation from Hornet. 89

Photograph 96: Banded open space fill alunite-sphalerite-pyrite-enargite veins from V2, within the Mount Carlton Project. 90

Photograph 97: Banded to colliform acanthite (silver sulphide) and stromeyerite (silver copper sulphide) in quartz-kaolin-dickite altered epiclastic to volcaniclastic sediments from A39, within the Mount Carlton Project 90

Photograph 98: (left) Specimen from discovery outcrop of A39; (right) A39 open cut, Mount Carlton Project 91

Photograph 99: Casting gold bullion. 92

Photograph 100: The preserved boiler at the historic Anglo Saxon mine. 96

Photograph 101: Intrusive auriferous chalcopyrite-pyrite quartz vein mineralisation from Charters Towers 97

Photograph 102: The Warrior plant at night. 97

Photograph 103: Leaf gold from the Mary Lou mine in the Charters Towers Gold Field 98

Photograph 104: Historical workings in the vicinity of the Big Vein resource at Woolgar. 99

Photograph 105: Intrusion-related breccia, with infilled sulphides into granite, from Mount Leyshon. 100

Photograph 106: Breccia with mineralisation within the Millaroo Granite from Mount Wright underground mine. 100

Photograph 107: Panorama view of the Sarsfield open cut in 2011, showing the plant in the background and waste refill in the back section of the pit. 100

Photograph 108: Gold mineralisation in the structurally controlled Inglewood Lode quartz, Gympie mine 102

Photograph 109: Headframe of the Gympie Scottish Nr.2, around 1996. 102

Photograph 110: The Gympie Eldorado treatment plant in 1996. 103

Photograph 111: Treatment plant at Mount Rawdon. 103

Photograph 112: Mount Rawdon open cut viewed from the lookout point.. 103

Photograph 113: Pyroclastic rock within the Aranbanga Volcanic Group hosted very fine disseminated auriferous pyrite, from Mount Rawdon. 104

Photograph 114: Mineralised (non-visible disseminated auriferous pyrite) dacite within the Aranbanga Volcanic Group, from Mount Rawdon. 104

Photograph 115: Horn Island Gold Mine plant in 1990. 104

Photograph 116: (left) Gold and base metal (mostly lead and zinc) in a silicified porphyry breccia from Horn Island; (right) massive sphalerite, chalcopyrite and galena bands as vein-infill from Horn Island. 105

Photograph 117: Welcome Siliceous Breccia with tin-quartz-fluorite mineralisation from Horn Island. 105

Photograph 118: Outcrop of mineralisation in sheared granite at Big Reef East, Georgetown region. 106

Photograph 119: (left) Epithermal quartz veins from Pajingo; (right) mineralised sheared fault in Vera Nancy (Pajingo) open cut (image courtesy Vladimir Lisitsin, GSQ). 107

Photograph 120: (left) Twin Hills processing plant in 2005; (right) Twin Hills underground portal opened in 2005 108

Photograph 121: Golden Plateau open cut with underground portal in 1997, Cracow Gold mine. 108

Photograph 122: (above) Auriferous colliform quartz veining and brecciation, Cracow Gold mine; (right) auriferous quartz veining with adularia alteration, GoldenPlateau open cut, Cracow Gold mine. 108

Photograph 123: Mineralised vein breccia and silicified volcanic rock at Roses Pride underground mine, Cracow. 109

Photograph 124: Cracow Gold Mine plant in 'care and maintenance' in 1997, as operated by the Cracow Mining Venture. 109

Photograph 125: Siliceous epithermal breccia in Robin Hood Granodiorite near Sherwood, Agate Creek Project. 110

Photograph 126: Stockworked veining in highly altered Robin Hood Granodiorite near Sherwood, Agate Creek Project.. 110

Photograph 127: Discovery outcrop at A39; outcrop expression of high grade silver mineralisation, Mount Carlton Project. 111

Photograph 128: Mineralised quartz veins from Glen Eva. 111

Photograph 129: Mount Morgan mine site showing the main chimney and former mine buildings.. 112

Photograph 130: (a, left) Fine quartz-feldspar laminite bands in Corella Formation, host to the gold mineralisation at Tick Hill; (b, centre) High-grade gold mineralisation in quartz-feldspar laminate bands granofels “galahstone’ in Corella Formation at Tick Hill; (c, right) The Tick Hill open cut looking south. The steeply dipping light coloured band of laminated granofels, which holds the gold mineralisation, is distinct at the ‘back’ of the pit flanked by the quartzites and biotite schists (purple-red colours). . 113

Photograph 131: Sulphide mineralisation (arsenopyrite with gold) from an ore lens in the Lorena Gold mine open cut. 114

Photograph 132: Copper (arsenic) phosphate mineralisation from oxidised zone at Lorena Gold mine. 114

Photograph 133: Red Dome open pit. 115

Photograph 134: Processing of alluvial gravel at the Prophet Gold Mine, Kilkivan. 115

Photograph 135: Sluice box with carbon matt for collecting fine alluvial gold from gravel at the Prophet Gold Mine, Kilkivan. 116

Photograph 136: Primary (unoxidised) iron ore concentrate at -70µm (>63% Fe) produced at Mount Moss, (this product is used in the coal washing industry or as sinter cake in the steel refining industry). 117

Photograph 137: Open pit of Mount Moss magnetite mine. 120

Photograph 138: Magnetite screening plant at Mount Moss. 120

Photograph 139: Magnetite bearing ferrigabbro within layered basic igneous complex within Rawbelle Batholith in Delubra Quarry, Hawkwood deposit. 121

Photograph 140: Biggenden open cut and underground portal in 2009. 122

Photograph 141: Fault breccia infill in highly altered metasediments with molybdenite and rhenium mineralisation from the Merlin deposit. 125

Photograph 142: Porphyry breccia with earlier chalcopyrite veinlets and later-stage molybdenite and rhenium mineralisation veinlets from Merlin deposit. 125

Photograph 143: Crystalline platy molybdenite from pipe margins of intrusive quartz lodes into greisenised granite from the Wolfram Camp mine. 126

Photograph 144: Remains of the headframe and the mullock heap of the Wonbah Molybdenite mine, near Mount Perry. 127

Photograph 145: Yabulu nickel refinery; stockpile of imported nickel laterite 128

Photograph 146: Aluminium-scandium master alloy, Metallica Metals 2012. 131

Photograph 147: Lateritic nickel ore from the Greenvale Nickel mine open cut. 132

Photograph 148: Erythrite (secondary cobalt mineralisation) veins in metasediments from Mount Cobalt. 133

Photograph 149: Tin vein (Cornish style) mineralisation in granite from New St Patrick mine, near Herberton.. 137

Photograph 150: Tin mineralisation from the Great Adventure mine, near Irvinebank. 137

Photograph 151: General view of the Mount Veteran tin milling plant. 138

Photograph 152: Exploration work on the Dalcouth tin prospect. 138

Photograph 153: Cassiterite quartz vein mineralisation at Dalcouth prospect. 139

Photograph 154: Outcrop expression (tin mineralisation) at Gillians prospect, near Mount Garnet 139

Photograph 155: Tungsten quartz vein mineralisation from Mount Carbine wolfram mine.. 142

Photograph 156: Wolframite and molybdenite mineralisation in Wolfram Camp open cut.. 142

Photograph 157: Wolframite and molybdenite mineralisation in quartz vein lode within granitic greisen in Wolfram Camp open cut. 142

Photograph 158: Panorama view of the open cut, waste dump and plant operations at Wolfram Camp mine. 143

Photograph 159: Scheelite mineralisation under ultra violet light in drill core from the Watershed tungsten project. 143

Photograph 160: Quartz veins with disseminated scheelite mineralisation intruding metasediments of the Hodgkinson Formation at the Watershed tungsten project.. 143

Photograph 161: Mount Carbine open cut (water is about 45m deep). 144

Photograph 162: (left) Mount Carbine tailings retreatment plant; (right) Mount Carbine tailings dam currently being re-worked. Note the fine layering in the material in the background. 144

Photograph 163: Mary Kathleen open cut 145

Photograph 164: Conglomerate ridges with sediment-hosted uranium mineralisation at Huarabagoo, Westmoreland.. 147

Photograph 165: Drilling site of the Valhalla uranium prospect. 149

Photograph 166: High grade uranium mineralisation from Mary Kathleen open cut, sampled around 1980 from mining operations. . . . 149

Photograph 167: High grade uranium mineralisation from Mary Kathleen open cut, sampled around 1980 from mining operations. . . . 149

Photograph 168: Uranium mineralisation within shear zones in Saint James Volcanics at the Ben Lomond prospect. . . . 150

Photograph 169: Secondary torbernite crystals from the Milo project. . . . 150

Photograph 170: Drill core from Elaine Dorothy in quartz veined and foliated pyroxenite with an extremely high radioactive response (uranium mineralisation present). . . . 151

Photograph 171: Drill core from Elaine Dorothy in coarse-grained massive sulphides in pyroxenite with an extremely high radioactive response (uranium mineralisation present). . . . 151

Photograph 172: R.C. drill chips of yttrium mineralisation contained in the mineral xenotime from the Korella Rare Earths prospect.. . . . 154

Photograph 173: Svanbergite-rich concretionary nodules from the Coorabulka deposit. . . . 154

Photograph 174: IOCG style Cu–Au–Ag–Mo–U–Co mineralisation from the Milo project.. . . . 154

Photograph 175: Chrysoprase from the Marlborough deposit. . . . 156

Photograph 176: Chrysoprase veins in nickeliferous laterite from the Marlborough deposit. . . . 156

Photograph 177: The Gumigil Marlborough open cut worked for chrysoprase.. . . . 157

Photograph 178: Rough and polished Queensland opal (boulder opal) . . . 157

Photograph 179: Numerous examples of polished boulder opal displaying some ironstone rock along margins . . . 157

Photograph 180: Small miner’s opal mining claim near Quilpie. . . . 158

Photograph 181: Cut gold and blue sapphires from the central Queensland gem fields.. . . . 159

Photograph 182: (left) One of several deep open cuts down to the ‘wash’ levels of the alluvium at the Australia Mine; (right) mobile alluvial screening plant at Australia Mine. . . . 159

Photograph 183: A bentonite seam in the Walloon Coal Measures at the Jeebropilly open-cut coal mine, Rosewood . . . 162

Photograph 184: Cedars mine open cut, source of sodium bentonite from flat-lying altered volcanic sediments formed in a lacustrine environment.. . . . 163

Photograph 185: Diatomite frustlules (25 to 30 microns long) from the Conjuboy diatomite deposit . . . 165

Photograph 186: Lacustrine style bentonite deposit overlain by basalt lava flows at Mount Sylvia bentonite mine . . . 165

Photograph 187: Mount Sylvia bentonite processing and drying plant. . . . 165

Photograph 188: Maidenwell processing plant . . . 166

Photograph 189: Bentonite rock from the Maidenwell deposit. . . . 166

Photograph 190: Dolomite and palygorskite (bottom levels) mined from Wadley Lease by Moreton Dolomite.. . . . 169

Photograph 191: The Skardon River kaolin processing plant in 2003, before it was removed around 2008 . . . 173

Photograph 192: East End limestone mine open cut. . . . 176

Photograph 193: Some varieties of limestone from the East End open cut (above and right).. . . . 177

Photograph 194: Sibelco’s Riverton limestone plant viewed from the limestone quarry. . . . 177

Photograph 195: The Murgon limestone open cut in 2005. . . . 178

Photograph 196: (left) Automated slab polisher at Cairns Marble & Granite’s workshop (=trade name for Cairns Marble Australia Pty Ltd); (centre) showroom at Cairns Marble & Granite display of tiles, furniture and sculptures made of Chillagoe marble; (right) slab cutting box at Cairns Marble Australia Pty Ltd’s Chillagoe processing facility. . . . 178

Photograph 197: (a) White fine-grained marble (trade name: Bianca) within the Chillagoe Formation, from Bianca Quarry; (b) White to cream-coloured marble (trade name: Gold Drop) within the Chillagoe Formation from the Champagne 2 quarry; (c) Fine to medium grained pink crystalline marble within the Chillagoe Formation from the 5-Storey quarry; (d) Light grey to cream-coloured marble with limonite breccia infill (trade name: Oracia Gold) within the Chillagoe Formation from the Oracia quarry; (e) Medium to coarse-grained light to dark blue crystalline marble (trade name: Aquamarina) within the Chillagoe Formation from the Aquamarina quarry; (f) Very coarse-grained crystalline white marble (trade name: White Pearl) within the Chillagoe Formation from the White Pearl quarry; (g) Variably grained light grey and white marble within the Chillagoe Formation, which contains skarn minerals like wollastonite and vesuvianite. The marble also contains common medium-grey metasediment clasts and shows signs of brecciation. The marble originates from the Wollastonite pit. (h) Very fine to fine-grained black limestone (trade name: Black Ice) with megafossils (bivalves) at the top level in outcrop (not in the photograph). This limestone is also part of the Chillagoe Formation originating from the Black Ice pit. (i) A marble breccia hosted in the black limestone with recrystallised white calcite and red iron-oxidised carbonates (Trade name: Dreamtime, also called Airport, since this stone was used at the terminal of Cairns International Airport). This marble has been cut from surface outcrop. A small pit is referred to as Airport pit. 179

Photograph 198: (a) White marble blocks stockpiled for future use at the White Pearl quarry; (b) the Aquamarina quarry; (c) the 5-Storey quarry; (d) the Bianca quarry.. 180

Photograph 199: The Bajool Marble East pit.. 180

Photograph 200: Crushing operations at Bajool Marble mine.. 181

Photograph 201: The historic Ulam Marble quarry, source of some building stone in the Brisbane CBD in the early 1900s. 181

Photograph 202: The Kunwarara Magnesite plant operations 183

Photograph 203: Light-coloured magnesite nodular horizon under black clay-soil overburden at Pit 23, Kunwarara Magnesite mine 183

Photograph 204: Parkhurst magnesia processing plant near Rockhampton. 183

Photograph 205: A white palygorskite clay is overlain by dolomite in the open cut on the Wadley Lease on the Flinders Dolomite Ridge. 184

Photograph 206: Machinery at the Moreton Dolomite Leases 184

Photograph 207: Making crushed perlite expand under red heat (demonstration only), ... 186

Photograph 208: The Nychum perlite open cut, north of Chillagoe.. 186

Photograph 209: Dark green Nychum perlite. 187

Photograph 210: The ‘Chillagoe’ perlite processing plant in Mareeba. 187

Photograph 211: Cut banded perlite from Numinbah. 187

Photograph 212: Mining phosphate rock from flat-lying phosphatic siltstone within the Beetle Creek Formation at Phosphate Hill 190

Photograph 213: Ammonium phosphate fertiliser stockpiled at Phosphate Hill 190

Photograph 214: Phosphate rock sample from Krucible’s Korella project 191

Photograph 215: The white silica sand dunes of Cape Flattery. 195

Photograph 216: Bulk loading of sillica sand in conveyor belt to the wharf at Cape Flattery 195

Photograph 217: White sand dune sands held by vegetation at Morgans Landing, Cape Flattery. 195

Photograph 218: Two quartz bluffs at Lighthouse quartz deposit, with crushed and screen material in foreground. 196

Photograph 219: Automated cutting of clay pavers prior to kiln firing at Claypave’s Dinmore plant 197

Photograph 220: One of several clay pits within the Dinmore clay mining leases 197

Photograph 221: Clay pavers stacked loosely for firing in Kiln train at Claypave’s Dinmore plant. 198

Photograph 222: The mineral sands dredge on Stradbroke Island around 2005 200

Photograph 223: Rutile, zircon and ilmenite products undergo final separation and clean-up at the dry mill at Pinkenba 201

Photograph 224: The new ilmenite, zircon and rutile processing plant at the Goondicum Crater near Monto.. 201

Photograph 225: Exposure of weathered ilmenite, zircon and rutile in decomposed gabbro and pegmatite dykes within the Goondicum Crater. 201

Photograph 226: The pen marks area in photograph showing wollastonite mineralisation in Chillagoe marble from the Wollastonite pit, owned by Chillagoe Marble Australia Pty Ltd. 202

Photograph 227: Queensland Zeolite’s processing plant at Willow zeolite mine.. 203

Photograph 228: Open cut at Willow zeolite mine exposing flat-lying, very fine-grained water-lain ash-tuff beds. 203

Photograph 229: Zeolite crystals in basalt from the Main Range Volcanics, near Toowoomba. 204

Photograph 230: Lowmead oil shale open pit. 206

Photograph 231: Stage one of QER Pty Ltd’s Stuart Oil Shale project 207

Photograph 232: Stage one Stuart Oil Shale plant; rotary dryer and processor 208

Photograph 233: The Stuart oil shale plant, 2013. 208

Tables

Table 1. Subprovinces of the Kennedy Province (after Mackenzie & Wellman, 1997) . . . 21
Table 2. Incratonic basins of the Tasman Orogenic Zone . . . 24
Table 3. Cainozoic basins of Queensland . . . 25
Table 4. Major antimony deposits of Queensland . . . 35
Table 5. Bauxite deposits of Queensland . . . 37
Table 6. Major copper deposits of Queensland . . . 43
Table 7: Major Ag-Pb-Zn deposits of Queensland . . . 74
Table 8. Major (medium-large-giant) gold deposits in Queensland . . . 94
Table 9. Major ironstone and magnetite deposits in Queensland . . . 119
Table 10. Molybdenum and rhenium deposits of Queensland . . . 124
Table 11. Major nickel and cobalt deposits of Queensland . . . 130
Table 12. Tin deposits of Queensland. . . . 134
Table 13. Tungsten deposits of Queensland . . . 140
Table 14. Uranium deposits of Queensland . . . 146
Table 15. Vanadium deposits of Queensland. . . . 153
Table 16. Significant bentonite deposits of Queensland. . . . 160
Table 17. Dolomite and earthy lime deposits of Queensland . . . 167
Table 18. Kaolin production and resources in Queensland. . . . 171
Table 19. Major limestone deposits in Queensland . . . 175
Table 20. Major phosphate deposits in Queensland . . . 188
Table 21. Major silica and foundry sand deposits in Queensland . . . 194
Table 22. Major rutile, ilmenite and zircon deposits in Queensland . . . 200
Table 23. Oil shale deposits of Queensland . . . 206

Appendices

1. Summary reports for operating mines in Queensland
2. Summary reports for major prospects in Queensland
3. Total contained metal in Queensland's major mineral deposits calculated from reported resource/reserve figures
4. Contained metal in known reserves/resources by commodity and reserve/resource classification
5. Resource grade and contained metal for Queensland's significant mineral deposits
6. Total commodity produced from Queensland's major mineral deposits
7. Deposit model and host geological province
8. Classification table
9. The JORC Code
10. General contact and company contact information
11. Principal holders of mineral exploration tenure in Queensland as at September 2014

Queensland Minerals

2014

A summary of major mineral resources, mines and projects

Preamble

The Queensland Minerals publication is designed primarily to provide a summary of the major mineral resources in Queensland and to assist in promoting exploration and mining development. A more comprehensive review of Queensland's non-energy mineral deposits and resources was given by Denaro (2011). The following report presents known reserves/resources, production and geological information for the significant mines (both operating and abandoned) and prospects in Queensland. In addition to this publication there is a detailed database available on DVD as *Mineral Occurrence and Geology Observations*, which contains all available data on mines, prospects and mineral occurrences in Queensland. Deposit summary reports have been produced from this database for the major deposits and are included as Appendices 1 and 2. Tabulations of geology, resource and production data form the remaining appendices.

Introduction

Queensland is an important mineral producing state in Australia. In 2011–12 (2012–13) the total value of production of Queensland's minerals was A$7.86 (A$7.88) billion (excluding coal, gas and petroleum). The value of metalliferous mining to Queensland in 2012–13 was $7.39 billion compared with $7.86 billion in 2011–12. Although coal remains Queensland's largest export commodity, and the burgeoning coal seam gas industry will be another major driver of our economy in the near future, metalliferous mining continues to be a significant contributor, with Queensland currently leading Australia in the production of copper, lead, silver and zinc. Mining (including coal and petroleum) currently provides more than 60.7% of Queensland's total exports. The mining sector employs around 69 000 people directly as well as another 210 000 people indirectly in regional and outback Queensland.

In 2011–12 (2012–13) Queensland produced 429°783 t (421°549 t) metallic minerals of lead, 1 008°416 t (971°425 t) of zinc, 1481 t (1481 t) of silver, 271°623 t (260°359 t) of copper, 21°560°315 t (25°276°338 t) of bauxite and 16.2 t (11.8 t) of gold. Also since 2011 Queensland produced 31 t for A$ 881°977 (226 t for A$ 7.04 million) of tungstic oxide. A wide range of industrial minerals are also produced in Queensland, of which phosphate rock (883°047 t for A$37.08 million) (2°062°509 t for A$184.67 million), limestone (3°281°794 t for A$28.1 million) (3°513°856 t for A$33.5 million), zircon (60°897 t for $132.9 million) (83°731°t for A$128.5 million), silica sand and lump 2°263°758 t for A$37.4 million (2°336°281 t for A$ 58.8 million) and magnesite (587°688 t for A$52.9 million) (503°735 t for A$35.3 million) yielded the highest returns.

The state has also begun a new era with the mining of magnetite, tungsten, molybdenum and rhenium. The number of advanced mineral projects in Queensland is also encouraging and includes some commodities not currently being mined such as nickel, cobalt, scandium and tin. Rhenium and scandium are important to emerging technologies. Since November 2012 the mining ban of uranium in Queensland has been lifted, but the lead time for uranium projects to reach production may take several years. Various operating mines that may be able to process uranium as a by-product, may also need time to incorporate an additional circuit.

North Queensland contains several significant deposits including the Pajingo epithermal gold-silver deposit, intrusive-related gold systems at Ravenswood and Charters Towers, lateritic nickel–cobalt deposits at Greenvale and Bell Creek, and volcanic-hosted massive sulphide (VHMS) deposits at Balcooma, Dry River South and Surveyor. The Cape York region, in far north Queensland, is well known for having undergone extensive lateritisation, producing large deposits of bauxite at Weipa and Aurukun and kaolin adjacent to the Skardon, Kendall and Pennefather Rivers. Along the east coast of far north Queensland, vast silica sand resources are mined at Cape Flattery. The Wolfram Camp and Mount Carbine tungsten mines were reopened early 2012.

North-west Queensland is a major base metals province and contains most of the state's giant orebodies, including Mount Isa (incorporating the Enterprise Cu and the Mount Isa, Hilton and George Fisher Ag-Pb-Zn orebodies), Century, Cannington, Ernest Henry, Osborne and Dugald River. This region produces about 75% of the value of metallic minerals recovered in Queensland and is Australia's largest source of copper. The Century zinc-lead-silver mine produces ~7.9% of the world zinc supply and the Cannington mine is currently the world's largest single mine silver-lead producer. Extensive phosphorite deposits are mined at Phosphate Hill, and a new phosphate rock mine was planned to commence at Korella in 2013, but is now on hold subject to ratification of sale to Daton Group Australia Ltd.

In central Queensland, epithermal gold deposits are mined at Cracow. Large lateritic nickel–cobalt resources have been defined in the Marlborough area. The Brolga mine commenced production in late 2012. This region also contains the world's largest deposit of cryptocrystalline magnesite at the Kunwarara Mine, north of Rockhampton. The magnesite is processed into caustic calcined, deadburned and electrofused magnesia, with future plans to diversify products further.

Infrastructure

Queensland is positioned in an ideal location for servicing the mining industry, with the State's major mining centres supported by an integrated network of communications, power, water pipelines, fuel access, road, rail, port and airports.

Air Travel

Three international airports in Brisbane; Townsville and Cairns facilitate overseas travel. Most regional centres are serviced by regular domestic aeroplane flights. However, remote mines usually fly employees out to the mine site using either their own planes or chartered flights.

Road

Queensland roads provide an efficient network of well-maintained major urban and rural roads totalling around 189 337 km. Queensland has the nation's largest state-controlled road network, consisting of 33 337 km of roads and more than 6500 bridges and major culverts. Additionally there are over 156 000 km of local government roads comprising 132 000 km of rural roads and 24 000 km of urban roads. Better road access reduces transport costs for companies and impacts on their competitive position in the domestic and global marketplace.

Rail

Queensland had 9982 km of railway line in the rail network in 2012, of which 1877 km was electrified with a 25 000v 50Hz AC supply. The rail network is narrow gauge (1067 mm), except for 99 km of standard gauge (1435 mm) track between Brisbane and the Queensland – New South Wales border and 36 km of dual gauge. Queensland Rail (a Government-owned corporation) provides a fully coordinated commercial rail transport service to the mining industry with currently 7600 km of railway line (Photograph 1). Queensland Rail finances funding for all locomotives and wagons required for the mining industry, except in circumstances where specialised equipment is necessary. Queensland Rail also maintains existing rail track and the rollingstock fleet, recovering costs through freight charges. Queensland Rail is the main commercial rail freight operator but third party access to the rail infrastructure is possible under recent rail reform programs. QR National operates 2670 km of railway line as a coal network heavy haul rail infrastructure in Central Queensland, providing the transport backbone for one of the world's largest coal supply chains.

During 2012 the Cloncurry rail load-out facility achieved Government support. Being developed under a joint venture between MMG Limited, CuDeco Limited and Xstrata Copper, the facility provides critical rail loading infrastructure for their mining operations at Dugald River, Rocklands, and Ernest Henry respectively. The facility is planned to be operational in 2014 and provide the ability to transport approximately 2.1 Mt per year of high-value mineral concentrates to the Port of Townsville for export. Progression of the facility to a true commercial multi-user development to potentially accommodate other new mineral projects into the future is also supported by the Government.

Photograph 1: QR's interconnected coal rail network links more than 30 mines with six export coal terminals (Courtesy QR, Queensland Minerals and Petroleum Review 2003).

Ports

The Queensland coastline is host to fifteen modern trading ports, two community ports, numerous non-trading ports and a capital city multi-cargo port. Trading ports predominantly handle bulk commodities, while community ports service local populations with general cargo. Port charges are set by commercial negotiation and there is no set government regulated schedule of fees. However, pilotage and conservancy dues (for channel beacons and marker maintenance) are government regulated.

The Queensland port system's total throughput in 2012–13 was 286.39 Mt. Of the total exports of 238.22 Mt, coal formed 75.58%, bauxite formed 12.15%, alumina and aluminium formed 2.19%, metals formed 2.08%, petroleum products formed 1.17%, and silica sand formed 0.73%.

There are five port entities operating Queensland's port system. All of these operate under the provisions of the *Transport Infrastructure Act 1994* and the *Government Owned Corporations Act 1993*. Of the five entities there are four government-owned corporations, as well as one private port leaser managing and operating ports in Queensland:

1. Port of Brisbane Pty Ltd is a private corporation owned by Q Port Holdings, which has operated the port of Brisbane since July 2010.

The four Government-owned corporations are:

2. North Queensland Bulk Ports Corporation (NQBP)
3. Port of Townsville Limited
4. Gladstone Port Corporation
5. Ports North.

1. **The Port of Brisbane** at Fisherman Islands, 20 km east of the Brisbane central business district, is Queensland's largest multi-user and general cargo port. This port (Photograph 2) is operated as a private company Port of Brisbane Pty Ltd, since July 2010, when the Government transferred all equipment and machinery, including the dredging fleet, from the former Port of Brisbane Corporation. Trade throughput for 2012–13 was 37.16 Mt which included the export of 81 372 t of silica sand, exported iron and steel (614 179 t), and 191 474 t of mineral ores and sands. The key export commodities remain coal (8 302 462 t) and refined oil (2 786 140 t). Imports included 346 458 t of gypsum and limestone and 760 868 t of iron and steel. The key import commodity comprises crude oil (8 354 946 t).

Photograph 2: Port of Brisbane (image courtesy of Brisbane Marketing, photo: Jesse Smith).

Photograph 3: Hay Point port facilities.

2. The North Queensland Bulk Ports Corporation (NQBP) operates four trading ports and one community port (Maryborough) in Queensland: The two ports of Abbot Point and Hay Point service the central Queensland coal mines. The Port of Abbot Point exported 17.7 Mt of coal in 2012–13. Hay Point, which handles about 35% of Queensland's total throughput via its Dalrymple Bay Coal Terminal and Hay Point Services Terminal (Photograph 3), exported 96.5 Mt of coal in 2012–13, an increase to previous years attributed to the 2011 wet weather conditions. Mackay is a general cargo port exporting sugar and grain and importing petroleum products and iron concentrates (52 439 t).

The Port of Weipa, on the Embley River on the west coast of Cape York Peninsula, is primarily dedicated to bauxite export. Total bauxite export throughput for 2012–13 was 29 041 572 t (Photograph 4). More than 70% of this was shipped to the Queensland Alumina Ltd and Yarwun alumina refineries in Gladstone. The remainder was shipped to the Eurallumina SpA refinery in Italy and a hydrating plant in Korea.

Photograph 4: Port of Weipa.

3. The Port of Townsville Limited incorporates the Port of Townsville and the Port of Lucinda (raw sugar). **The Port of Townsville** has nine operational berths (five equipped to handle metal and mineral cargo) equipped with bulk handling facilities including pipelines for oil, gas, chemicals and molasses; ship-loaders for sugar and metal concentrates; cranes for containers, metals, nickel ore and break-bulk cargo. A new commodity exported from this port is lump magnetite. In 2012–13 the Port of Townsville saw a repeated record high trade throughput reaching 12.6 Mt (2011-12 was 13.0 Mt), comprising of 6.67 Mt of imports and 5.43 Mt of exports (Photograph 5). Improvements at the Queensland or Palmer Nickel and Cobalt Refinery at Yabulu, the start of Mount Moss Mine lump magnetite exports and significantly increased export volumes of zinc ferrite and refined zinc from the Sun Metals refinery have contributed to the strong performance of the port. Trade throughput included export of 276 305 t of copper concentrate, 1705 t of silver concentrate, 484 363 t of refined mineral products, 365 430 067 t of lead concentrate, 889 953 t of zinc concentrate, 810 338 t of high analysis fertiliser, 210 175 t of zinc ferrites (metal by product) and 12 488 t of sulphuric acid. New export commodities included 773 177 t of lump magnetite. No more zinc oxide was exported due to the closure of Kagara. Imports included 3 958 967 t of nickel ore and 322 078 t of zinc concentrate.

4. The Gladstone Ports Corporation Limited controls the ports of Gladstone, Rockhampton (general cargo, ammonium nitrate) and Bundaberg (sugar and molasses). The **Port of Gladstone** is Queensland's largest multi-commodity port, housing the world's fourth largest coal export terminal. Total trade throughput for the three ports for 2012–13 was 85.8 Mt. The coal export through Gladstone, which was affected by the 2011 floods has recoverd to 64.6 Mt (which is a good average value for the last five years with

Photograph 5: Port of Townsville (© Ray Cash Photography).

exception of the 2011 figures). The total export also included 1 101 711 t of cement/cement clinker, 141 078 t of calcite, 28 527 t of limestone, 58 412 t of magnesia, 11 684 t of electrofused magnesia, 334 883 t of aluminium and 4 891 708 t of alumina. Imports included 16 321 662 t of bauxite and 98 312 t of magnetite (Photograph 6).

5. The Ports North (Far North Queensland Ports Corporation Limited; Government-Owned Corporation) operates nine ports in Queensland: They are the ports of Cairns, Quintell Beach, Thursday Island, Burketown, Cooktown, (all general cargo and community ports), Mourilyan (sugar and molasses), Karumba, Skardon River and Cape Flattery. The last three ports serve to export mineral products from the state to international markets.

The Port of Cape Flattery, 200 km north of Cairns, is dedicated to the export of silica sand, with an annual capacity of up to 2 Mtpa. In 2012–13, exports totalled 1 678 060 t of silica sand (Photograph 7).

Photograph 6: Port of Gladstone.

Photograph 7: Port of Cape Flattery (image courtesy Bob Bultitude, GSQ).

The Port of Karumba, at the mouth of the Norman River in the southeast corner of the Gulf of Carpentaria, is a general purpose port. In 2012–13 the port exported 880 123 t of zinc and lead concentrate. Lead-zinc concentrate is pumped via a slurry pipeline 304 km from the Century mine, dried and transported on 5000 t barges through the shallow inshore waters to larger export vessels.

No trade figures are reported for Skardon River.

Water

Water is the lifeblood of the State. The Department of Energy and Water Supply (DEWS) manages dams, weirs and irrigation, as well as supplying bulk water for irrigation, mining, industrial and urban use.

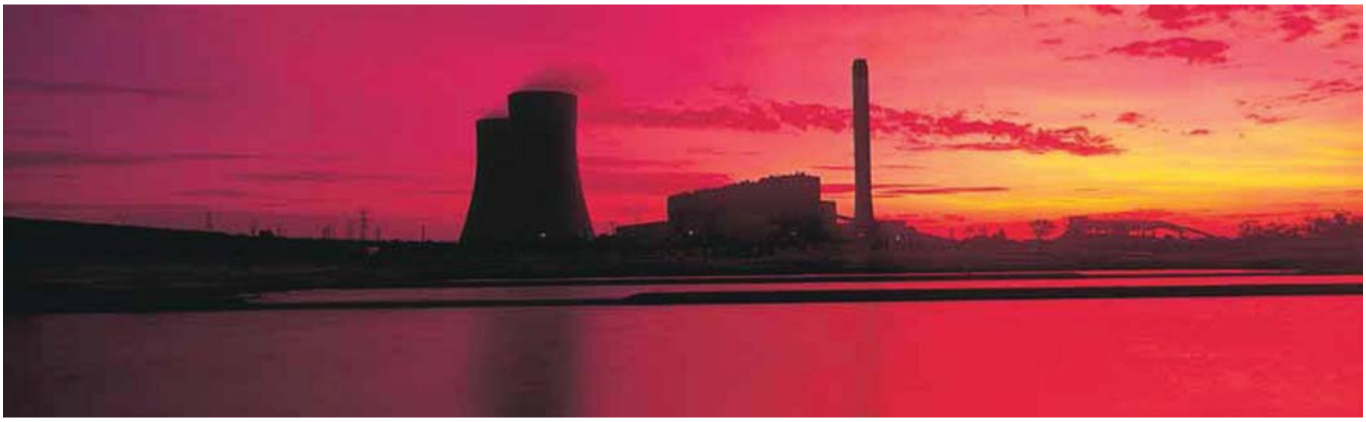
DEWS may license a company to take water direct from the source (river, stream or underground) or, by agreement, from dams, weirs, pipelines and borefields. Mining companies may also own and operate infrastructure, including dams, weirs, borefields and pipelines. DEWS also has the authority to license privately developed water conservation and supply schemes.

The Queensland Government has implemented a framework for allocating and managing the State's water resources. This framework is based on a formal water allocation and management planning process that promotes ecological sustainability and facilitates economic development, particularly in regional areas. The framework provides for the trading of water entitlements and the adoption of an effective pricing regime.

Energy

Queensland is the fastest growing region in the National Electricity Market. Since 1998, $4.7 billion or 75% of new generation investment in the National Electricity Market (NEM) has occurred in Queensland.

Queensland has substantial reserves of energy, ensuring its ability to provide economical and dependable electricity that is mainly derived from coal-fired power stations (about 81% in 2012, Photograph 8). Reserves of coal-bed methane, natural gas and oil supplement industrial and domestic requirements. Renewable energy is also playing an important role in contributing about 4% of electricity generated and about 5% of generating capacity in Queensland. The challenge to maintain high quality and low cost of Queensland fuel sources, its potential renewable energy sources, and their proximity to load growth to support generation investment in this state will continue, since cost and quality of energy is one major factor for feasibility studies for new and existing mineral projects.



Photograph 8: Stanwell Power Station (image courtesy Stanwell Corporation; Queensland Mineral and Petroleum Review, 2003).

The State currently has a generation capacity of more than 14 500 megawatts (2012), and this originally increased with the physical connection of Queensland to the national grid in 2001. This ensured that consumers enjoyed the maximum benefits available from the competitive electricity market. Since 2012 the Department of Energy and Water Supply (DEWS) has been responsible for the state's energy and water industries.

Reference: https://www.business.qld.gov.au/industry/energy/electricity-industry/electricity-queensland/electricity-generation

Queensland has considerable reserves of coal seam gas and decreasing reserves of natural gas, which are playing a continually important role as a clean and cost-effective energy resource.

Queensland Government policy has also driven the exploration and development of the large coal seam gas (CSG) resources in Queensland. Queensland's CSG industry has grown rapidly over the past 15 years — the annual number of wells drilled increased from 10 in the early 1990s to a record 771 in 2011–12. Drilling rates have climbed to 1371 wells in 2012–13 comprising 54 conventional and 1317 CSG wells.

In 2012–13, total gas production stands at 298 petajoules, comprising 264 petajoules of CSG and 34 petajoules of conventional gas. At the end of the same period future reserves of CSG were calculated at 37 729 petajoules, whereas the remaining conventional gas reserves have declined to 497 petajoules.

Smelters/Refineries

Queensland Alumina Ltd Refinery — Gladstone: The Queensland Alumina Ltd (QAL) refinery at Gladstone is one of the world's largest alumina refineries and is owned by a consortium of two international companies — Rio Tinto Alcan (80%) and Rusal (20%). The refinery processes bauxite from Weipa and began production of smelter grade alumina in 1967. At commencement, the alumina production capacity of the refinery was 732 000 t per year. Four major expansions have more than trebled QAL's capacity to 3.95 Mt of alumina per year. The refinery uses the Bayer process, in which the aluminium component of bauxite ore is dissolved in sodium hydroxide. Alumina trihydrate is precipitated and calcined to produce alumina (aluminium oxide) (Photograph 9).

Photograph 9: Queensland Alumina Refinery – Gladstone (© Bruce Peebles 2008).

Yarwun Alumina Refinery — Gladstone: The Yarwun alumina refinery is 10 km northwest of Gladstone. It is 100% owned by Rio Tinto Alcan. The refinery utilises the BAYER process to refine bauxite into alumina. Grinding mills prepare the bauxite for high temperature digestion where aluminium hydroxide is dissolved from the bauxite into a solution of caustic liquor. The resultant liquor and solids are separated in clarifiers before the liquor is sent to precipitation. Open top precipitation tanks allow hydroxide crystals to form from the super saturated liquor. These crystals are then heated in calciners to remove water molecules and produce alumina powder which is stored for shipment to domestic and international customers. The first stage of the refinery has an annual capacity of 1.4 Mt of smelter-grade alumina. The first shipments from the refinery were made in November 2004. A US$1.8 billion expansion has been completed which increased the annual production to 3.4 Mt when Yarwun 2 became operational.

Boyne Smelters Ltd — Gladstone: Boyne Smelters Ltd is on Boyne Island, just south of Gladstone and is owned by a joint venture between Rio Tinto Alcan (59.39%) and six junior partners. It is the largest aluminium smelter in Australia and also one of the world's largest.

Alumina is transported by a 10 km conveyor from the QAL refinery to Boyne Smelters Ltd (BSL) for the third stage of the aluminium production process — smelting. The smelter began operation in 1982 and uses the Hall-Heroult process to reduce alumina to aluminium metal. BSL is Australia's largest aluminium smelter producing more than 556 000 t of aluminium in 2009. Further significant modernisations worth $685 million with the re-building of Carbon Baking Furnace 3 and construction of Carbon Baking Furnace 4 have been completed.

The smelter operates three reduction lines, a metal casting house, an anode production plant and ancillary facilities. Almost 60% of the aluminium produced is in the form of purity ingot for the Japanese and Southeast Asian market. T-bar is another purity product produced by the cast house. The remainder is cast as alloy in the form of extrusion billet for further processing in Australia and for export to Asian extrusion mills.

Mount Isa copper and lead smelters — Mount Isa: The Xstrata copper smelter in Mount Isa smelts concentrates from the Mount Isa and Ernest Henry mining projects in northwest Queensland (Photograph 10). There are three main stages in the copper smelter — the Copper ISASMELT furnace (Photograph 11) which produces matte copper (58 to 62% Cu), the four converters which produce blister copper (97% Cu) and the anode furnace (Photograph 12) producing copper anode (99.7% Cu). The copper anodes produced in Mount Isa are then railed to the Townsville copper refinery for refining to cathode copper.

Photograph 10: The town of Mount Isa with the prominent Copper ISASMELT chimney (left) and the lead ISASMELT chimney (right).

Photograph 11: Mount Isa copper smelter (image courtesy DNRM; Queensland Mineral and Petroleum Review, 2002).

The copper smelter underwent an expansion to increase its capacity from 240 000 tpa to 280 000 tpa by the end of 2006 and to 300 000 tpa during the first half of 2007.

The lead smelter uses an ISASMELT furnace to treat lead concentrates from the Mount Isa, Hilton and George Fisher deposits to produce crude lead that is treated at Xstrata Zinc's United Kingdom refinery to produce high-quality lead, lead alloys and silver. The production for 2011 is reported at 237 700 t of copper cathode from this smelter.

Townsville Copper Refinery — Townsville: The Xstrata Townsville copper refinery is one of the world's leading electrolytic copper refineries. It produces 99.99% pure LME Grade A copper cathode from copper anode produced at Mount Isa. The production for 2011 is reported at 276 500 t of copper cathode. The refinery was originally opened in 1959 and Xstrata have also decided to phase out this smelter by 2016.

Photograph 12: Mount Isa copper anode wheel at the copper smelter (image courtesy Xstrata Copper; Queensland mining and petroleum 2005).

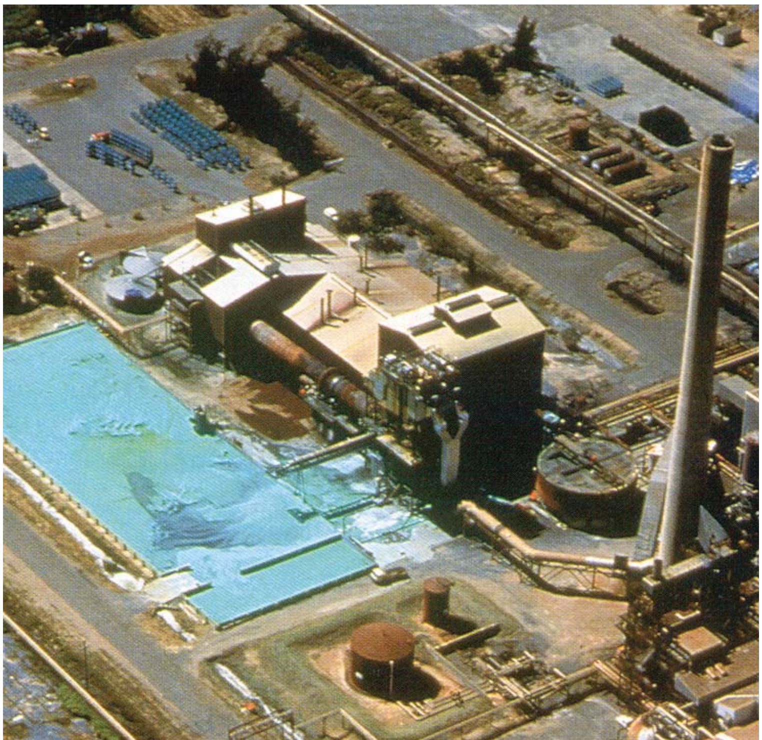
The refinery uses the MIM-developed ISA PROCESS, which utilises permanent stainless steel cathode plates in association with copper cathode stripping machinery. The refinery has the capacity to refine 300 000 t of copper per year. It has undergone a A$3 million capital improvement project to convert its fuel source from liquid fuel to coal seam gas.

Sun Metals Zinc Smelter — Townsville: The Sun Metals Corporation (a subsidiary of Korea Zinc Company Ltd) zinc smelter is at Stuart, 11 km south of Townsville. The smelter commenced production in late 1999 and processes 420 000 t per annum of zinc concentrates, mainly sourced from northwest Queensland, to produce ~200 000 t of zinc metal. Concentrates are blended on site to provide a consistent chemical composition for the smelting process. The solid zinc oxide (ZnO, Calcine) is separated from the gaseous sulphur dioxide (SO_2) utilising various techniques (roasting). The collected zinc oxide is sent to the leaching plant where it is leached and purified and the zinc metal is recovered in an electrolysis process. Melting and casting in an electric furnace are the end processes to produce zinc metal ingots ready for shipment. The sulphur dioxide goes to the sulphuric acid plant via the gas cleaning plant. Approximately 380 000 t of sulphuric acid is produced as a by-product with minimum of 98% H_2SO_4 and is used elsewhere in the state to produce high-quality agricultural fertilisers (Photograph 13).

Palmer Nickel and Cobalt Refinery (Yabulu Nickel Refinery) — Townsville: The Yabulu Nickel Refinery, 25 km northwest of Townsville, is 100% privately owned by Clive Palmer. It is one of the largest, most cost efficient lateritic nickel–cobalt plants in the world, with an annual processing capacity of ~3.6 million wet tonnes of lateritic ore. More than 10% of the world's nickel supply and ~8% of the cobalt supply come from Yabulu (Photograph 14). The refinery was built in 1974 to process lateritic nickel ore from the Greenvale Mine, but until recently has relied entirely on ore imported from New Caledonia, Indonesia and the Philippines. With Queensland Nickel Group re-opening the Brolga mine in late 2012, a new source of lateritic nickel will complement the overseas imports.

The refinery uses a modified Caron hydrometallurgical (ammonia leach) process with an annual production capacity of ~34 000 t of nickel and 1900 t of cobalt. The lateritic nickel ore is piled on solar drying stockpiles at the refinery and then fed into three rotary driers to remove moisture. Ball mills grind the ore to fine powder, which is then mixed with fuel oil reductant and fed into 12 multi-hearth furnaces, where nickel and cobalt compounds are reduced at very high temperatures to reactive metals. The hot ore is cooled then leached in an ammonium carbonate solution and the nickel and cobalt dissolve into soluble amines. The nickel and cobalt amines are separated from the waste products by progressively washing in fresh ammonia solution in eight thickeners. Nickel is separated from the cobalt by the ammoniacal solvent extraction (ASX) process, a technology developed at this refinery and operational since 1989. Nickel carbonate is precipitated from solution by boiling off ammonia. By calcining the carbonate at 1200°C it is converted to nickel oxide. The nickel oxide is then converted to metal at 1000°C in a hydrogen atmosphere. Most of the output from the refinery is in form of nickel metal compacts, ready for export to international customers. Cobalt is separated from the metal-laden ammonia solution as cobalt sulphide. The cobalt sulphide is then processed in the cobalt plant, which was commissioned in 1997, to produce value-added cobalt products (Photograph 15).

Photograph 13: Sun Metals Zinc Smelter — Townsville; roasting plant.



Photograph 14: Aerial view of Yabulu Nickel Refinery around 2005 (now renamed to Palmer Nickel and Cobalt Refinery) (image courtesy DNRM).

Photograph 15: Yabulu Cobalt Refinery (now renamed to Palmer Nickel and Cobalt Refinery) (image courtesy DNRM).

Geological framework

(Compiled by I.W. Withnall & L.C. Cranfield)

The geological framework outlined here provides a basic overview of the geology of Queensland and draws particularly on work completed by Geoscience Australia and the Geological Survey of Queensland.

Queensland contains mineralisation in rocks as old as Proterozoic (~1880 Ma) and in Holocene sediments, with world-class mineral deposits as diverse as Proterozoic sediment-hosted base metals and Holocene age dune silica sand. Potential exists for significant mineral discoveries in a range of deposit styles, particularly from exploration under Mesozoic age shallow sedimentary cover fringing prospective older terranes.

The geology of Queensland is divided into three main structural divisions: the Proterozoic North Australian Craton in the northwest and north, the Paleozoic–Mesozoic Tasman Orogen (including the intracratonic Permian to Triassic Bowen and Galilee Basins) in the east, and overlapping Mesozoic rocks of the Great Australian Basin (Figure 1). The structural framework of Queensland has recently been revised in conjunction with production of a new 1:2 million-scale geological map of Queensland (Geological Survey of Queensland, 2012), and also the volume on the geology of Queensland (Withnall *et al.*, 2013). In some cases the divisions have been renamed. Because updating of records in the Mineral Occurrence database—and therefore the data sheets that accompany this product—has not been completed, the old nomenclature as shown in Figure 1 is retained here, but the changes are indicated in the discussion below.

North Australian Craton

Proterozoic rocks crop out in northwest Queensland in the Mount Isa Province as well as the McArthur and South Nicholson Basins and in the north as the Etheridge Province in the Georgetown, Yambo and Coen Inliers and Savannah Province in the Coen Inlier. In addition, Neoproterozoic – early Paleozoic rocks crop out in the Georgina Basin in northwest Queensland, Iron Range Province in the north, Anakie Province in central Queensland, Cape River Province in the Charters Towers – Greenvale area and Barnard Province in the Innisfail coastal area.

Mount Isa Province

Rocks of the Mount Isa Province are exposed over an area in excess of 50 000 km^2 in northwest Queensland, roughly centred on the township of Mount Isa. The rocks can be divided into three subprovinces of differing character and history (Figure 1). Early Paleoproterozoic basement forms the Kalkadoon–Leichhardt Subprovince, a meridional belt dividing the younger domains that comprise the Eastern and Western fold belt subprovinces. Recent work by the Geological Survey of Queensland (2011) has divided the Mount Isa Province into 15 domains (Figure 2), and the records in the Mineral Occurrence database have been updated to reflect this nomenclature. The Kalkadoon–Leichhardt Subprovince corresponds to the Kalkadoon–Leichhardt Domain, the Western Fold Belt Subprovince comprises the Century, Mount Oxide, Sybella and Leichhardt River domains, and the Eastern Fold belt Province comprises the Mary Kathleen, Mitakoodi, Tommy Creek, Marimo–Staveley, Doherty – Fig Tree, Kuridala – Selwyn, Soldiers Cap and Canobie domains. In the northwest, the Camooweal–Murphy Domain includes rocks of the Murphy Province, McArthur Basin and South Nicholson Basin. The most recent summaries of the geology of the Mount Isa Province are by Withnall & Hutton (2013) and the Geological Survey of Queensland (2011).

The precise age and context of the Kalkadoon–Leichhardt Subprovince remains unresolved. Its rock assemblages registered deformation and metamorphism, generally to amphibolite grade, during the Barramundi Orogeny, which was widespread in the North Australian Craton at 1900–1870 Ma (Etheridge, Rutland & Wyborn, 1987; Betts *et al.*, 2006). For the Mount Isa Inlier, this episode of orogenesis reflects east–west contraction (Blake & Stewart, 1992).

In the northwest an east-trending basement high separates the McArthur Basin to the north from the South Nicholson Basin to the south (Figure 1). It is sometimes referred to as the Murphy Tectonic Ridge and was described by Ahmad & Wygralak (1990). It comprises the comagmatic 1860–1850 Ma Cliffdale Volcanics and Nicholson Granite Complex.

Protoliths of late Paleoproterozoic metasedimentary rocks of the Eastern and Western fold belts were generally marine sediments deposited during three discrete episodes of basin formation (Jackson, Scott & Rawlings, 2000; Southgate *et al.*, 2000; Betts *et al.*, 2006). The Leichhardt Superbasin (1790–1730 Ma) is best represented in the Western Fold Belt, along the north–south Leichhardt Rift (Derrick, 1982; O'Dea *et al.*, 1997b) at the western margin of the Kalkadoon–Leichhardt Domain. Its basin fill includes the products of bimodal volcanism.

Successions of the Calvert Superbasin (1720–1670 Ma) were deposited in half-grabens formed by northwest–southeast extension. They consist largely of marine siliciclastics locally intercalated with rift-related volcanics. Successions of the Isa Superbasin (1670–1590 Ma), best represented in the Western Fold Belt, are predominantly marine siliciclastics with geometries that relate to extensional faulting. Inversion history for the Leichhardt and Calvert superbasins remains unclear but involved significant granitic plutonism. The Isan Orogeny, terminal to the basinal development, involved components of both north–south and east–west shortening strain and extensive plutonism. Although these generalisations apply to the inlier as a whole, different areas within its

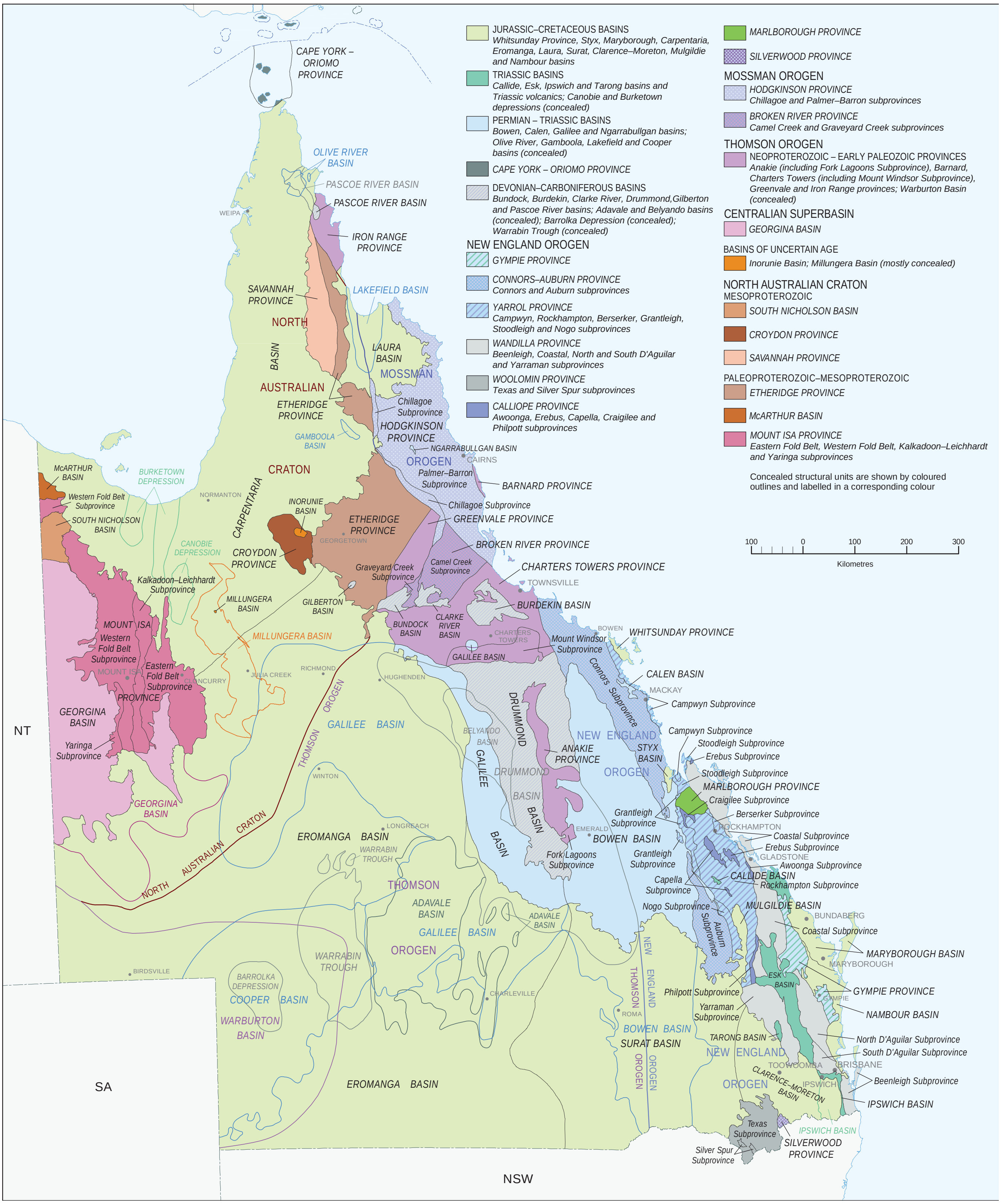


Figure 1. Structural framework map of Queensland (Jell, 2013)

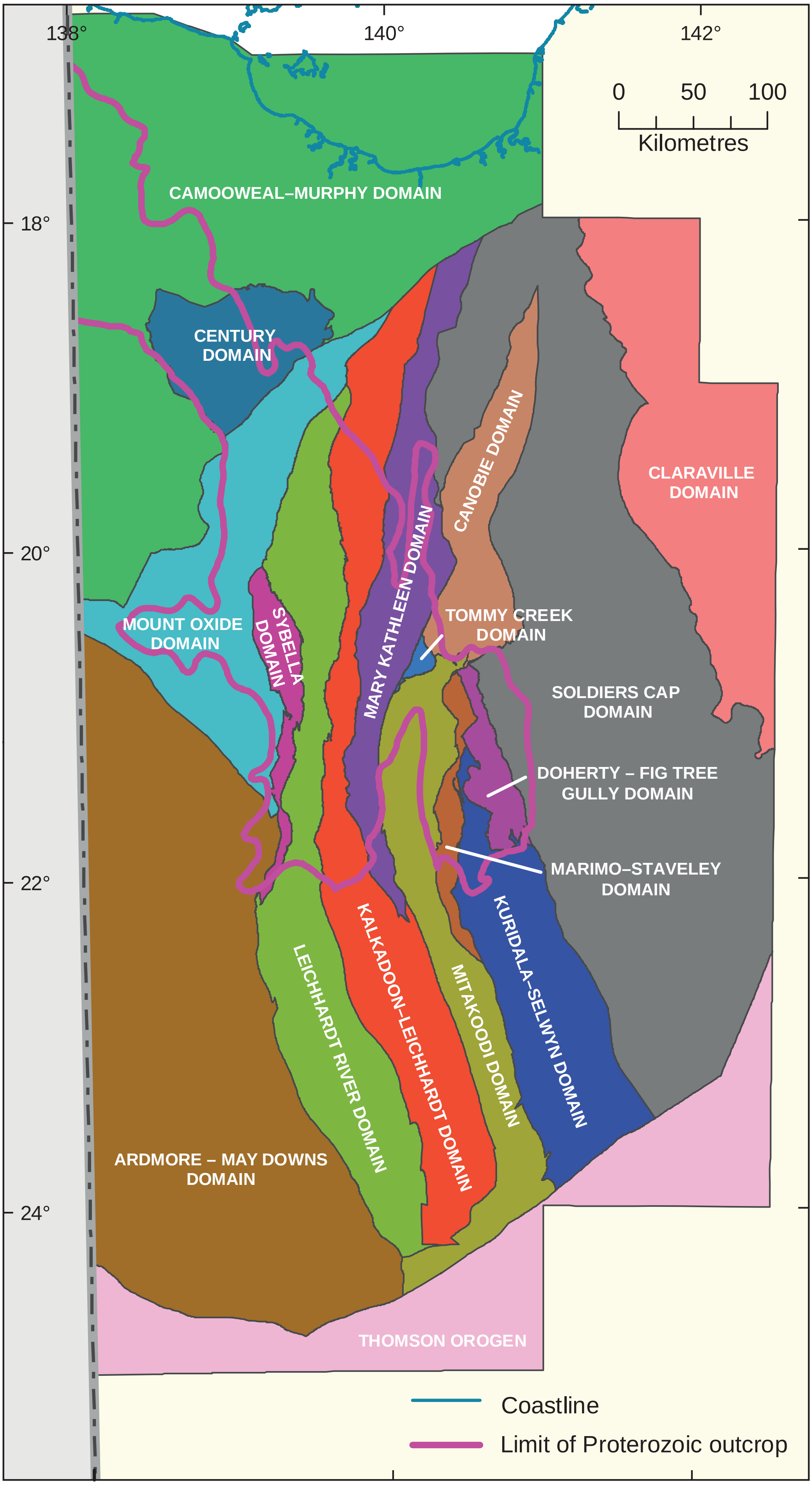


Figure 2. Solid geology map of the Mount Isa Province (Jell, 2013)

compass show considerable diversity, as recognised in the most recent assessment (Geological Survey of Queensland, 2011), in which 15 domains are recognised.

Rocks of the Mount Isa Province have been overprinted by regional metasomatism to an extraordinary degree. The inlier is host to globally significant base metal deposits (Geological Survey of Queensland, 2011), with some 11% of the world's Pb and Zn resources (Wallis *et al.*, 1998). Stratiform Pb–Zn–Ag ore bodies are considered to be syngenetic/diagenetic in origin (McGoldrick & Large, 1998; Large *et al.*, 2005; Chapman, 2004), whereas the origin of stratabound copper and iron oxide copper–gold deposits are thought to involve deep crustal fluids (Perkins, 1984), in some cases linked to plutonism (Wang & Williams, 2001).

The assembly of Proterozoic geology of northwestern Queensland includes small parts of the Paleoproterozoic McArthur Basin (Sweet *et al.*, 1981), which is broadly correlative with the superbasin successions of the Mount Isa Province, the early Paleoproterozoic Murphy inlier (Ahmad & Wygralak, 1990) and the Mesoproterozoic South Nicholson Basin (Jackson *et al.*, 1999) extending across the Northern Territory border between Lawn Hill and the Gulf of Carpentaria. The relationship of the Mount Isa Province to other Proterozoic provinces of the North Australian Craton to the west, such as the Tennant Creek, Arunta and Tanami provinces, is impeded by expanses of Phanerozoic sedimentary cover and remains contentious (Greene, 2010). However, the interpretation of late Paleoproterozoic superbasinal successions of the Mount Isa Province as backarc to a plate boundary to the east (Cawood & Korsch, 2008) or south (Betts *et al.*, 2006) is widely held.

Granites and mafic intrusions were emplaced at various times before ~1100 Ma. Granites older than 1550 Ma are metamorphosed and generally deformed. From west to east the main batholiths exposed are the Sybella (1670 Ma) in the Western Fold Belt Province, the Kalkadoon and Ewen (1870–1850 Ma) in the Kalkadoon–Leichhardt Domain, the Wonga (1750–1725 Ma) in the Mary Kathleen Domain, and the post-orogenic Williams and Naraku Batholiths in the domains to the east. Intrusives of the Williams and Naraku Batholiths have been shown to be of at least three different ages (1750–1730 Ma, 1545–1530 Ma and 1520–1490 Ma).

The Mount Isa Province has had a complex history of deformation, which has been dominated at different periods by extension, shortening and transcurrent faulting (Blake & Stewart, 1992). The earliest deformation is recorded in basement units that were tightly folded and in places partially melted before the onset of volcanism of the Leichhardt Superbasin. This early shortening is attributed to the Barramundi Orogeny. The Barramundi compressional event was followed by extension, leading to basin formation and deposition of rocks of the Leichhardt Superbasin.

At ~1620 Ma an early phase of thrusting and folding resulting from north–south compression took place and was followed between 1550 Ma and 1520 Ma by the east–west compression of the Isan Orogeny. This event formed the major north-trending upright folds that characterise much of the Mount Isa Province. A period of later extension is implied by the intrusion of the Williams and Naraku Batholiths at ~1500 Ma. The main faults mapped in the Mount Isa Province have kilometre-scale, predominantly strike-slip displacements. These faults were active during the Proterozoic, and some may have been active also during the Phanerozoic.

Since the discovery of copper and gold near Cloncurry in the 1860s the rocks of the Mount Isa Province have been significant producers of copper, lead, zinc and silver. Significant resources remain, with the Mount Isa Province containing 21.2% of the world's lead resources, 11% of the world's zinc resources, 5% of the world's silver resources and 1.7% of the world's copper resources.

Four main styles of mineralisation account for the majority of the mineral resources within the rocks of the Mount Isa Province.

1. *Sediment-hosted silver–lead–zinc*

Sediment-hosted silver–lead–zinc accounts for the majority of lead-zinc and a high proportion of the silver resources within Queensland. These deposits occur mainly within the fine-grained sedimentary rocks of the Isa Superbasin in the Western Fold Belt Subprovince and include the Black Star (Mount Isa Pb-Zn), Century, George Fisher North, George Fisher South (Hilton) and Lady Loretta deposits. Sediment-hosted base metal mineralisation also occurs within Isa Superbasin equivalents at Dugald River in the Eastern Fold Belt Province.

2. *Brecciated sediment-hosted copper*

Brecciated sediment-hosted copper deposits occur predominantly within rocks of Leichhardt, Calvert and Isa Superbasin of the Western Fold Belt Subprovince. These copper deposits include the Mount Isa copper orebodies and the Esperanza/Mammoth mineralisation. Mineralisation is commonly hosted by brecciated dolomitic, pyritic and carbonaceous sedimentary rocks or brecciated sandstone proximal to regional fault/shear zones.

3. *Iron oxide–copper–gold*

Iron oxide–copper–gold deposits consist predominantly of chalcopyrite-pyrite-magnetite/hematite mineralisation that occurs within high-grade metamorphic rocks in the Eastern Fold Belt Subprovince. Deposits of this style include Ernest Henry, Osborne and Selwyn. The Ernest Henry deposit is breccia-hosted, and thus is distinctly different from the stratabound Osborne and Selwyn deposits.

4. *Broken Hill type silver–lead–zinc*

Broken Hill type silver–lead–zinc deposits occur within high-grade metamorphic rocks in the Eastern Fold Belt Province. Cannington is the major example, but several smaller currently subeconomic deposits such as Pegmont are known.

Gold has been produced mainly as a by-product of copper from the iron oxide–copper–gold deposits of the Eastern Fold Belt Subprovince. However, a significant exception occurs at the now mined-out Tick Hill deposit where high-grade gold mineralisation occurred within quartz-feldspar 'laminite' bands within a broader strongly strained, high strain zone in the Corella Formation of the Eastern Fold Belt Subprovince (Forrestal *et al.*, 1998). This deposit forms a remarkable and important exception in that it produced 15 900 kg of gold at an extraordinary average grade of 22.5 g/t and is a unique but poorly understood deposit style.

Culpeper *et al.* (2000) and Denaro *et al.* (1999a, 1999b, 2001b, 2003a, 2003b, 2004a) provide overviews of the outcropping mineralisation of this orogen by 1:250 000 map sheet.

McArthur Basin

Rocks of the McArthur Basin occur in both Queensland and the Northern Territory and unconformably overlie the Murphy Province along its northern margin (Figure 1). This basin fill sequence consists essentially of sedimentary and volcanic rocks (Tawallah Group) that are unconformably overlain by sandstone and minor conglomerate of the McArthur Group (Ahmad & Wygralak, 1990).

Within Queensland, the McArthur Basin hosts the Westmoreland (Redtree) uranium deposits. In the Northern Territory, it hosts the major McArthur River (HYC) stratiform lead-zinc-silver deposit.

The Murphy Province and McArthur Basin are covered by the Westmoreland 1:250 000 map sheet, and mineral occurrences for this region were described by Culpeper *et al.* (1999).

South Nicholson Basin

The South Nicholson Basin, which occurs both in Queensland and the Northern Territory, unconformably overlies rocks of the Lawn Hill Subprovince of the Western Fold Belt Province (Figure 1). This basin fill consists predominantly of sandstone, siltstone and shale of the South Nicholson Group. The only significant known mineralisation is sedimentary ironstone in the Constance Range area (Harms, 1965) where oolitic hematite, siderite and chamosite beds occur within the Train Range Ironstone Member. Mineral occurrences and mines from this basin are covered in the report by Culpeper *et al.* (1999).

Etheridge Province

The Etheridge Province crops out over a significant proportion of north Queensland, extending from Woolgar in the south to Lockhart River in the north (Figure 1). The Province is divided into the Forsayth and Yambo Subprovinces. The geology of the Etheridge Province was outlined by Withnall *et al.* (*in* Bain & Draper, 1997, pages 449–454) with details on the Forsayth Subprovince given in Withnall *et al.* (*in* Bain & Draper, 1997, chapter 3) and Yambo Subprovince in Blewett & Knutson (*in* Bain & Draper, 1997, pages 118–122). The distribution of units in the area was updated as part of the Georgetown GIS product, which forms stage 1 of the North Queensland Gold Study (Withnall *et al.*, 2002). The most recent summary of the entire region can be found in Withnall & Hutton (2013).

Rocks of the Forsayth Subprovince crop out in the Georgetown area and constitute a metasedimentary sequence deposited in an intracratonic rift setting between 1700 Ma to at least 1650 Ma. A major metamorphic and deformational event at ~1550 Ma was accompanied by S-type granite emplacement. Two major Proterozoic folding events have affected the rocks of the Forsayth Subprovince, with the second episode corresponding to the peak of metamorphism at ~1550–1555 Ma. The first event may have occurred at ~1590 Ma, corresponding with the emplacement of S-type granites recently recognised in the Lyndbrook area (unpublished SHRIMP data). At least four additional episodes of folding have also been recognised.

Rocks of the Forsayth Subprovince host important gold mineralisation that includes the Etheridge Goldfield (historic production of >19 500 kg Au bullion and an additional 3400 kg fine Au and 5500 kg Ag). This mineralisation, however, is probably genetically related to Siluro-Devonian and Permo-Carboniferous intrusives of the Pama and Kennedy Provinces. Small, massive, stratabound concentrations of iron and base metal sulphides are known from the base of the Etheridge Group within the Forsayth Subprovince. Mineral occurrences and mines in the Forsayth Subprovince have been described by Barker *et al.* (1996b, 1997), Bruvel *et al.* (1991), Culpeper *et al.* (1990, 1996, 1997), Dash *et al.* (1988), Denaro & Morwood (1997), Denaro *et al.* (2001a), Lam (1994c), Lam *et al.* (1988, 1989), Rees & Genn (1999) and Sawers *et al.* (1987). Denaro *et al.* (1997) published a resource assessment of the Georgetown–Croydon area, thus providing a useful overview of the mineralisation within the Forsayth Subprovince. An update of the area was provided in the Georgetown GIS (Withnall *et al.*, 2002).

Rocks of the Yambo Subprovince occur in the northern part of the Etheridge Province within the Yambo Inlier and eastern Coen Inlier (Figure 1). They consist of high-grade metasedimentary and meta-igneous rocks that were probably deposited after 1640 Ma and are locally metamorphosed to granulite facies. Dating has indicated a major period of emplacement of I and S type granite at ~1580 Ma, followed by metamorphism at ~1575 Ma. Six regional deformation events have been recognised, but these do not appear to correlate directly with those recognised within the Forsayth Subprovince.

The Yambo Subprovince has no significant defined mineral resources. Mineral occurrences and mines in the Yambo Inlier are covered in reports by Culpeper (1993), Culpeper & Burrows (1992), Denaro *et al.* (1994b) and Lam *et al.* (1991). Mineral occurrences in the eastern Coen Inlier are described by Culpeper & Burrows (1992), Culpeper *et al.* (1992b), Denaro & Morwood (1992b) and Denaro *et al.* (1993).

Savannah Province

The Savannah Province is a north–south-trending belt of mainly metasediments, with lesser amounts of metadolerite and amphibolite, which forms the western part of the Coen Inlier in Cape York Peninsula (Figure 1). The geology of the Savannah Province was summarised by Blewett (*in* Bain & Draper, 1997, pages 454–455) and details of the constituent units are described by Blewett *et al.* (*in* Bain & Draper, 1997, chapter 4).

The Savannah Province consists primarily of greenschist to upper amphibolite facies metasediments intruded by metadolerite and amphibolite. The metasediments are mainly slate, phyllite, schist and gneiss interbedded with massive quartzite. They are interpreted as having been deposited between 1585 Ma and 1550 Ma in a shallow water environment within an intracontinental setting. Six penetrative regional deformation events have been recognised, with the climax event associated with a prograde low-P high-T metamorphism and largely S-type magmatism at 407 Ma.

Rocks of the Savannah Province host small gold-quartz vein deposits that are probably related to late Paleozoic I-type magmatism. Small stratiform/stratabound massive and disseminated sulphide mineralisation is also present. Mineral occurrences within the province have been recorded by Culpeper & Burrows (1992), Culpeper *et al.* (1992b), Denaro & Morwood (1992b, 1992c) and Denaro *et al.* (1993).

Croydon Province

A sequence of Mesoproterozoic S-type volcanic rocks and related granites in the Croydon area in the western part of the Georgetown Inlier is assigned to the Croydon Province (Figure 1). Mackenzie (*in* Bain & Draper, 1997, pages 455–458) outlined the overall geology of this province and the component units were described by Withnall *et al.* (*in* Bain & Draper, 1997, chapter 3) and Withnall & Hutton (2013). Denaro & Morwood (1997) provide an overview of the mineralisation.

Exposed rocks of the Croydon Province are rhyolitic to dacitic ignimbrite, rhyolite and rare andesite of the Croydon Volcanic Group, granites of the Esmeralda Supersuite and shallow-water quartzose, mainly arenaceous sedimentary rocks of the Inorunie Group, which unconformably overlie the Croydon Volcanic Group. The Croydon Volcanic Group and Esmeralda Supersuite are contained within a cauldron subsidence structure that is likely to have been emplaced at ~1550 Ma, at the close of the main deformation event in the Forsayth Subprovince.

Significant mesothermal gold deposits of the Croydon Goldfield (historic production of ~60 000 kg Au bullion) are hosted by rocks of the Croydon Province. This mineralisation was regarded by Denaro *et al.* (1997) as being related to Proterozoic volcanism. However, dating of the associated alteration indicates a possible Permo-Carboniferous age (Henderson, 1989).

Neoproterozoic – Early Paleozoic

Several areas of Neoproterozoic – Early Paleozoic rocks in central, northern and northwest Queensland have been assigned to the Iron Range, Cape River (now Charters Towers and Greenvale provinces), Barnard and Anakie Provinces and the Georgina Basin.

Georgina Basin

The Georgina Basin is a large intracratonic basin in Queensland and the Northern Territory that flanks the western and southwestern margins of the Mount Isa Province. It occupies an area of ~325 000 km^2 of which ~90 000 km^2 are in Queensland (Figure 1). The geology of the Georgina Basin was outlined by Smith (1972) and Shergold & Druce (1980). An up-to-date summary is given by Jell (2013).

The basin fill is mainly Cambrian to Middle Ordovician marine sedimentary rocks. The Cambrian and Early Ordovician rocks are dominantly carbonate rocks with minor sandstone and siltstone whereas the Middle Ordovician rocks are dominated by siltstone and sandstone. Silurian(?) to Devonian freshwater sandstone and Permian boulder beds overlie rocks of the early Paleozoic Georgina Basin succession and are thought to represent younger successions laid down in superimposed basins (Allen, 1975). The Georgina Basin was deformed by minor to moderate folding and faulting throughout with moderate to strong folding, faulting and overthrusting along the southern margin.

Phosphatic marine sediments (phosphorite) occur in the Middle Cambrian and Middle Ordovician rocks of the basin. The Middle Cambrian rocks host significant phosphate resources that include the Phosphate Hill deposit. Mineral occurrences within the Georgina Basin have been described by Denaro *et al.* (1999a, 1999b, 2001b, 2003a, 2003b).

Tasman Orogenic Zone

Rocks of the Tasman Orogenic Zone occur throughout eastern Australia, from the islands of Torres Strait south to Tasmania. Within Queensland, the zone can be subdivided into the Mossman, Thomson and New England Orogens. The Thomson Orogen consists mainly of latest Neoproterozoic to Ordovician rocks and crops out in the Anakie, Charters Towers, Greenvale and Innisfail areas, but is mostly buried by younger basins in southwestern Queensland. Rocks in the Iron range area in Cape York Peninsula may also be part of the Thomson Orogen. The Mossman Orogen consists predominantly of early Paleozoic, fairly deep-marine quartz-rich sandstone and mudstone intercalated with submarine mafic and felsic volcanic rocks. The New England Orogen consists of middle Paleozoic to early Mesozoic marine to continental sedimentary and volcanic rocks. Details on the subdivision of the Tasman Orogenic Zone were given by Day *et al.* (1978) and the tectonic development and metallogeny of the zone was outlined by Murray (1986). The most recent review of the elements within the Tasman Orogenic Zone is by Withnall *et al.* (2013).

Thomson Orogen

Charters Towers Province (formerly Cape River Province)

The Charters Towers Province forms several widely spaced outcrop areas of metamorphic rocks in the Charters Towers region. Each area has been assigned a separate stratigraphic name, namely, the Cape River, Running River, Argentine and Charters Towers Metamorphics. Withnall & Hutton (*in* Bain & Draper, 1997, pages 459–462) described the overall geology of the units referring to them as the Cape River Province, and Hutton *et al.* (*in* Bain & Draper, 1997, chapter 6) outlined the geology of each of the component units. The province is now referred to as the Charters Towers Province (Geological Survey of Queensland, 2012), Withnall *et al.* (2013), Fergusson & Henderson (2013), but most records in the Mineral Occurrence Database still reflect the old nomenclature.

All units within the Charters Towers Province consist predominantly of psammo-pelitic metamorphic rocks with subordinate mafic volcanic rocks and local areas of banded iron formation. These units probably formed a single terrane before being dismembered by granite emplacement in the Paleozoic and overlain by younger basin fill. Although the age of rocks in the Charters Towers Province is uncertain, magmatic zircons in granites intruding Cape River Metamorphics show SHRIMP U-Pb zircon ages ranging from 469 ± 12 Ma to 493 ± 10 Ma, providing a minimum age constraint of Late Cambrian or early Ordovician. A maximum age for the province is constrained by dates of 1145±21 Ma for detrital zircons within the Cape River Metamorphics.

The structure of the Charters Towers Province is poorly understood. The main fabric is manifested as a spaced differentiated foliation that is interpreted as a second-generation fabric, possibly correlatable with the main deformation in the Anakie Province (at ~510 Ma). Little significant mineralisation is genetically associated with the rocks of the Charters Towers Province, but minor magnetite has been recorded in banded iron formation. Mineralisation in the province has been described by Gunther *et al.* (1994), Garrad (1996), Hartley (1996), Hartley & Dash (1992), Lam (1994a, 1994b, 1996), Morwood & Dash (1996), Morwood *et al.* (2001) and Sennitt & Hartley (1994).

Mount Windsor Subprovince (formerly Thalanga Province)

Hutton & Withnall (*in* Bain & Draper, 1997, pages 469–471) summarised the geology of the Thalanga Province, and the details of its component units were summarised by Hutton *et al.* (*in* Bain & Draper, 1997, chapter 6). The mapping of the units was revised by Withnall *et al.* (2002, 2003).

The Thalanga Province, as defined by these authors, includes two belts of Late Cambrian to early Ordovician volcanic rocks and volcanogenic sediments (Figure 1). The main belt is south of the Ravenswood Batholith in the Charters Towers area and consists of deep water sedimentary rocks and subaqueous felsic and mafic to intermediate volcanic rocks assigned to the Seventy Mile Range Group. These rocks have been metamorphosed to mainly sub-greenschist to greenschist facies. These are now referred to as the Mount Windsor Subprovince of the Charters Towers Province (Withnall *et al.*, 2013; Fergusson & Henderson, 2013), but the Mineral Occurrence Database still reflects the old nomenclature.

Three major deformations are recognised within the Seventy Mile Range Group, which hosts significant volcanic-hosted massive sulphide (VHMS) resources including the Highway–Reward and Thalanga deposits. The mineral occurrences of the Thalanga Province were described by Barker *et al.* (1997), Denaro *et al.* (2004b), Hartley & Dash (1993), Hartley (1996), Lam (1994c, 1995b) and Sennitt & Hartley (1994).

The second belt, formerly assigned to the Thalanga Province, occurs within the eastern part of the Georgetown Inlier, within the Greenvale Province, but has not been renamed as a subprovince. It is described below.

Greenvale Province (formerly part of the Cape River Province)

A belt of metamorphic rocks in the extreme east of the Georgetown Inlier (west of the Broken River Province), comprising gneiss, mica schist and mafic/ultramafic complexes, was previously thought to be part of the Etheridge Province. It was recognised as part of the Cape River Province (Withnall *et al.*, 2002, 2003), but is now referred to as the Greenvale Province (Withnall *et al.*, 2013; Fergusson & Henderson, 2013), because it is separated from the rest of the former Cape River Province (now Charters Towers Province) by the intervening Broken River Province. However it is likely to be continuous with the Charters Towers Province at deeper crustal levels. Rocks within this belt belong to the Oasis and Halls Reward Metamorphics. They are separated from the Etheridge Province by the Lynd Mylonite Zone. The ultramafic complexes are associated with lateritic nickel–cobalt–scandium deposits such as the Greenvale and Lucknow deposits.

Two units formerly assigned to the Thalanga Province in this area are: the Balcooma Metavolcanic Group comprising marine or possibly subaerial rhyolitic metavolcanics, metasediments and minor mafic volcaniclastics and lava; and the Lucky Creek Metamorphic Group comprising leucogneiss, quartzite, amphibolite, phyllite, andesitic meta-volcanics, and minor marble. The Balcooma Metavolcanic Group was metamorphosed to lower to middle amphibolite facies and the Lucky Creek Metamorphic Group to upper greenschist to lower amphibolite facies. The Balcooma Metavolcanic Group preserves a steep schistosity that may be a second-generation fabric. The Lucky Creek Metamorphic Group contains a relatively pervasive shallowly dipping mylonitic foliation. The Balcooma Metavolcanics and Seventy Mile Range Group host significant volcanic-hosted massive sulphide (VHMS) resources including the Balcooma and Surveyor deposits.

Barnard Province

Rocks of the Barnard Province occur along the coast and on several islands in the Innisfail area in north Queensland (Figure 1). The overall geology of the Barnard Province is given in Bultitude *et al.* (*in* Bain & Draper, 1997, pages 462–464 and chapter 7), Garrad & Bultitude (1999) and Fergusson & Henderson (2013).

The Barnard Metamorphic Province forms a narrow north-trending belt east of the Russell–Mulgrave Shear Zone in north Queensland and includes the Barnard Metamorphics and Babalangee Amphibolite. Rock types comprise phyllite, meta-arenite, quartzite, 'greenstone', schist and gneiss. Metamorphic grades are mainly of greenschist facies but are locally up to hornblende granulite facies. The high-grade zones are commonly spatially associated with areas of Ordovician granite, which intrudes the metamorphic rocks. Three main regional deformation events are recognised. The second-generation fabric is an intense crenulation cleavage or schistosity that forms the main foliation in most outcrops. The Ordovician granites contain a pervasive fabric correlated with the second-generation foliation in the metamorphic rocks, thus implying a maximum age of late Ordovician for the second deformation. The metamorphic rocks of the Barnard Province are probably an uplifted lower plate basement assemblage on the southeastern margin of the Hodgkinson Province. The presence of anomalously high metamorphic grade rocks implies that the unit may consist of several discrete fault blocks. No significant mineral resources are known within the rocks of the Barnard Province. Mineral occurrences in the province were described by Garrad & Rees (1995).

Anakie Province

The Anakie Province contains predominantly metamorphic rocks of Neoproterozoic – early Paleozoic age that are assigned to the Anakie Metamorphic Group (Figure 1). The geology was outlined by Withnall *et al.* (1995) and Fergusson & Henderson (2013).

The Anakie Metamorphic Group includes mica schist, quartzite, meta-arenite and greenstone. Three major deformations and subsequent minor folding events have affected the metamorphic rocks. The first deformation produced a strong foliation parallel to relict bedding. Bedding is best preserved in the thinly bedded quartzite units, which are deformed by tight asymmetric second-generation folds. Within metapelites, the first-generation fabric is strongly overprinted by a second-generation layer differentiated crenulation cleavage that is axial planar to tight second-generation folds. The third period of deformation produced northeast-trending upright folds that are overprinted by later more open east-trending regional folds and some southeast-trending folds. Metamorphism was of the low pressure-high temperature type, accompanied the first and second deformations, and ranged from greenschist to amphibolite facies. The depositional age of the Anakie Metamorphic Group is uncertain although K–Ar age dating suggests that the rocks were deformed and metamorphosed at ~510 Ma (Withnall *et al.*, 1996).

The only significant resource within the Anakie Province is that of the Peak Downs deposit, where copper mineralisation is present in ironstone, muscovite-quartz schist and chlorite-quartz schist. Mineralisation within the province has been described by Denaro *et al.* (2004b), Garrad & Lam (1993), Lam (2005b) and Lam & Garrad (1993).

Ordovician sedimentary rocks outcropping along the southeastern margin of the Anakie Province are assigned to the **Fork Lagoons Subprovince** (Figure 1). The contact between rocks of the Fork Lagoons Province and the Anakie Metamorphic Group to the northwest occurs along a steeply dipping thrust zone. Withnall *et al.* (1995) described the geology of the Fork Lagoon Province and the Fork Lagoon beds.

The metamorphic rocks of the Anakie Province are intruded by a large composite assemblage of Middle – Late Devonian mainly I-type granitoids of the **Retreat Batholith**. Rock types range in composition from diorite through monzodiorite and granodiorite to granite. Rb-Sr ages range from 366 Ma to 385 Ma. The geology of the Retreat Batholith was described in detail by Withnall *et al.* (1995).

Volcanic rocks consisting predominantly of mafic lavas and lesser volcaniclastics assigned to the Theresa Creek Volcanics unconformably overlie the Anakie Metamorphic Group southwest of Clermont (Figure 3). The Teresa Creek Volcanics are unconformably overlain by the Silver Hills Volcanics (the basal sequence of the Drummond Basin). Geochemical studies of the Theresa Creek Volcanics and Retreat Batholith indicate that they are genetically related.

No significant mineral resources are associated with the Retreat Batholith or Theresa Creek Volcanics.

Iron Range Province

Rocks of the Iron Range Province are exposed over ~450 km^2 in the northern part of the Coen Inlier in Cape York Peninsula (Figure 1). Blewett (*in* Bain & Draper, 1997, pages 458–459) described the overall geology of the Iron Range Province and Blewett *et al.* (*in* Bain & Draper, 1997, chapter 4) described the component units.

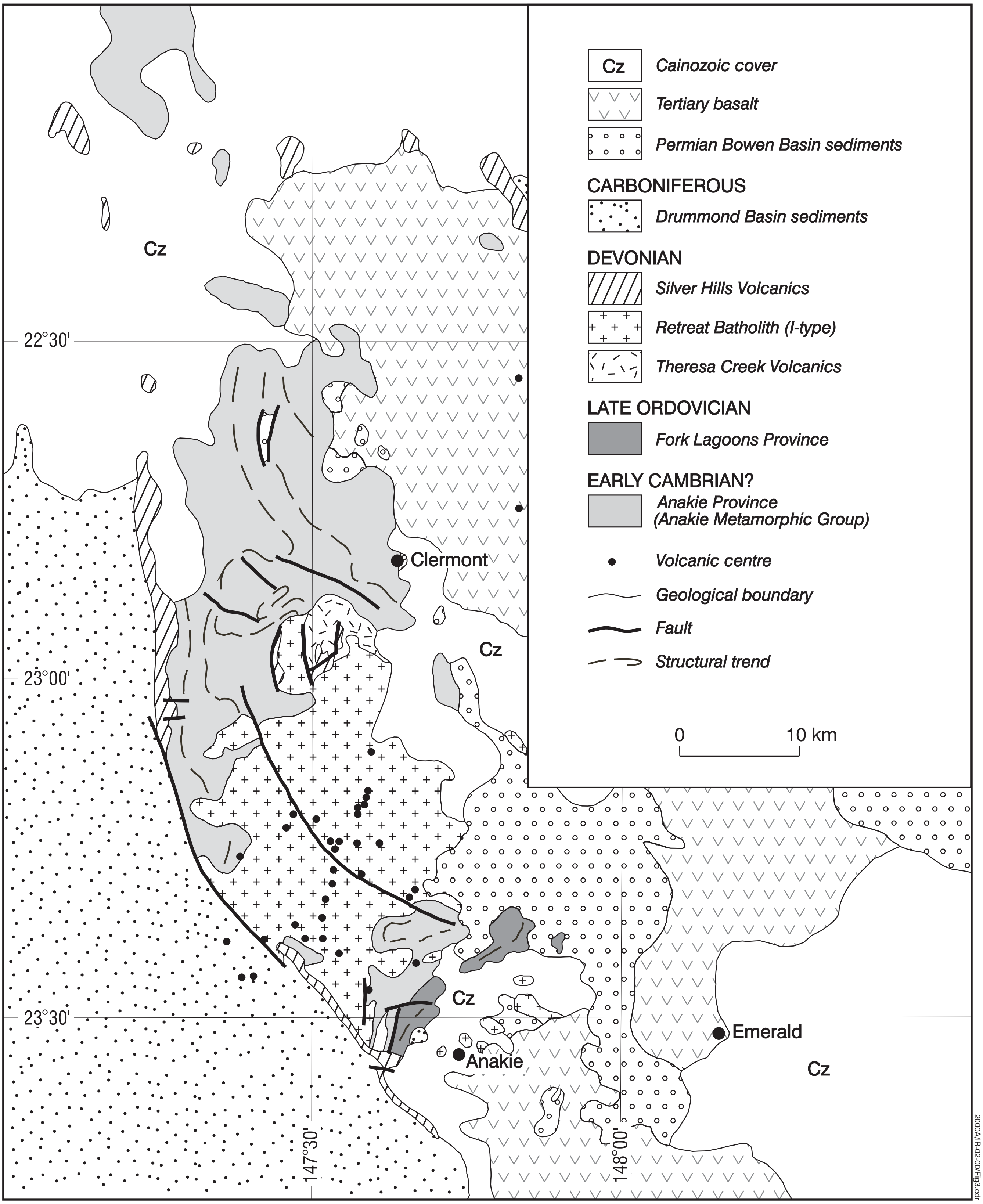


Figure 3. General geology of the southern Anakie Inlier (after Withnall et al., 1995)

The Iron Range Province contains a single mapped unit (the Sefton Metamorphics) that is composed of a variety of rock types of predominantly sub-greenschist to greenschist facies, including schist, quartzite, greenstone, limestone, marble and calc-silicate. The age of the Iron Range Province is interpreted as younger than detrital zircons dated at ~1130 Ma but the age of metamorphism is unknown. Little significant mineralisation is associated with these rocks. Mineralisation in the Iron Range Province was described by Bruvel & Morwood (1992) and Denaro & Morwood (1992a, 1992b).

Mossman Orogen

Rocks of the Mossman Orogen in north Queensland and have been subdivided into the Hodgkinson and Broken River Provinces (Withnall *et al.*, 2013; Henderson *et al.*, 2013). They are intruded by the inter-regional Macrossan, Pama and Kennedy igneous and volcanic provinces (Figure 3).

Hodgkinson Province

The Hodgkinson Province consists of early to middle Paleozoic turbiditic sedimentary rocks with subordinate limestone, chert and basic volcanic rocks that extend for ~500 km from south of Innisfail to Cape Melville and inland for ~150 km from the coast to the Palmerville Fault (Figure 1). Detailed descriptions of the geology of the Hodgkinson Province are included in Bultitude, Domagala *et al.* (in Bain & Draper, 1997, chapter 7), Bultitude, Garrad *et al.* (in Bain & Draper, 1997, chapter 7) and Garrad & Bultitude (1999) and Henderson *et al.* (2013).

The dominant rock types are quartzo-feldspathic arenite and mudstone, which represent deep-water density current deposits, interlayered with subordinate conglomerate, chert, metabasalt and minor shallow-water limestone; these for the Hodgkinson Formation. Older siliciclastic rocks of probable early Ordovician age are preserved in fault-bounded lenses adjacent to the Palmerville Fault along the western margin of the province. Within the Hodgkinson Province, the rocks are strongly folded and are disrupted into north-trending fault-bounded belts each of which is extensively disrupted by numerous thrust faults. The province has undergone generally sub-greenschist facies metamorphism, with localised higher-grade zones associated with contact aureoles around late Paleozoic intrusives. The Hodgkinson Province has been affected by several significant deformational events of both regional and local extent.

The tectonic setting for the Hodgkinson Province remains controversial. Some workers (e.g. Henderson, 1980) have interpreted that the Hodgkinson Province succession accumulated in a fore-arc–accretionary wedge setting to the east of an active continental magmatic arc. Recent work by the Geological Survey, however, favours an extensional rather than compressional regime, with a possible rifted continental margin or back-arc basin setting (Garrad & Bultitude, 1999).

Rocks of the Hodgkinson Formation host significant mesothermal quartz vein-hosted gold mineralisation, including the hard rock and derived alluvial deposits of the Hodgkinson and Palmer goldfields. A detailed study of mineralisation in the Hodgkinson Goldfield was given by Peters (1987). This mineralisation is thought to have formed from metamorphic fluids produced during the devolatilisation of the sedimentary pile (slate-belt style) with distribution of fluids localised along major shear zones (Phillips & Powell, 1992). Quartz-stibnite veins that locally crosscut these gold-only veins are probably sourced from a separate fluid phase that moved along separate flow paths, although a metamorphic source is still envisaged (Garrad & Bultitude, 1999). The Hodgkinson Province locally hosts significant skarn mineralisation such as that at Red Dome, where Permian–Carboniferous intrusives of the Kennedy Province intrude carbonate-rich rocks of the Chillagoe Formation. The Chillagoe Formation is also host to significant limestone resources. Mineralisation within the Hodgkinson Province has been summarised by Bruvel *et al.* (1991), Clarke *et al.* (1994), Culpeper *et al.* (1990, 1994), Dash & Cranfield (1993), Dash & Morwood (1994), Dash *et al.* (1988, 1991), Denaro *et al.* (1992, 1994a, 1994b), Garrad (1993), Garrad & Rees (1995), Lam (1993), Lam & Genn (1993), Lam *et al.* (1988, 1991), Morwood & Dash (1996) and Sawers *et al.* (1987).

Broken River Province

The Broken River Province consists of Ordovician to Devonian marine sedimentary rocks with subordinate, mainly mafic volcanic rocks and Late Devonian to early Carboniferous fluviatile and minor shallow marine sedimentary rocks. These are exposed over an area of ~7000 km^2 in the Clarke River area (Figure 1). The geology of the Broken River Province is given by Withnall & Lang (1993), Withnall *et al.* (*in* Bain & Draper, 1997, chapter 8 and pages 476–479) and Henderson *et al.*, 2013.

The Province has been divided into the Camel Creek Subprovince and Graveyard Creek Subprovince, separated by the Gray Creek Fault (Arnold & Henderson, 1976).

The Camel Creek Subprovince is more complexly deformed than the Graveyard Creek Subprovince and consists predominantly of alternating, fault-bounded packages of Ordovician to Early Devonian age quartz-rich and quartz-intermediate turbidites, tholeiitic basalt and calc-alkaline lavas and volcaniclastic rocks. It is overlain by the Late Devonian to Carboniferous Clarke River Basin, which contains continental sedimentary rocks and subordinate felsic volcanic rocks.

In the Graveyard Creek Subprovince, a basal unit of tholeiitic basalt, quartz keratophyre and quartz-rich turbidites is overlain unconformably by Silurian to Middle Devonian age shallow marine conglomerate, feldspathic and lithofeldspathic sandstone, volcaniclastics, mudstones and limestone. In the Late Devonian, the pull-apart Bundock Basin developed in the southwest of the subprovince and received a thick sequence of fluviatile and some shallow marine sedimentary rocks.

The Broken River Province hosts significant limestone resources. In addition, podiform chromite resources (*e.g.* Gray Creek South) as well as lateritic nickel–cobalt–scandium resources (*e.g.* Lucknow) are hosted by the Gray Creek Complex, a basement inlier of Greenvale Province rocks enclosed by the Graveyard Creek Subprovince. Small slate-belt style gold occurrences have also been recognised. Mineral occurrences in the Broken River Province have been described by Barker *et al.* (1997), Lam (1994a, 1994c, 1995a, 1995b, 1996), Morwood & Dash (1996) and Morwood *et al.* (2001).

Macrossan Province

Ordovician age plutonic rocks in north Queensland are assigned to the Macrossan Province (Hutton, Bultitude & Withnall, *in* Bain & Draper, 1997, chapter 14). In the new Geology of Queensland volume (Withnall *et al.*, 2013; Fergusson & Henderson, 2013), igneous provinces have been referred to as igneous associations, but apart from this, the Macrossan Igneous Association is identical in concept, age and extent to the 'Macrossan Province'. These are principally I-type granites and mafic intrusives in the Ravenswood Batholith in the Charters Towers area and S-type and hornblende-bearing granites in the Fat Hen Complex adjacent to the Lolworth Batholith (Figure 3). A small area of Ordovician S-type granites also intrudes rocks of the Barnard Province along the coastline near Innisfail.

No significant mineralisation is attributed to rocks of the Macrossan Province, although Ordovician granites in the Charters Towers area do host significant gold mineralisation thought to be associated with Devonian intrusive activity of the Pama Province. These deposits are described by Hartley & Dash (1993).

Pama Province

Silurian–Devonian granitic rocks in north Queensland were assigned to the Pama Province (Hutton, Knutson *et al.*, *in* Bain & Draper, 1997, chapter 14). In the new Geology of Queensland volume (Withnall *et al.*, 2013; Henderson *et al.*, 2013), they were referred to as the Pama Igneous Association, which otherwise is identical in concept, age and extent to the 'Pama Province'. These rocks extend as a discontinuous belt from the Coen Region in Cape York southwards to the Georgetown and Charters Towers regions (Figure 3). Pama Province rocks make up a large proportion of the Cape York Peninsula Batholith in Cape York, the Nundah, Tate, Robin Hood, Copperfield, White Springs, Glenmore, Dumbano and Dido Batholiths in the Georgetown region and the Ravenswood, Lolworth and Reedy Springs Batholiths in the Charters Towers region. The Pama Province rocks of Cape York comprise mostly S-type granite and leucogranite and some I-type granodiorite, whereas in the Georgetown and Charters Towers regions they are mostly I-type granitic rocks. The subdivision of the Pama Province in the Georgetown and Charters Towers regions was modified by Withnall *et al.* (2002, 2003).

Alteration associated with mesothermal quartz–gold–base metal sulphide vein deposits of the Etheridge Goldfield is considered to be of Silurian–Devonian age based on isotopic age dates (Bain *et al.*, 1998). It is thought that these deposits are genetically linked to fluid circulation systems associated with emplacement of the Silurian–Devonian granites in the area. Dating of alteration associated with mesothermal quartz vein mineralisation in the Charters Towers area also indicates a Devonian age (Carr *et al.*, 1988; Morrison, 1988). This mineralisation may be related to igneous activity associated with the Pama Province although a metamorphic origin has also been postulated (Hutton *et al.*, 1994).

Kennedy Province

Early Carboniferous to Early Permian igneous rocks extending throughout north Queensland were assigned to the Kennedy Province (Mackenzie & Wellman, *in* Bain & Draper, 1997, pages 488–500). In the new Geology of Queensland volume (Withnall *et al.*, 2013; Champion & Bultitude, 2013), they were referred to as the Kennedy Igneous Association, which otherwise is similar in concept, age and extent to the 'Kennedy Province'. This province extends from south of Bowen northwest through Cape York Peninsula and across Torres Strait (Figure 3). Most of these igneous rocks are concentrated in two belts, the Townsville–Mornington Island Belt

Table 1. Subprovinces of the Kennedy Province (after Mackenzie & Wellman, 1997)

Igneous subprovince	Corresponding basement province
Jardine	Northern Savannah Province; Iron Range Province
Lakefield (concealed)	Lakefield Basin
Daintree	Hodgkinson Province (northern)
Herberton	Hodgkinson Province (southern)
Tate	(North-eastern Forsayth Subprovince), Etheridge Province
Kidston	(Main part of Forsayth Subprovince), Etheridge Province
Kangaroo Hills	Broken River Province
Paluma	Cape River Province; Thalanga Province
Connors	Drummond Basin; northern New England Province

and the Badu–Weymouth Belt. The Townsville–Mornington Island Belt extends parallel to the coast from near Home Hill, southeast of Townsville, to the Atherton area and then west to the limit of pre-Mesozoic exposure north of Georgetown. The Badu–Weymouth Belt extends from the Mount Carter–Cape Weymouth area in eastern Cape York Peninsula to Badu Island in southern Torres Strait and into Papua New Guinea. The Kennedy Province has been subdivided into several subprovinces, the boundaries of which largely reflect the underlying/enclosing basement provinces as outlined in Table 1.

Rocks of the Kennedy Province are largely I-type intrusives and extrusives that form major batholiths and volcanic 'fields'. A-type extrusives occur mainly in the Herberton Subprovince whereas A-type intrusives occur largely within the Kidston Subprovince. S-type intrusives occur within the Daintree Subprovince. The rocks commonly occur in large cauldron subsidence structures and are interpreted to be the result of crustal melting in an extensional (or transtensional), possibly back-arc, tectonic environment.

Rocks of the Kennedy Province have been responsible for a diverse group of mineral deposit styles throughout north Queensland. These include porphyry-related breccia gold deposits (of which Kidston and Mount Leyshon are examples), vein and greisen type tin deposits (including those of the Herberton and Cooktown tinfields) and skarn deposits such as Red Dome.

New England Orogen

The New England Orogen forms the eastern part of the Tasman Orogenic Zone and in Queensland is subdivided into several geological provinces.

Silverwood Province and older blocks within the Yarrol Province

The oldest tectonostratigraphic sequences of the New England Orogen range in age from mid-Ordovician to Middle Devonian. They occur in the **Silverwood Province** (van Noord, 1999), and in inliers and structural blocks enclosed within the **Yarrol Province** (the Stanage, Craigilee, Calliope and Philpott Blocks of Day *et al.*, 1983). These older rocks in the Yarrol Province are now assigned to the Calliope Province, which contains the Awoonga, Erebus, Capella, Craiglee and Philpott Subprovinces (Withnall *et al.*, 2013; Donchak *et al.* (2013), but the database currently retains the old nomenclature. The Awoonga Subprovince corresponds to the former Calliope Subprovince, the Erebus Subprovince to the former Mount Holly Subprovince, and the Capella Subprovince includes the former Mount Morgan and Kroombit Subprovinces. The Craiglee and Philpot Subprovinces are unchanged.

The rocks comprise volcaniclastic sediments, coralline limestone lenses, and some primary volcanic rocks. Their submarine environment of deposition, the lack of quartz in sedimentary units, and the geochemistry of volcanic and related intrusive rocks support an island arc origin. Day *et al.* (1978, 1983) interpreted all the component blocks in this linear belt as part of a single arc, the Calliope Volcanic Arc. However, the recent recognition that individual structural blocks contain lithologically distinct but coeval sequences suggests that they may not have been directly related, but in fact represent a number of separate exotic terranes (Simpson *et al.*, 1998; Murray *et al.*, 2003, 2012).

By far the most important metalliferous deposit within this Ordovician to Middle Devonian island arc assemblage is the world-class Mount Morgan gold–copper deposit. It occurs within a belt of Middle Devonian volcanic and sedimentary rocks forming a roof pendant in the Late Devonian Mount Morgan Tonalite intrusion. Two main theories have been proposed for the genesis of the Mount Morgan mineralisation. The mineralisation has been proposed as a Devonian, volcanogenic, massive sulphide pipe deposit (*e.g.* Taube, 1986) and as a structurally controlled Devonian replacement body related to the tonalite (*e.g.* Arnold & Sillitoe, 1989). Recent work, however, indicates it forms an end member of the volcanic-hosted massive sulphide type (Messenger *et al.*, 1997). These rocks also contain substantial resources of high-grade limestone. An updated interpretation of this deposit using a variation of the volcanic-hosted massive sulphide model, but emphasising the separation of the gold and copper mineralisation as separate events, was presented by Blake (2003). Mineralisation in the Mount Morgan 1:100 000 Sheet area was described by Morwood (2002b).

Wandilla, Texas, Yarrol and Connors–Auburn Provinces and Gogango Overfolded Zone

In the Late Devonian–Carboniferous, the basic tectonostratigraphic framework of the New England Orogen was established as a convergent continental plate margin above a west-dipping subduction zone (Day *et al.*, 1978). Three parallel belts representing accretionary wedge (east), forearc basin (centre), and continental margin magmatic arc (west) have been described.

Rocks of the accretionary wedge form the **Wandilla** Province along the coast, and the **Texas Subprovince** further inland. The Texas Subprovince is part of the **Wooloomin Province**, which is better developed in New South Wales. They consist of a stack of deep water sedimentary and volcanic rocks that are generally steeply dipping, structurally complex, and sparsely fossiliferous. In the Wandilla Province, a gross regional stratigraphy is preserved, with a western (oldest) assemblage characterised by radiolarian jasper and chert, a central belt of volcaniclastic greywacke and argillite, and an enigmatic eastern (youngest) sequence of quartzose sandstone and argillite. Limited age control is provided by radiolarians and conodonts from chert, conodonts from sparse limestone lenses, and by the occurrence in the central belt of a persistent horizon of sandstone beds containing ooliths, which must have been sourced from early Carboniferous limestones of the forearc basin to the west. Mineral resources in the Wandilla Province were described by Burrows (2004), Cranfield & Garrad (1991), Cranfield *et al.* (2001), Garrad & Withnall (2004b), Lam (2005a), Morwood (2002a, 2003) and Randall *et al.* (1996).

The accretionary wedge assemblage in the Texas Subprovince has been folded into a large-scale double orocline (Murray *et al.*, 1987). The Texas Subprovince also contains numerous allochthonous lenses of early Carboniferous coralline limestone (Flood, 1999). Overall, the accretionary wedge is sparsely mineralised, but it does contain some slate belt type gold-bearing veins and stockworks in the Warwick area and at Kingston, south of Brisbane, and small high-grade manganese deposits. Mineralisation in the Stanthorpe–Texas–Inglewood area of the Texas Province was described by Denaro (1989) and Denaro & Burrows (1992).

The accretionary wedge is separated from the forearc basin sequence to the west by the major Yarrol Fault System, which is marked by serpentinite lenses. In the Marlborough area, these ultramafic rocks form an extensive flat-lying thrust sheet of early Paleozoic ocean floor and upper mantle material. Significant lateritic nickel–cobalt deposits have been developed as enriched residual deposits on the ultramafics during a Cainozoic deep weathering event (Garrad & Withnall, 2004b).

The **Yarrol Province** was described most recently by Murray *et al.* (2012) and Donchak *et al.* (2013). It consists mainly of a Late Devonian to Carboniferous forearc basin succession, assigned to the Rockhampton Subprovince in the south and the Campwyn Subprovince along the coast between Marlborough and Mackay. The basin fill mainly consists of volcaniclastic sedimentary rocks deposited on a marine shelf that was shallower to the west and became progressively more emergent with time. The early Carboniferous part of the sequence is characterised by the widespread development of oolitic limestone. The forearc basin succession unconformably overlies the Middle Devonian and older rocks (Kirkegaard *et al.*, 1970; Leitch *et al.*, 1992). The forearc basin succession is only sparsely mineralised except in the vicinity of later intrusives. Mineralisation in the Yarrol Province is summarised in reports by Burrows (2004), Garrad & Withnall (2004a, 2004b), Lam (2004, 2005a), Morwood (2002a, 2002b, 2003) and Morwood & Blake (2002).

West of the Yarrol Province, the **Connors–Auburn Province** is a linear belt of predominantly subaerial, terrestrial felsic volcanics and granitoids of the Auburn Subprovince in the south and the Connors Subprovince in the north (Withnall *et al.*, 2009). The northern part of the Connors Subprovince is dominated by plutonic rocks, which are also abundant in the southern part of the Auburn Subprovince. The two subprovinces form broad arches flanked by Permian sediments of the Bowen Basin and are separated by deformed equivalents of those sediments in the Gogango Thrust Zone. Most of the magmatic belt is late Carboniferous – early Permian, but some volcanics and granitoids are early Carboniferous and considered to represent an Andean-style, continental volcanic arc associated with the Yarrol Province forearc assemblage and the accretionary wedge of the Wandilla Province. Towards the top of the volcanic succession in the latest Carboniferous – early Permian, a transition to a more bimodal association (along with geochemical patterns) suggests development of an extensional setting with thinning crust that heralded the onset of deposition in the Bowen Basin (to which the volcanic rocks are basement). Bimodal dyke swarms in the northern Connors Subprovince may be related to this extension.

Early Permian strata that overlie the Late Devonian – Carboniferous forearc basin and accretionary wedge sequences have recently been interpreted as the fill of a series of extensional basins that developed at the same time as the Bowen Basin to the west. This interpretation is consistent with the fact that many outcrops of the Permian rocks unconformably overlie early Carboniferous or older rocks, implying removal or non-deposition of a substantial part of the stratigraphic section.

Some early Permian rocks are prospective for a volcanic hosted massive sulphide (VHMS) style of mineralisation. The Mount Chalmers gold–copper deposit is a classic Kuroko-type deposit, and the nearby Develin Creek prospect and the Silver Spur silver–lead deposit in the Texas area are also considered to represent VHMS mineralisation. Early Permian volcanic rocks along the western side of the Connors–Auburn Province that host the Cracow epithermal gold deposit are equated to the extensional event that formed the Bowen Basin. Mineralisation within the Connors–Auburn Province has been described by Burrows (2004), Garrad & Withnall (2004a, 2004b) and Lam (2004, 2005a).

The late Permian – Triassic Hunter–Bowen Orogeny deformed the rocks of the New England Orogen, producing WNW directed thrusting and associated folding.

The Bowen Basin is a major element of Queensland geology, characterised by a thick Permian–Triassic succession of marine siliciclastics succeeded by coal measures, which continues south beneath the Great Australian Basin into New South Wales as the Gunnedah and Sydney basins (Korsch & Totterdell 2009a, 2009b). Although rich in coal, it is poorly mineralised.

The **Gogango Overfolded Zone or Thrust Zone** is a belt of strongly cleaved sandstone, mudstone, and deformed mafic to felsic volcanic rocks that separates the Connors–Auburn Province into a northern and a southern section. Stratigraphic, sedimentological and structural studies (Fergusson, 1991; Fergusson *et al.*, 1994; Fielding *et al.*, 1994; Withnall *et al.*, 2009) have led to the conclusion that the Gogango Overfolded Zone is simply a part of the Bowen Basin that was more intensely deformed by thrusting during the Hunter–Bowen Orogeny. There is no evidence that the Connors–Auburn Province was a positive feature during deposition in the Bowen Basin and it is therefore thought that the arching results from later tectonism. The boundary between the Gogango Thrust Zone and the less deformed Yarrol Province is a line of major east dipping roof thrusts, but it is likely that the Bowen Basin originally extended eastwards because there is no obvious basin marginal facies. Mineralisation in this area has been described by Burrows (2002), Garrad & Withnall (2004a, 2004b), Lam (2005a) and Morwood (2002b).

Gympie Province

The geology of the Gympie Province was outlined by Cranfield *et al.* (1997). This province is unique as it contains the only record of Early Triassic marine rocks in eastern Australia. It comprises the Kin Kin Subprovince in the south (containing the Gympie Goldfield) and the Brooweena Subprovince.

The province comprises Early Permian to Early Triassic arc-related mafic to felsic volcanic, volcaniclastic and marine sedimentary rocks in a north-northwesterly trending belt extending from Nambour to west of Bundaberg in southern Queensland.

The rocks have long been considered to represent a unique stratotectonic unit that does not fit into the overall palaeogeographic pattern of the Tasman Orogenic Zone (Day *et al.*, 1978). It has therefore been proposed as an exotic terrane that collided with the continent in the Triassic (*e.g.* Harrington, 1983; Cawood, 1984; Waterhouse & Sivell, 1987).

Mineralisation in the Gympie Province is dominated by gold associated with the emplacement of Early to Middle Triassic and Late Triassic plutonic and volcanic rocks of the Southeast Queensland Volcanic and Plutonic Province. The most significant mineralisation is within the Gympie Goldfield (historic production in excess of 108 000 kg fine Au) in which structurally controlled mesothermal low-sulphide quartz reefs are associated with Late Triassic granodiorite and the northwest-trending Inglewood Structure. Although the fluid source is thought to be primarily related to granodiorite, the composition of the host rocks, in particular the presence of carbonaceous shales, has played a significant role in concentrating the gold mineralisation within the quartz lodes (Kitch & Murphy, 1990). Mineralisation in the Gympie Province has been described by Barker *et al.* (1993), Cranfield & Garrad (1991), Cranfield *et al.* (1997) and Randall *et al.* (1996).

Southeast Queensland Volcanic and Plutonic Province

The Southeast Queensland Volcanic and Plutonic Province is a grouping used for volcanic and plutonic rocks of late Permian – Triassic age in southeast Queensland. Rock types consist mainly of I-type intrusives and comagmatic continental volcanic rocks. Intrusive compositions range from layered gabbro to granite, with granodiorite the most common composition. Gust *et al.* (1993) proposed that active subduction produced the voluminous Late Permian and Early Triassic plutonism, and was replaced by an extensional phase marked by bimodal and alkalic magmatism in the Late Triassic.

Early–Late Triassic intrusives of the Southeast Queensland Volcanic and Plutonic Province are associated with gold mineralisation within the Gympie Province including that of the Gympie Goldfield. In addition, porphyry-style mineralisation such as that at Coalstoun Lakes is associated with intrusions of the Southeast Queensland Volcanic and Plutonic Province. Late Triassic skarn-related deposits include Mount Biggenden and Ban Ban Springs.

Intracratonic basins

Paleozoic – early Mesozoic sedimentary basins overlying the 'basement' rocks within the state are also assigned to the Tasman Orogenic Zone. These are listed in Table 2.

Table 2. Incratonic basins of the Tasman Orogenic Zone

Age	Northern Queensland	Central Queensland	Western Queensland	Southern Queensland
Late Carboniferous to Triassic	Ngarrabullan; Olive River	Bowen; Callide; Galilee; Miclere	Cooper	Ipswich; Tarong
Early Devonian to early Carboniferous	Bundock; Burdekin; Clarke River; Gilberton; Pascoe River	Drummond	Adavale	

The Early Devonian to Early Carboniferous basins are largely unmineralised, with the important exception of the Drummond Basin (Figure 1) which developed between the Late Devonian and early Carboniferous and contains a thick succession of continental sedimentary and volcanic rocks with sporadic marine beds near its base. Olgers (1972) subdivided the basin fill into three cycles. Cycle 1 comprises the volcanic and sedimentary rocks at the base of the basin, which are unconformably overlain by a sequence of quartzose and feldspathic, dominantly fluvial sedimentary rocks (Cycle 2). Cycle 3 records a return to volcanic and volcanolithic-rich sedimentary rocks. The basin hosts significant epithermal gold mineralisation such as the Pajingo (Vera-Nancy) and Wirralie deposits within early Carboniferous volcanic rocks currently thought to be part of the Cycle 1 group of rocks. Mineralisation in the northern part of the Drummond Basin is described by Denaro *et al.* (2004b).

The Gilberton Basin sedimentary rocks are known to host stratabound fluorite-uranium-molybdenum mineralisation such as the Maureen deposit, where mineralisation is apparently confined to relatively coarse, fluviatile arkosic sediments of the Gilberton Formation. Mineralisation, however, is probably genetically related to igneous activity of the Kennedy Province, although it also strongly controlled by sedimentary and diagenetic features. Limestone resources are known from the Burdekin Basin and oil shale occurs within the Galilee Basin.

The late Carboniferous to Triassic basins are also poorly mineralised, with the exception of the Permian Miclere Basin, in which the basal conglomeratic unit hosts the Miclere gold deposits (Lam, 2005b). Basins such as Ipswich, Tarong, Callide and Bowen contain significant coal resources.

Great Australian Basin

Rocks of the Great Australian Basin occur predominantly in western Queensland, with several isolated basins in the east (Figure 1). The Great Artesian Basin includes the Eromanga, Carpentaria, Surat, Laura, Mulgildie, Nambour, Maryborough and Clarence-Moreton Basins.

The Mesozoic age sediments of the Great Australian Basin are dominantly continental in origin and were deposited in huge sags in the early Mesozoic surface of Queensland. Deformation of these basinal sediments is characteristically mild and the structural trends are generally inherited from the older basement rocks.

On the whole the Great Australian Basin is poorly mineralised. However, the basin does host significant coal, coal seam gas, hydrocarbon and artesian water resources, and significant oil shale and vanadium resources occur with the Toolebuc Formation of the Eromanga Basin.

Cainozoic sediments, volcanics and weathering

During the Cainozoic, tectonism was generally mild with western areas experiencing rejuvenation of existing fault and fold structures and a continuation of crustal sagging over the sites of older basins, forming features such as the Karumba Basin in the State's north. Tectonic activity was more pronounced in eastern regions, where epeirogenic uplift, block faulting and extensive basaltic eruptions occurred. Onshore, numerous narrow fault-controlled basins were formed; including the significant oil shale deposits within the Nagoorin, Narrows and Yaamba basins. These basins locally contain thick sequences of basaltic volcanics of Paleocene to Eocene age. Table 3 lists the Cainozoic basins of Queensland.

Table 3. Cainozoic basins of Queensland

Northern Queensland	Central Queensland	Western Queensland	Southern Queensland
Karumba	Biloela; Casuarina; Duaringa; Herbert Creek; Hillsborough; Lowmead; Nagoorin; Narrows; Water Park; Yaamba	Marion; Noranside; Old Cork; Springvale	Amberley; Booval; Elliott; Oxley; Petrie; Pomona, Beaudesert

Younger Cainozoic (mainly basaltic) volcanic rocks are irregularly distributed along the whole length of the continental margin of Queensland and are assigned to the Eastern Australian Cainozoic Igneous Province. These rocks range in age from early Miocene to Pleistocene. A detailed subdivision and description of Cainozoic intraplate volcanics is given in Johnson *et al.* (1989).

Repeated deep weathering during the Cainozoic produced significant bauxite and kaolin resources such as the Weipa and Skardon River deposits on Cape York and magnesite resources such as the Kunwarara deposit near Rockhampton. Opal deposits formed as a result of the deep weathering processes in western Queensland. These deposits are concentrated in the Winton and Quilpie regions. In addition, significant heavy mineral and silica sand resources are found within dune systems along the coast. Significant alluvial deposits of gold and tin occur within Cainozoic alluvium, particularly in north Queensland, and alluvial sapphire deposits are worked at Anakie in the central Queensland gemfields.

References

AHMAD, M. & WYGRALAK, A.S., 1990: Murphy Inlier and environs — regional geology and mineralization. In: Hughes, F.E. (Editor): Geology of the Mineral Deposits of Australia and Papua New Guinea. *The Australasian Institute of Mining and Metallurgy Monograph Series*, **14**, 819–826.

ALLEN, C.M., WILLIAMS, I.S., STEPHENS, C.J. & FIELDING, C.R., 1998: Granite genesis and basin formation in an extensional setting: the magmatic history of the northern-most New England Orogen. *Australian Journal of Earth Sciences*, **45**, 875–888.

ALLEN, R.J., 1975: Petroleum resources of Queensland 1975. *Geological Survey of Queensland, Report* **87**.

ARNOLD, G.O. & HENDERSON, R.A., 1976: Lower Paleozoic history of the southwestern Broken River Province, North Queensland. *Journal of the Geological Society of Australia*, **23**, 73–93.

ARNOLD, G.O. & SILLITOE, R.H., 1989: Mount Morgan gold-copper deposit, Queensland, Australia: Evidence for an intrusion-related replacement origin. *Economic Geology*, **84**, 1805–1816.

BAIN, J.H.C., 1985: Developing models for gold genesis in northern Queensland . *BMR Research Newsletter*, **2**, 9–10.

BAIN, J.H.C. & DRAPER, J.J., 1997: North Queensland Geology. *Australian Geological Survey Organisation Bulletin **240**, and Queensland Department of Mines and Energy Queensland Geology* **9**.

BAIN, J.H.C., WITHNALL, I.W., BLACK, L.P., ETMINAN, H., GOLDING, S.D. & SUN, S.S., 1998: Towards an understanding of the age and origin of mesothermal gold mineralisation in the Etheridge Goldfield, Georgetown region, north Queensland. *Australian Journal of Earth Sciences*, **45**, 247–263.

BARKER, R.M., BURROWS, P.E, GENN, D.L.P. & CULPEPER, L.G., 1997: Mineral occurrences in the Einasleigh 1:250 000 Sheet area, north Queensland. *Queensland Geological Record* **1997/05**.

BARKER, R.M., BURROWS, P.E., SCOTT, M., GENN, D.L.P. & CRANFIELD, L.C., 1993: Mineral occurrences, Gympie and Laguna Bay 1:100 000 Sheet areas. *Queensland Geological Record* **1993/14**.

BARKER, R.M., EVANS, P.E., GENN, D.L.P. & CULPEPER, L.G., 1996a: Review of mineral exploration in the Einasleigh 1:250 000 Sheet area, north Queensland. *Queensland Geological Record* **1996/11**.

BARKER, R.M., GENN, D.L.P., BURROWS, P.E. & DENARO, T.J., 1996b: Summary of geology, mineral occurrences and company exploration in the Red River and Normanton 1:250 000 Sheet areas. *Queensland Geological Record* **1996/03**.

BETTS, P.G., GILES, D., MARK, G., LISTER, G.S., GOLEBY, B.R. & AILLERES, L., 2006: Synthesis of the Proterozoic evolution of the Mount Isa Inlier. *Australian Journal of Earth Sciences*, **53**, 187–211.

BLAKE, D.H., 1987: Geology of the Mount Isa Inlier and environs, Queensland and Northern Territory. *Bureau of Mineral Resources, Geology and Geophysics, Australia, Bulletin* **225**.

BLAKE, D.H., ETHERIDGE, M.A., PAGE, R.W., STEWART, A.J., WILLIAMS, P.R. & WYBORN, L.A.I., 1990: Mount Isa Inlier — regional geology and mineralisation. *In:* Hughes, F.E. (Editor): *Geology of the Mineral Deposits of Australia and Papua New Guinea*, The Australian Institute of Mining and Metallurgy, 915–925.

BLAKE, D.H. & STEWART, A.J., 1992: Stratigraphic and tectonic framework, Mount Isa Inlier. *In:* Detailed Studies of the Mount Isa Inlier. *AGSO Bulletin* **243**, 1–11.

BLAKE, P.R., 2003: Where is the next Mount Morgan? Digging Deeper Symposium Proceedings on CD. Geological Survey of Queensland.

BLAKE, P.R., CROUCH, S.B.S., DOMAGALA, J. & HAYWARD, M.A., 1995: Review of mineral exploration within the Mount Morgan (8950) and Bajool (9050) 1:100 000 Sheet areas, central Queensland. *Queensland Geological Record* **1995/01**.

BLAKE, P.R., HAYWARD, M.A., SIMPSON, G.A., OSBORNE, J.H. & MURRAY, C.G., 1996: Review of mineral exploration within the Biloela (9049), Calliope (9149), Monto (9148) and Scoria (9048) 1:100 000 Sheet areas, central Queensland. *Queensland Geological Record* **1996/12**.

BLAKE, P.R., SIMPSON, G.A., FORDHAM, B.G., & HAYWARD, M.A., 1998: The Yarrol forearc basin: a complex suite of volcanic facies and allochthonous limestone blocks. *Geological Society of Australia Abstracts*, **49**, 42.

BRUVEL, F.J., BULTITUDE, R.J., CULPEPER, L.G., GARRAD, P.D., LAM, J.S.F. & MORWOOD, D.A., 1991: Mineral occurrences — Ravenshoe 1:100 000 Sheet area, Queensland. *Queensland Resource Industries Record* **1991/05**.

BRUVEL, F.J. & MORWOOD, D.A., 1992: Mineral occurrences — Cape Weymouth 1:100 000 Sheet area, Cape York Peninsula, Queensland. *Queensland Resource Industries Record* **1992/04**.

BURROWS, P.E., 1991: Mine production data, Palmer Goldfield (compiled from Annual Reports of the Department of Mines 1877-1981). *Queensland Resource Industries Record* **1991/18**.

BURROWS, P.E., 2004: Mines, mineralisation and mineral exploration in the Rookwood, Ridgelands and Rockhampton 1:100 000 Sheet areas, central Queensland. *Queensland Geological Record* **2004/03**.

BURROWS, P.E. & CULPEPER, L.G. 2000: Mineral exploration in the Dobbyn 1:250 000 Sheet area, northwest Queensland. *Queensland Geological Record* **2000/02**.

CARR, G.R., DEAN, J.A. & MORRISON, G.W., 1988: Lead isotopes as an exploration technique and as an aid in genetic modelling for gold deposits in northeast Queensland. *In*: Goode, A.D.T. & Bosma, L.I. (Compilers): Bicentennial Gold 88, Extended Abstracts Oral Programme, *Geological Society of Australia, Abstracts* **22**, 265–271.

CAWOOD, P.A., 1984: The development of the SW Pacific margin of Gondwana; correlations between the Rangitata and New England orogens. *Tectonics*, **3**, 539–553.

CAWOOD, P.A. & KORSCH, R.J., 2008: Assembling Australia: Proterozoic building of a continent, *Precambrian Research*, **166**, 1–38.

CHAMPION, D.C. & BULTITUDE, R.J., 2013: Chapter 6 Kennedy Igneous Association. *In:* Jell, P.A. (Editor): *Geology of Queensland*. Geological Survey of Queensland, Brisbane, 473–513.

CHAPMAN, L.C., 2004: Geology and mineralisation styles of the George Fisher Zn-Pb-Ag deposit, Mount Isa, Australia. *Economic Geology*, **99**, 233–55.

CLARKE, G.W., MORWOOD, D.A. & DASH. P.H., 1994: Review of the Ollera Creek Mineral Field, north Queensland. *Queensland Geological Record* **1994/08**.

CONEY, P.J., EDWARDS, A., HINE, R., MORRISON, F. & WINDRIM, D., 1990: The regional tectonics of the Tasman orogenic system, eastern Australia. *Journal of Structural Geology*, **12**, 519–543.

CRANFIELD, L.C., 1999: *Gympie, Special Sheet 9445, Part 9545, Queensland, 1:100 000 Geological Map Commentary.* Queensland Department of Mines and Energy, Brisbane.

CRANFIELD, L.C., DONCHAK, P.J.T., RANDALL, R.E. & CROSBY, G.C., 2001: Geology and mineralisation of the Yarraman Subprovince, southeast Queensland. *Queensland Geology* **10**.

CRANFIELD, L.C. & GARRAD, P.D., 1991: Mines and prospects in the Maryborough 1:250 000 Sheet area. *Queensland Resource Industries Record* **1991/03**.

CRANFIELD, L.C., SHORTEN, G., SCOTT, M. & BARKER, R.M., 1997: Geology and mineralisation of the Gympie Province. *Geological Society of Australia Special Publication* **19**, 128–147.

CULPEPER, L.G., 1993: Mineral occurrences — Carpentaria and Karumba Basins, Cape York Peninsula, Queensland. *Queensland Geological Record* **1993/19**.

CULPEPER, L.G. & BURROWS, P.E., 1992: Mineral occurrences — Hann River 1:250 000 Sheet area, Cape York Peninsula, Queensland. *Queensland Resource Industries Record* **1992/18**.

CULPEPER, L.G., BURROWS, P.E., BARKER, R.M., DENARO, T.J. & GENN, D.L.P., 1997: Geology, mineralisation and company exploration in the Georgetown and Forsayth 1:100 000 Sheet areas, north Queensland. *Queensland Geological Record* **1997/08**.

CULPEPER, L.G., BURROWS, P.E. & DENARO, T.J., 1996: Summary of the geology, mineral occurrences and company exploration in the Forest Home and North Head 1:100 000 Sheet areas. *Queensland Geological Record* **1996/10**.

CULPEPER, L.G. & DENARO, T.J, 1999: Mineral exploration in the Camooweal 1:250 000 Sheet area, northwest Queensland. *Queensland Geological Record*, **1999/03**.

CULPEPER, L.G., DENARO, T.J., BURROWS, P.E. & MORWOOD, D.A., 1999: Mines and mineralisation of the Westmoreland 1:250 000 Sheet area, northwest Queensland. *Queensland Geological Record* **1999/06**.

CULPEPER, L.G., DENARO, T.J., BURROWS, P.E. & MORWOOD, D.A., 2000: Mines and mineralisation of the Dobbyn 1:250 000 Sheet area, northwest Queensland. *Queensland Geological Record* **2000/03**.

CULPEPER, L.G., DENARO, T.J., MORWOOD, D.A. & BURROWS, P.E., 1994: Mineral occurrences — Butchers Hill, Cooktown, Battle Camp and Kennedy Bend 1:100 000 Sheet areas, Cape York Peninsula, Queensland. *Queensland Geological Record* **1994/12**.

CULPEPER, L.G., DENARO, T.J., WILLMOTT, W.F., WHITAKER, W.G., BRUVEL, F.J., MORWOOD, D.A. & SHIELD, C.J., 1992a: Review of mineral exploration, Cape York Peninsula, 1969 to 1990. *Queensland Resource Industries Record* **1992/10**.

CULPEPER, L.G., GARRAD, P.D. & BURROWS, P.E., 1992b: Mineral occurrences — Ebagoola 1:250 000 Sheet area, Cape York Peninsula, Queensland. *Queensland Resource Industries Record* **1992/14**.

CULPEPER, L.G., LAM, J.S., MORWOOD, D.A. & BURROWS, P.E., 1990: Mineral occurrence data sheets — Bellevue 1:100 000 Sheet area. *Queensland Resource Industries Record* **1990/04**.

DASH, P., BARKER, R.M., MORWOOD, D.A., CULPEPER, L.G. & LAM, J.S.F., 1991: Mineral occurrences — Atherton 1:100 000 Sheet area. *Queensland Resource Industries Record* **1991/14**.

DASH, P. H. & CRANFIELD, L.C., 1993: Mineral occurrences, Rumula 1:100 000 Sheet area, north Queensland. *Queensland Geological Record* **1993/17**.

DASH, P., GARRAD, P. & MITCHELL, G., 1988: Mineral occurrence data sheets, Chillagoe 1:100 000 map Sheet area, Metallogenic Studies Program. Geological Survey of Queensland Record 1988/17.

DASH, P.H. & MORWOOD, D.A., 1994: Mineral occurrences, Cairns 1:100 000 Sheet area, north Queensland. *Queensland Geological Record* **1994/06**.

DAY, R.W., MURRAY, C.G. & WHITAKER, W.G., 1978: The eastern part of the Tasman Orogenic Zone. *Tectonophysics*, **48**, 327–364.

DAY, R.W., WHITAKER, W.G., MURRAY, C.G., WILSON, I.W. & GRIMES, K.G., 1983: Queensland Geology, A companion volume to the 1:2 500 000 scale geological map (1975). *Geological Survey of Queensland Publication*, **383**.

DENARO, T.J., 1989: Mineral occurrences — Inglewood, Texas and Ashford 1:100 000 Sheet areas. Geological Survey of Queensland Record 1989/32.

DENARO, T.J., 1992: A compilation of mine production data for the Stanthorpe Mining District from Annual Reports of the Department of Mines. *Queensland Resource Industries Record* **1992/12**.

DENARO, T.J., 1993: Mineral occurrences — Torres Strait 1:250 000 Sheet area, Cape York Peninsula, Queensland. *Queensland Geological Record* **1993/18**.

DENARO, T.J., 2011: A review of Queensland's non-energy mineral deposits and resources. *Queensland Geological Record* **2011/10**.

DENARO, T.J. & BURROWS, P.E., 1992: Mineral occurrences — Stanthorpe and Drake 1:100 000 Sheet areas, Queensland. *Queensland Resource Industries Record* **1992/08**.

DENARO, T.J. & CULPEPER, L.G., 1999a: Mineral exploration in the Westmoreland 1:250 000 Sheet area, northwest Queensland. *Queensland Geological Record* **1999/01**.

DENARO, T.J. & CULPEPER, L.G., 1999b: Mineral exploration in the Lawn Hill 1:250 000 Sheet area, northwest Queensland. *Queensland Geological Record* **1999/02**.

DENARO, T.J., CULPEPER, L.G., BURROWS, P.E. & MORWOOD, D.A., 1999a: Mines and mineralisation, of the Camooweal 1:250 000 Sheet area, northwest Queensland. *Queensland Geological Record* **1999/04**.

DENARO, T.J., CULPEPER, L.G., BURROWS, P.E., & MORWOOD, D.A., 2001a: Mining history of the Woolgar Goldfield, north Queensland. *Queensland Geological Record* **2001/05**.

DENARO, T.J., CULPEPER, L.G., BURROWS, P.E., & MORWOOD, D.A., 2004a: Mines, mineralisation, and mineral exploration in the Cloncurry 1:250 000 Sheet area, northwest Queensland. *Queensland Geological Record* **2004/01**.

DENARO, T.J., CULPEPER, L.G., MORWOOD, D.A. & BURROWS, P.E., 1993: Mineral occurrences — Coen, Rokeby and Silver Plains 1:100 000 Sheet areas, Cape York Peninsula, Queensland. *Queensland Geological Record* **1993/09**.

DENARO, T.J., CULPEPER, L.G., MORWOOD, D.A. & BURROWS, P.E., 1994a: Mineral occurrences, Helenvale 1:100 000 Sheet area, Cape York Peninsula, Queensland. *Queensland Geological Record* **1994/13**.

DENARO, T.J., CULPEPER, L.G., MORWOOD, D.A. & BURROWS, P.E., 1994b: Mineral occurrences, Laura 1:100 000 Sheet area, Cape York Peninsula, Queensland. *Queensland Geological Record* **1994/14**.

DENARO, T.J., CULPEPER, L.G., MORWOOD, D.A. & BURROWS, P.E., 1999b: Mines and mineralisation of the Lawn Hill 1:250 000 Sheet area, northwest Queensland. *Queensland Geological Record* **1999/05**.

DENARO, T.J., CULPEPER, L.G., MORWOOD, D.A. & BURROWS, P.E., 2001b: Mines and mineralisation of the Mount Isa 1:250 000 Sheet area, northwest Queensland. *Queensland Geological Record* **2001/03**.

DENARO, T.J., KYRIAZIS, Z., FITZELL, M.J., MORWOOD, D.A. & BURROWS, P.E., 2004b: Mines, mineralisation and mineral exploration in the northern Drummond Basin, central Queensland. *Queensland Geological Record* **2004/06**.

DENARO, T.J. & MORWOOD, D.A., 1992a: Mineral occurrences — Temple Bay 1:100 000 Sheet area, Cape York Peninsula, Queensland. *Queensland Resource Industries Record* **1992/13**.

DENARO, T.J. & MORWOOD, D.A., 1992b: Mineral occurrences — Lockhart River and Cape Sidmouth 1:100 000 Sheet areas, Cape York Peninsula, Queensland. *Queensland Resource Industries Record* **1992/20**.

DENARO, T.J. & MORWOOD, D.A., 1992c: Mineral occurrences, Wenlock 1:100 000 Sheet area, Cape York Peninsula, Queensland. *Queensland Resource Industries Record* **1992/21**.

DENARO, T.J. & MORWOOD, D.A., 1997: Geology, mineralisation and company exploration in the Croydon 1:250 000, and Gilbert River and Esmeralda 1:100 000 Sheet areas, north Queensland. *Queensland Geological Record* **1997/01**.

DENARO, T.J., MORWOOD, D.A., DUGDALE, J.S. & GARRAD, P.D., 1992: Mineral occurrences — Cape Melville 1:250 000 Sheet area, Cape York Peninsula, Queensland. *Queensland Resource Industries Record* **1992/01**.

DENARO, T.J., WITHNALL, I.W., BAIN, J.H.C. & MACKENZIE, D.E., 1997: *Mineral resource assessment — Georgetown–Croydon area*. Queensland Minerals and Energy Review Series, Queensland Department of Mines and Energy.

DENARO, T.J., WITHNALL, I.W., CULPEPER, L.G., BURROWS, P.E. & MORWOOD, D.A., 2003a: Mines, mineralisation and mineral exploration in the Duchess and Boulia 1:250 000 Sheet areas, northwest Queensland. *Queensland Geological Record* **2003/04**.

DENARO, T.J., WITHNALL, I.W., CULPEPER, L.G., MORWOOD, D.A. & BURROWS, P.E., 2003b: Mines, mineralisation and mineral exploration in the Urandangi 1:250 000 sheet area, northwest Queensland. *Queensland Geological Record* **2003/02**.

DUGDALE, J.S., 1991: Compilation of mine production data for the Cooktown, Thursday Island and Weipa mining districts from Annual Reports of the Department of Mines (1884-1988/89). *Queensland Resource Industries Record* **1991/01**.

DERRICK, G.M. 1982: A Proterozoic rift zone at Mount Isa, Queensland, and implications for mineralisation. *BMR Journal of Australian Geology & Geophysics*, **7**, 81–92.

DONCHAK, P.J.T., PURDY, D.J., WITHNALL, I.W., BLAKE, P.R. & JELL, P.A., 2013: Chapter 5 New England Orogen. *In:* Jell, P.A. (Editor): *Geology of Queensland*. Geological Survey of Queensland, Brisbane, 305–472.

ETHERIDGE, M.A., RUTLAND, R.W.R. & WYBORN, L.A.I., 1987: Orogenesis and tectonic processes in the Early to Middle Proterozoic of northern Australia. *American Geophysical Union, Geodynamic Series*, **17**, 131–47.

FAWCKNER, J.F., 1981: Structural and stratigraphic relations and a tectonic interpretation of the western Hodgkinson Province, northeastern Australia. Ph.D. Thesis, James Cook University of North Queensland, Townsville, Department of Earth Sciences.

FERGUSSON, C.L., 1991: Thin-skinned thrusting in the northern New England Orogen, central Queensland, Australia. *Tectonics*, **10**, 797–806.

FERGUSSON, C.F. & HENDERSON, R.A., 2013: Chapter 3 Thomson Orogen. *In:* Jell, P.A. (Editor): *Geology of Queensland*. Geological Survey of Queensland, Brisbane, 113–224.

FERGUSSON, C.L., HENDERSON, R.A. & LEITCH, E.C., 1994: Tectonics of the New England Fold Belt in the Rockhampton Gladstone region, central Queensland. *In:* Holcombe, R.J., Stephens, C.J. & Fielding, C.R.(Editors): *1994 Field Conference, Capricorn region, central coastal Queensland.* Geological Society of Australia Inc. (Queensland Division), 1–16.

FERGUSSON, C.L., HENDERSON, R.A., LEITCH, E.C. & ISHIGA, H., 1993: Lithology and structure of the Wandilla terrane, Gladstone-Yeppoon district, central Queensland, and an overview of the Paleozoic subduction complex of the New England Fold Belt. *Australian Journal of Earth Sciences*, **40**, 403–414.

FIELDING, C.R., HOLCOMBE, R.J. & STEPHENS, C.J., 1994: A critical evaluation of the Grantleigh Trough, east-central Queensland. *In:* Holcombe, R.J., Stephens, C.J. & Fielding, C.R. (Editors): *1994 Field Conference, Capricorn region, central coastal Queensland.* Geological Society of Australia Inc. (Queensland Division), 17–30.

FLOOD, P.G., 1999: Exotic seamounts within Gondwanan accretionary complexes, eastern Australia. *In:* Flood, P.G.(Editor): *New England Orogen NEO '99 Conference.* Earth Sciences, School of Physical Sciences and Engineering, University of New England, Armidale, 23–29.

FORRESTAL, P.J., PEARSON, P.J., COUGHLIN, T. & SCHUBERT, C.J., 1998: Tick Hill Gold Deposit. *In:* Hughes, F.E. (Editor): *Geology of the Mineral Deposits of Australia and Papua New Guinea*. The Australian Institute of Mining and Metallurgy, 699–706.

GARRAD, P.D., 1991: A compilation of mine production data for Herberton Mining District from Annual Reports of the Department of Mines (1883-1989). *Queensland Resource Industries Record* **1991/04**.

GARRAD, P.D., 1993: Mineral occurrences, Mount Mulligan 1:100 000 Sheet area, north Queensland. *Queensland Geological Record* **1993/11**.

GARRAD, P.D., 1996: Mineral occurrences of the Lolworth, Pentland and White Mountains 1:100 000 Sheet areas, north Queensland. *Queensland Geological Record* **1996/06**.

GARRAD, P.D. & BULTITUDE, R.J., 1999: *Geology, mining history and mineralisation of the Hodgkinson and Kennedy Provinces, Cairns region, north Queensland*. Queensland Minerals and Energy Review Series, Queensland Department of Mines and Energy.

GARRAD, P.D. & LAM, J.S.F., 1993: Mineral occurrences, Emerald 1:250 000 Sheet area. *Queensland Geological Record* **1993/02**.

GARRAD, P.D. & REES, I.D., 1995: Mineral occurrences, Innisfail 1:250 000 Sheet area, north Queensland. *Queensland Geological Record* **1995/03**.

GARRAD, P.D. & WITHNALL, I.W., 2004a: Mineral occurrences and district analysis — Banana, Theodore and Scoria 1:100 000 Sheet areas, central Queensland. *Queensland Geological Record* **2004/02**.

GARRAD, P.D. & WITHNALL, I.W., 2004b: Mineral occurrences — Saint Lawrence and Port Clinton 1:250 000 Sheet areas, central Queensland. *Queensland Geological Record* **2004/07**.

GEOLOGICAL SURVEY OF QUEENSLAND, 2011: *North-West Queensland Mineral and Energy Province report*. Queensland Department of Employment, Economic Development and Innovation, Brisbane.

GEOLOGICAL SURVEY OF QUEENSLAND, 2012: *Queensland Geology, Scale 1:2 000 000*. Department of Natural Resources and Mines, Brisbane.

GREENE, D.C., 2010: Neoproterozoic rifting in the southern Georgina Basin, central Australia: implications for reconstructing Australia in Rodinia. *Tectonics*, **29**, TC5010, 1–20. doi:10.1029/2009TC002543.

GUNTHER, M.C., MORWOOD, D.A., DENARO, T.J. & DASH, P.H., 1994: Mineral occurrences of the Kangaroo Hills Mineral Field. *Queensland Geological Record* **1994/03**.

GUST, D.A., STEPHENS, C.J. & GRENFELL, A.T., 1993: Granitoids of the northern NEO: their distribution in time and space and their tectonic implications. *In:* Flood, P.G. & Aitcheson, J.L. (Editors): *NEO '93 Conference Proceedings*. Department of Geology and Geophysics, University of New England, 565–571.

HARMS, J.E., 1965: Iron ore deposits of Constance Range. *In:* McAndrew, J. (Editor): *Geology of Australian Ore Deposits.* Eighth Commonwealth mining and metallurgical congress Australia and New Zealand, The Australian Institute of Mining and Metallurgy, Melbourne, 264–269.

HARRINGTON, H.J., 1983: Correlation of the Permian and Triassic Gympie Terrain of Queensland with the Brooks Street and Maitai terranes of New Zealand. *In: Permian Geology of Queensland*, Geological Society of Australia, Queensland Division, Brisbane, 431–436.

HARTLEY, J.S., 1996: Mineral occurrences — Ravenswood 1: 100 000 Sheet area. *Queensland Geological Record* **1996/02**.

HARTLEY, J.S. & DASH, P.H., 1993: Mineral occurrences, Charters Towers 1:100 000 Sheet area. *Queensland Geological Record* **1993/06**.

HAYWARD, M.A., DOMAGALA, J., BLAKE, P.R., SIMPSON, G.A. & CROUCH, S.B.S., 1995: Review of mineral exploration within the Rookwood (8851) and Ridgelands (8951) 1:100 000 Sheet areas, central Queensland. *Queensland Geological Record* **1995/02**.

HENDERSON, G.A.M., 1989: Notes on Croydon, North Queensland, fieldwork July/August 1988 and results of K/Ar dating of sericitic alteration. *Bureau of Mineral Resources, Geology and Geophysics, Australia, Record* **1989/46**.

HENDERSON, R.A., 1980: Structural outline and summary geological history for northeastern Australia. *In:* Henderson, R.A. & Stephenson, P.J. (Editors):*The Geology and Geophysics of Northeastern Australia.* Geological Society of Australia, Queensland Division, Brisbane, 1–26.

HENDERSON, R.A., DONCHAK, P.J.T. & WITHNALL, I.W., 2013: Chapter 4 Mossman Orogen. *In:* Jell, P.A. (Editor): Geology of Queensland. Geological Survey of Queensland, Brisbane, 225–304.

HOLCOMBE, R.J., STEPHENS, C.J., FIELDING, C.R., GUST, D., LITTLE, T.A., SLIWA, R., McPHIE, J. & EWART, A., 1997: Tectonic evolution of the northern New England Fold Belt: Carboniferous to Early Permian transition from active accretion to extension. *Geological Society of Australia Special Publication* **19**, 66–79.

HUTTON, L.J., RIENKS, I.P., TENISON WOODS, K., HARTLEY, J.S. & CROUCH, S.B.S., 1994: A geochemically and structurally based interpretation of the Ravenswood Batholith, North Queensland. *In:* Henderson, R.A. & Davis, B.K. (Editors): Extended conference abstracts. New developments in geology and metallogeny: northern Tasman Orogenic Zone. James Cook University of North Queensland, Department of Earth Sciences, *Economic Geology Research Unit, Contribution* **50**, 3–6.

HUTTON, L.J., WITHNALL, I.W., BULTITUDE, R.J., von GNIELINSKI, F.E. & LAM, J.S., 1999: South Connors-Auburn-Gogango Project: progress report on investigations during 1998. *Queensland Geological Record* **1999/7**.

JACKSON, M.J., SWEET, I.P., PAGE, R.S. & BRADSHAW, B.E., 1999: The South Nicholson and Roper Groups: Evidence for the Early Mesoproterozoic Roper Superbasin. Australian Geological Survey Organisation, Record 1999/19.

JACKSON, M.J., SCOTT, D.L. & RAWLINGS, D.J. 2000: Stratigraphic framework for the Leichhardt and Calvert superbasins: review and correlations of the pre-1700 Ma successions between Mt Isa and McArthur River. *Australian Journal of Earth Sciences*, **47**, 381–403.

JOHNSON, R.W., KNUTSON, J., TAYLOR, J. & ROSS, S., 1989. *Intraplate volcanism in eastern Australia and New Zealand.* Cambridge University Press in association with the Australian Academy of Science.

KIRKEGAARD, A.G., SHAW, R.D. & MURRAY, C.G., 1970: Geology of the Rockhampton and Port Clinton 1:250 000 sheet areas. *Geological Survey of Queensland Report* **38**.

KITCH, R.B. & MURPHY, R.W., 1990: Gympie Gold Field. *In:* Hughes, F.E. (Editor): *Geology of the Mineral Deposits of Australia and Papua New Guinea.* The Australian Institute of Mining and Metallurgy, 1515–1518.

LAM, J.S.F., 1993: Summary of the mineral occurrences of the Mossman 1:100 000 Sheet area (7965), north Queensland. *Queensland Geological Record* **1993/13**.

LAM, J.S.F., 1994a: Summary of company exploration and mineral occurrences of the Chudleigh Park 1:100 000 Sheet area, north Queensland. *Queensland Geological Record* **1994/15**.

LAM, J.S.F., 1994b: Summary of company exploration and mineral occurrences of the Maryvale 1:100 000 Sheet area, north Queensland. *Queensland Geological Record* **1994/19**.

LAM, J.S.F., 1994c: Summary of mineral occurrences and company exploration of the Lyndhurst 1:100 000 Sheet area, north Queensland. *Queensland Geological Record* **1994/20**.

LAM, J.S.F., 1995a: Summary of mineral occurrences and company exploration of the Clarke River 1:100 000 Sheet area, north Queensland. *Queensland Geological Record* **1995/05**.

LAM, J.S.F., 1995b: Summary of mineral occurrences and company exploration of the Burges 1:100 000 Sheet area, north Queensland. *Queensland Geological Record* **1995/06**.

LAM, J.S.F., 1996: Summary of company exploration and mineral occurrences of the Wando Vale 1:100 000 Sheet area, north Queensland. *Queensland Geological Record* **1996/01**.

LAM, J.S.F., 1998: A review of company exploration for metalliferous deposits in the Mundubbera 1:250 000 Sheet area. *Queensland Geological Record* **1998/04**.

LAM, J.S, 2004: A review of company exploration and metalliferous mineralisation in the Mackay 1:250 000 Sheet area, central Queensland. *Queensland Geological Record* **2004/04**.

LAM, J.S, 2005a: A review of mines and metalliferous mineralisation in the Mundubbera 1:250 000 Sheet area, *Queensland. Queensland Geological Record* **2005/01**.

LAM, J.S, 2005b: A review of exploration, mines and metalliferous mineralisation in the Clermont 1:250 000 map Sheet area. *Queensland Geological Record* **2005/02**.

LAM, J.S.F. & GARRAD, P.D., 1993: Mineral occurrences — Monteagle (8352) & Albro (8252) 1:100 000 Sheet areas, central Queensland. *Queensland Geological Record* **1993/01**.

LAM, J.S.F. & GENN, D.L.P., 1993: Mineral occurrences, South Palmer River 1:100 000 north Queensland. *Queensland Geological Record* **1993/26**.

LAM, J.S.F., DENARO, T.J., BURROWS, P.E. & GARRAD, P.D., 1991: Summary of the mineral occurrences of the Maytown 1:100 000 Sheet Area (7765), north Queensland. *Queensland Resource Industries Record* **1991/10**.

LAM, J.S.F., DENARO, T.J., GARRAD, P.D., HOLMES, P. & KAY, J., 1989: The mineral occurrences of the Lyndbrook 1:100 000 Sheet area. *Geological Survey of Queensland Record* **1989/06**.

LAM, J.S.F., GARRAD, P. & MITCHELL, G., 1988: Mineral occurrence data sheets, Bullock Creek 1:100 000 map Sheet area, Metallogenic Studies Program. Geological Survey of Queensland Record 1988/12.

LARGE, R.R., BULL, S.W., McGOLDRIC, P.J., WALTERS, S., DERRICK, G.M. & CARR, G.R., 2005: Stratiform and strata-bound Zn-Pb-Ag deposits in Proterozoic sedimentary basins, northern Australia. Economic Geology, 100, 931–63.

LEITCH, E.C., FERGUSSON, C.L., & HENDERSON, R.A., 1992: Geological note: The intra-Devonian unconformity at Mount Gelobera, south of Rockhampton, central Queensland. *Australian Journal of Earth Sciences*, **39**, 121–122.

LEVY, I.W. & STOREY, N.J.M., 1990: Horn Island gold deposit. *In:* HUGHES, F.E. *Geology of the Mineral Deposits of Australia and Papua New Guinea,* The Australasian Institute of Mining and Metallurgy, 1451–1454.

McGOLDRICK, P.J. & LARGE, R.R., 1998: Proterozoic stratiform sediment-hosted Zn-Pb-Ag deposits. *AGSO Journal of Australian Geology & Geophysics*, **17**, 189–96.

MESSENGER, P.R., GOLDING, S.D. & TAUBE, A., 1997: Volcanic setting of the Mount Morgan Au–Cu deposit, central Queensland: implication for ore genesis. *Geological Society of Australia Special Publication* **19**, 109–127.

MORRISON, G.W., 1988: Paleozoic gold deposits of northeast Queensland. *In:* Morrison, G.W. (Editor): Epithermal and porphyry style gold deposits in North Queensland. James Cook University of North Queensland, Townsville, Department of Earth Sciences*, Economic Geology Research Unit, Contribution*, **29**, 11–21.

MORWOOD, D.A., 1992: Compilation of mine production data for the Kangaroo Hills Mineral Field, north Queensland, from Annual Reports of the Department of Mines (1887–1990). *Queensland Resource Industries Record* **1992/09**.

MORWOOD, D.A., 2002a: Mineral occurrences — Monto, Calliope and Biloela 1:100 000 Sheet areas. *Queensland Geological Record* **2002/02**.

MORWOOD, D.A., 2002b: Mineral occurrences — Mount Morgan 1:100 000 Sheet area. *Queensland Geological Record* **2002/03**.

MORWOOD, D. A., 2003: Mineral occurrences — Gladstone and Cape Capricorn 1:100 000 Sheet areas. *Queensland Geological Record* **2003/01**.

MORWOOD, D.A. & BLAKE, P.R., 2002: Mineral occurrences — Bajool 1:100 000 Sheet area. *Queensland Geological Record* **2002/01**.

MORWOOD, D.A. & DASH, P.H., 1996: Mineral occurrences of the Ingham 1:250 000 Sheet area, north Queensland. *Queensland Geological Record* **1996/05**.

MORWOOD, D.A. & DENARO. T.J., 2000: Mineral exploration in the Mount Isa 1:250 000 Sheet area, northwest Queensland. *Queensland Geological Record* **2000/01**.

MORWOOD, D.A., DRAPER, J.J., EWINGTON, D.J., GUNTHER, M.C. & DENARO, T.J., 2001: Mineral occurrences of the Townsville 1:250 000 Sheet area, north Queensland. *Queensland Geological Record* **2001/02**.

MURRAY, C.G., 1986: Metallogeny and tectonic development of the Tasman Fold Belt System in Queensland. *Ore Geology Reviews* **1**, 315–400.

MURRAY, C.G., BLAKE, P.R., CROUCH, S.B.S., HAYWARD, M.A., ROBERTSON, A.D.C. & SIMPSON, G.A., 2012: Geology of the Yarrol Province and associated rocks of the northern New England Orogen. *Queensland Geology*, **13**, 1–524.

MURRAY, C.G., BLAKE, P.R., HUTTON, L.J., WITHNALL, I.W., HAYWARD, M.A., SIMPSON, G.A. & FORDHAM, B.G. 2003: Discussion and reply. Yarrol terrane of the northern New England Fold Belt: forearc or backarc? Discussion. *Australian Journal of Earth Sciences*, **50**, 271–278.

MURRAY, C.G., FERGUSSON, C.L., FLOOD, P.G., WHITAKER, W.G. & KORSCH, R.J., 1987: Plate tectonic model for the Carboniferous evolution of the New England Fold Belt. *Australian Journal of Earth Sciences*, **34**, 213–236.

O'DEA, M.G., LISTER, G.S., BETTS, P.G. & POUND, K.S. 1997: A shortened intraplate rift system in the Proterozoic Mount Isa Terrane, NW Queensland, Australia. *Tectonics*, **16**, 425–41.

OLGERS, F., 1972: Geology of the Drummond Basin, Queensland. *Bureau of Mineral Resources, Australia Bulletin*, **132**.

OSBORNE, J.H., SIMPSON, G.A., BLAKE, P.R., HAYWARD, M.A., CROUCH, S.B.S. & DOMAGALA, J., 1997: Review of mineral exploration within the Rockhampton (9051), Cape Capricorn (9151) and Gladstone (9150) 1:100 000 Sheet areas, central Queensland. *Queensland Geological Record* **1997/03**.

PAGE, R.W. & SWEET, I.P., 1998: Geochronology of basin phases in the western Mount Isa Inlier, and correlation with the McArthur Basin. *Australian Journal of Earth Sciences* **45**, 219–232.

PAGE, R.W. & SUN, S.S., 1998: Aspects of geochronology and crustal evolution in the Eastern Fold Belt, Mount Isa Inlier. *Australian Journal of Earth Sciences* **45**, 343–361.

PETERS, S.G., 1987: Geology, lode descriptions and mineralisation of the Hodgkinson Goldfield, northeastern Queensland. James Cook University of North Queensland, Townsville, Department of Earth Sciences. *Economic Geology Research Unit, Contribution* **20**.

PERKINS, W.G. 1984: Mount Isa silica–dolomite ore bodies: result of a synorogenic hydrothermal alteration system. *Economic Geology*, **79**, 601–37.

PHILLIPS, G.N. & POWELL, R., 1992: Gold only provinces and there common features. *Economic Geology Research Unit, Contribution* **43**.

QUEENSLAND DEPARTMENT OF MINES AND ENERGY, TAYLOR WALL & ASSOCIATES, SRK CONSULTING PTY LTD & ESRI AUSTRALIA, 2000: *Northwest Queensland Mineral Province Report*. Queensland Department of Mines and Energy, Brisbane.

RANDALL, R E., OSBORNE, J. H., DONCHAK, P. J.T., CROSBY, G. C. & SCOTT, M., 1996: Review of mineral exploration and known mineral occurrences within the Goomeri (9345), Nambour (9444) and Nanango (9344) 1:100 000 Sheet areas, southeast Queensland. *Queensland Geological Record* **1996/04**.

REES, I.D. & GENN, D.L.P., 1999: Mineral occurrences – Gilberton 1:250 000 Sheet area, north Queensland. *Queensland Geological Record* **1999/08**.

SAWERS, J.D., HAYWARD, M.A., COOPER, W., DASH, P.H., GARRAD, P.D., ISHAQ, S. & LAM, J.S.F., 1987: Metallogenic Studies Program, Mungana 1:100 000 Sheet, mineral occurrence data sheets. Geological Survey of Queensland Record 1987/29.

SENNITT, C.M. & HARTLEY, J.S., 1994: Mineral occurrences: Homestead 1:100 000 Sheet area , north Queensland. *Queensland Geological Record* **1994/16**.

SHERGOLD, J.H. & DRUCE, E.C., 1980: Upper Proterozoic and Lower Paleozoic rocks of the Georgina Basin. *In:* Henderson, R.A. & Stephenson, P.J. (Editors): *The Geology and Geophysics of Northeastern Australia* . Geological Society of Australia, Queensland Division, 149–174.

SIMPSON, G.A., BLAKE, P.R., MURRAY, C.G., HAYWARD, M.A & FORDHAM, B.G., 1998: Evidence for mid-Paleozoic exotic terranes in the Yarrol Province, central Queensland. *Geological Society of Australia Abstracts*, **49**, 408.

SMITH, K.G., 1972: Stratigraphy of the Georgina Basin. *Bureau of Mineral Resources, Australia, Bulletin*, **111**.

SOUTHGATE, P.N., BRADSHAW, B.E., DOMAGALA, J., JACKSON, M.J., IDNURM, M., KRASSAY, A.A., PAGE, R.S., SAMI, T.T., SCOTT, D.L., LINDSAY, J.F., McCONACHIE, B.A. & TARLOWSKI, C., 2000: Chronostratigraphic basin framework for Palaeoproterozoic rocks (1730–1575 Ma) in northern Australia and implications for mineralisation, *Australian Journal of Earth Sciences*, **47**, 461–85.

SWEET, I.P., MOCK, C.M. & MITCHELL, J.E., 1981: *Seigal, Northern Territory, Hedleys Creek Queensland, 1:100 000 geological map commentary*. Bureau of Mineral Resources, Australia, Canberra.

TAUBE, A., 1986: The Mount Morgan gold–copper mine and environment, Queensland: A volcanogenic massive sulphide deposit associated with penecontemporaneous faulting. *Economic Geology*, **81**, 1322–1340.

VAN NOORD, K.A.A., 1999: Basin development, geological evolution and tectonic setting of the Silverwood Group. *In:* Flood, P.G. (Editor): *New England Orogen NEO '99 Conference*. Earth Sciences, School of Physical Sciences and Engineering, University of New England, Armidale, 163–180.

von GNIELINSKI, F.E., 1996: Regional Geology, Exploration, Development and Failure of the Horn Island Gold Mine and its Environmental Clean-up. *MSc thesis at the Department of Geology, James Cook University of North Queensland*, June 1996.

WALLIS, D.S., DRAPER, J.J., DENARO, T.J., 1998: Paleo- and Mesoproterozoic mineral deposits in Queensland. *AGSO Journal of Australian Geology and Geophysics*, **17**(3), 47–59.

WATERHOUSE, J.B. & SIVELL, W.J., 1987: Permian evidence for trans-Tasman relationships between east Australia, New Caledonia and New Zealand. *Tectonophysics*, **142**, 227–240.

WITHNALL, I.W., BLAKE, P.R., CROUCH, S.B.S., TENNISON WOODS, K., GRIMES, K.G., HAYWARD, M.A., LAM, J.S., GARRAD, P. & REES, I.D., 1995: Geology of the southern part of the Anakie Inlier, central Queensland. *Queensland Geology*, **7**.

WITHNALL, I.W., GOLDING, S.D., REES, I.D. & DOBOS, S.K., 1996: K-Ar dating of the Anakie Metamorphic Group: evidence for an extension of the Delamerian Orogeny into central Queensland. *Australian Journal of Earth Sciences*, **43**, 567–572.

WITHNALL, I.W., HENDERSON, R.J., CHAMPION, & JELL, P.A., 2013: Chapter 1 Introduction. *In:* Jell, P.A. (Editor): *Geology of Queensland*. Geological Survey of Queensland, Brisbane, 1–21.

WITHNALL, I.W. & HUTTON, L.J., 2013: Chapter 2 North Australian Craton. *In:* Jell, P.A. (Editor): *Geology of Queensland*. Geological Survey of Queensland, Brisbane, 23–111.

WITHNALL, I.W., HUTTON, L.J. & BLIGHT, R.L. 2003: *North Queensland Gold and Base Metal Study Stage 2 Preliminary data release — Charters Towers GIS*. Geological Survey of Queensland, Department of Natural Resources and Mines, digital data released on CD-ROM.

WITHNALL, I.W., HUTTON, L.J., BULTITUDE, R.J., von GNIELINSKI, F.E. & RIENKS, I.P., 2009: Geology of the Auburn Arch, southern Connors Arch and adjacent parts of the Bowen Basin and Yarrol Province, central Queensland. *Queensland Geology*, **12**, 1–461.

WITHNALL, I.W., HUTTON, L.J., GARRAD, P.D., JONES, M.R. & BLIGHT, R.L. 2002: North Queensland Gold and Base Metal Study Stage 1 Preliminary data release — Georgetown GIS. Geological Survey of Queensland, Department of Natural Resources and Mines, digital data released on CD-ROM.

WITHNALL, I.W, HUTTON, L.J., RIENKS, I.P., BULTITUDE, R.J., von GNIELINSKI, F.E., LAM, J.S., GARRAD, P.D. & JOHN, B.H., 1998: South Connors–Auburn–Gogango Project: progress report on investigations during 1997. *Queensland Geological Record* **1998/1**.

WITHNALL, I.W. & LANG, S.C. (Editors), 1993: Geology of the Broken River Province, North Queensland. *Queensland Geology*, **4**.

Overview of mineral commodities for Queensland

Queensland's major mineral deposits are summarised below by commodity type. General geological descriptions of the major deposit models are included where appropriate. Summary resource and reserve figures are calculated by using all classification levels unless otherwise stated. Efforts have been made to ensure that resource figures quoted are not inclusive of other resource details tabulated, to ensure a clear understanding of the deposits' magnitude. The resource classification scheme used is the Australasian Code for Reporting of Minerals Resources and Ore Reserves (The JORC Code 2004 and 2012) and is included as **Appendix 9**. As the new 2012 JORC Code has become effective and mandatory since 01 December 2013, all new quoted resource figures should comply with the JORC Code 2012. Resource figures quoted before 1 December 2013 may only comply with the 2004 JORC as it was to the discretion of the companies which JORC Code they applied with establishing their resource figures in the transition period through 2013. Therefore it is presumed that all figures quoted prior to 2012 comply to the 2004 JORC Code only.

More detailed information for individual mines and prospects is available in the 'Mineral Deposit Summary Sheets' included as **Appendices 1 and 2**. The following information has been compiled from company reports, announcements and published documents. Commodity reviews and personal communications have also been extensively sourced.

Tabulations of mineral resources for Queensland are included as **Appendices 3 to 7**. Information tabulated includes the total metal content for the various reserve and resource classifications by deposit and commodity, contained metal grouped by host rock age, total production details, deposit models versus host rock provinces, and individual resources for each major deposit in Queensland. Only small to giant sized mineral deposits have been used in the tabulations. The size classification used is defined in **Appendix 8**. **Appendices 10 and 11** provide listings of the names and contact details of individuals and companies active in mining and exploration in Queensland.

Metalliferous Minerals

'Metalliferous minerals' is a collective term for the wide range of core metal commodities produced, which after coal mining continue to be the most significant contributor to Queensland's economy. While coal remains Queensland's largest export commodity and the coal seam gas industry will be another major driver of our economy in the future, Queensland (2012-13) leads Australia in the production of copper (33%), lead (70%), silver (82%) and zinc (64%). Queensland is Australia's second largest bauxite producer (32%) and third largest gold producer (4.2%).

In global terms in 2012–13 Queensland ranked 6th in the world in silver, 3rd in the world in zinc, 2nd in the world in lead, 6th in the world in bauxite and 12th in the world in copper production (Source: BREE and USGS). Generated value of the total 'metalliferous minerals' in 2011–12 (2012–13) comprises A$ 6 554 150 715 (A$ 7 298 499 605). Note these figures exclude titanium minerals as variance to quoted figures in the DNRM Queensland Annual Mineral Summary statistics.

The main metalliferous minerals commodities in Queensland are bauxite, silver, lead, zinc, copper, gold, magnetite, molybdenum, nickel, tin, and tungsten. Commodities with production potential in Queensland include antimony, scandium, rhenium, vanadium, uranium, lithium, tantalum, yttrium and various rare earth elements. All mentioned commodities are described separately below.

Antimony

Quartz-stibnite veins are widely distributed in eastern Queensland, with concentrations in the Hodgkinson and Broken River Provinces and, to a lesser extent, in the Gympie Province. The main centres of past antimony production include the Neardie mine (northeast of Gympie), the Northcote deposit, the Woodville deposit and the Mitchell River area (west of Cairns in far north Queensland).

Small scale mining of high-grade antimony vein deposits has occurred intermittently since 1873. Total historical Queensland production is ~5 500 t of antimony metal and concentrates (Photographs 16 and 17). Future antimony production may come from the development of small to medium-sized gold–antimony deposits in the Hodgkinson and Broken River Provinces (Table 4).

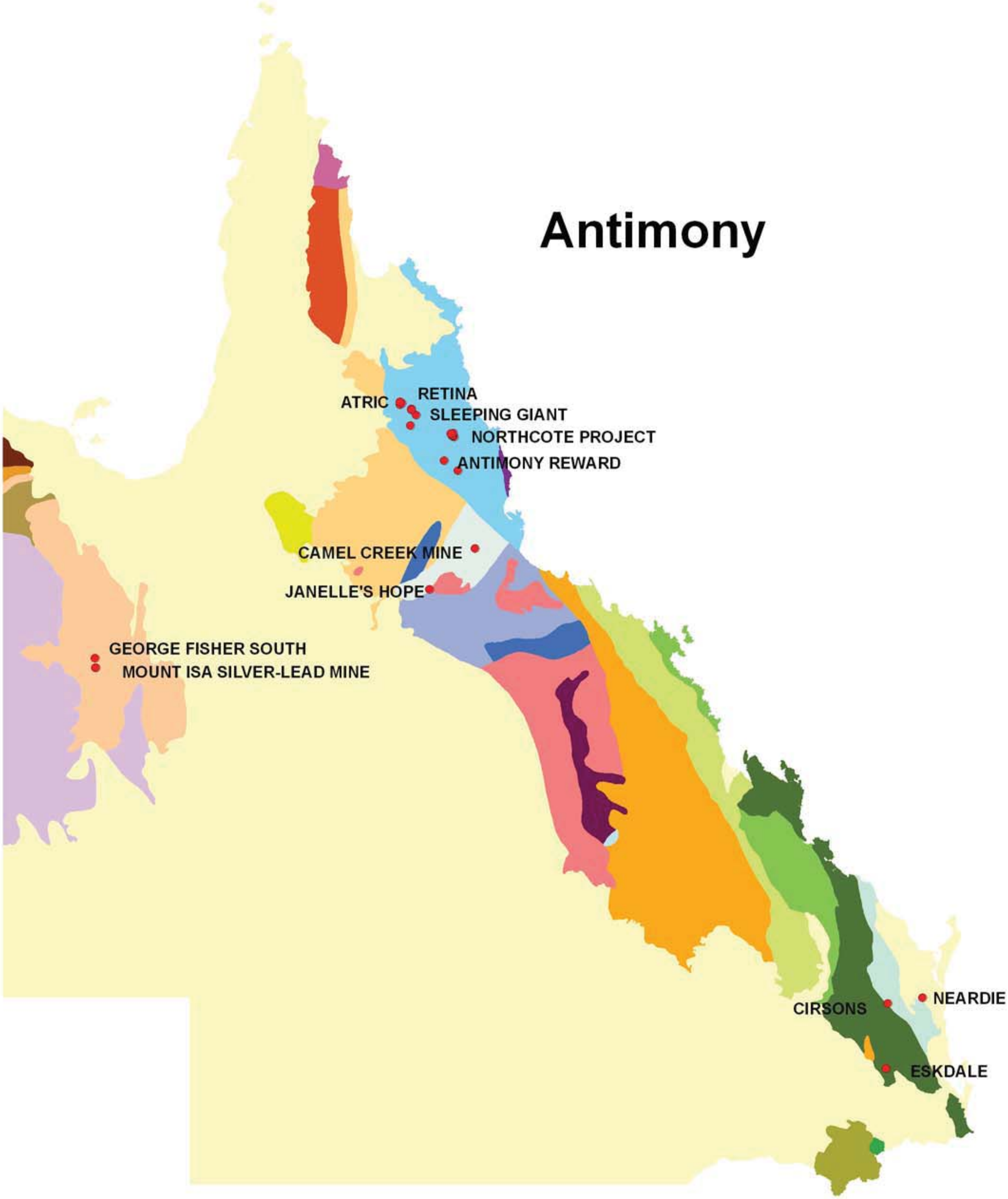
Antimony deposits can be classified as simple (structurally-controlled antimony gold veins) or complex. Almost all antimony mineralisation in Queensland is simple and is characterised by a high variability in grade along the vein system.

1) *Simple Deposit Style*

The simple (quartz-stibnite) deposit style typically consists of lenticular, structurally-controlled quartz veins containing massive stibnite with or without associated gold and accessory pyrite. Mineralisation is not restricted to any particular unit or rock type, but an association with gold is a feature in most metasedimentary host rock terrains in Queensland. Individual deposits rarely contain more than several thousand tonnes of ore. A metamorphic origin is favoured for the deposits in the Hodgkinson and Broken River Provinces (Photograph 18).

The Antimony Reward, Northcote and Retina deposits in north Queensland are the largest defined resources in the State. The Antimony Reward deposit contains an inferred resource of 16 500 t at 45% Sb and a probable reserve of 96 200 t at 6% Sb. The Retina deposit contains inferred resources of 45 000 t at 5.0% Sb. The Northcote Project (East Leadingham, Emily, Emily South,

Antimony



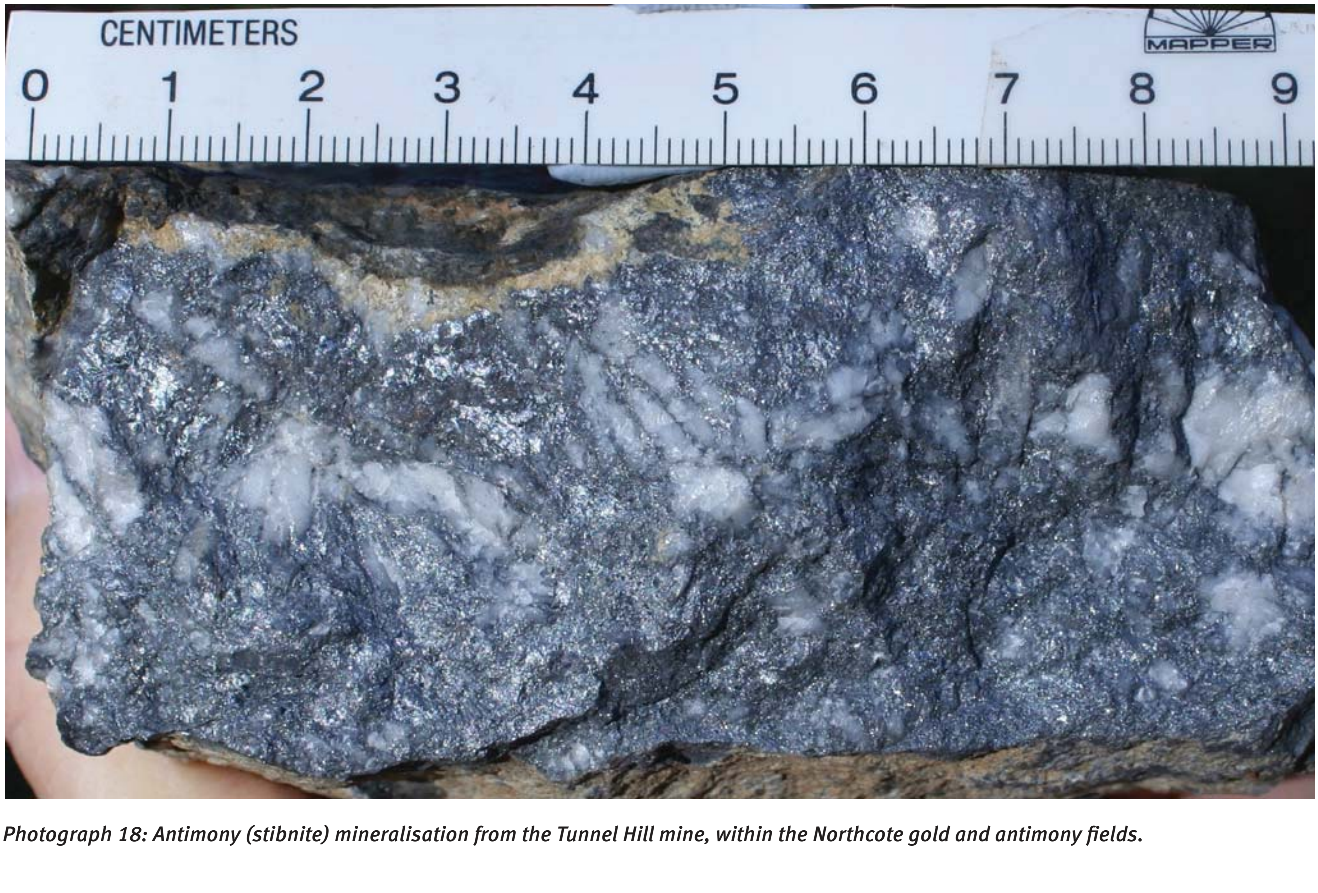
ATRIC
RETINA
SLEEPING GIANT
NORTHCOTE PROJECT
ANTIMONY REWARD
CAMEL CREEK MINE
JANELLE'S HOPE
GEORGE FISHER SOUTH
MOUNT ISA SILVER-LEAD MINE
NEARDIE
CIRSONS
ESKDALE

Table 4. Major antimony deposits of Queensland

Deposit name	Size	Total contained antimony in resources and reserves (t)	Total contained gold in resources and reserves (kg)
Antimony Reward	M	13 197	
Neardie	S	313	
Retina	S	2250	168
Northcote Group	M		
Belfast Hill	S	1031	341
Black Bess	S	3591	1875
East Leadingham	S	885	1275
Emily	S	598	1558
Emily South	S	86	501
Ethel	S	2035	1596
Navan Hill	VS	58	124
Tunnel Hill	S	1236	797
Total		**25 280**	**9020**

Photograph 16: Old St George Antimony workings around Mitchell River (image courtesy Vladimir Lisitsin, GSQ).

Photograph 17: Tunnel Hill mine (image courtesy Vladimir Lisitsin, GSQ).



Photograph 18: Antimony (stibnite) mineralisation from the Tunnel Hill mine, within the Northcote gold and antimony fields.

Ethel, Belfast Hill, Black Bess, Navan Hill and Tunnel Hill) contains measured, indicated and inferred resources of 3.98 Mt at 0.3% Sb and 5.01 Mt at 1.8 g/t Au (note individual deposit resources on datasheets is somewhat lower since the company chose not to report individual resource figures for the above listed deposits). This project, which is now termed Hodgkinson Basin project, is currently on hold since the sale to Territory Minerals Pty Ltd in July 2011 (see Gold section).

2) Complex Deposit Style

Complex deposit types, where antimony is a subordinate component of precious metal deposits, include high-level porphyry to epithermal deposits and Carlin or replacement-style deposits. Mount Isa is the most important example of a complex style of antimony deposit in Queensland. The most important antimony mineral in complex deposit styles is friebergite, which occurs as distinct microscopic grains usually enclosed in galena. Average antimony head grades in lead-zinc ore at Mount Isa are 0.01%.

Bauxite

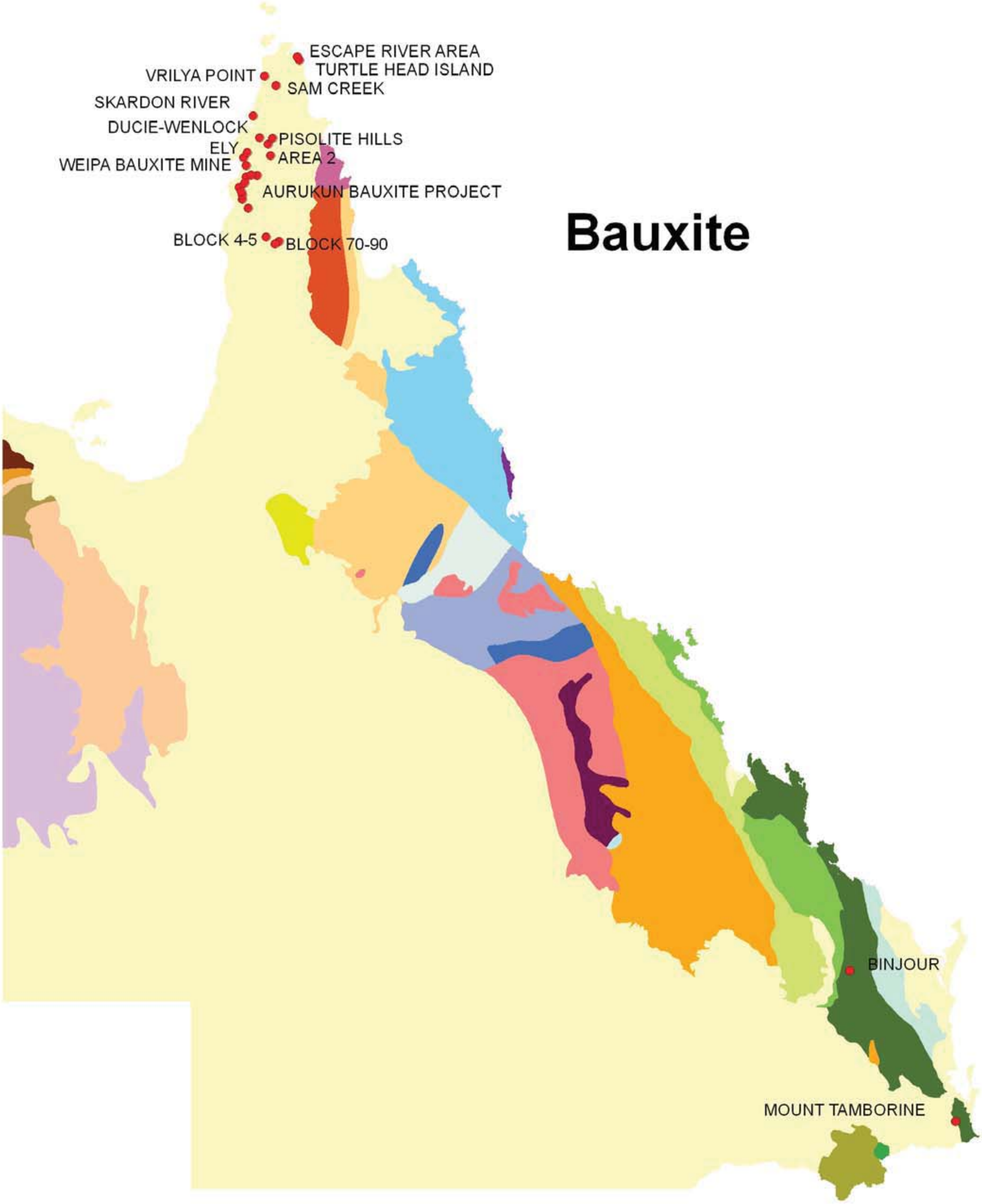
Bauxite is the primary ore of aluminium being first refined to form alumina, which is then smelted to form aluminium metal. Australia is the world's largest producer of bauxite and fifth largest producer of primary aluminium. Queensland's significant bauxite deposits (classified as medium to large) all occur within the Karumba Basin along the western coastal fringe of Cape York Peninsula and contain known reserves/resources totalling >5 billion tonnes of bauxite (Table 5).

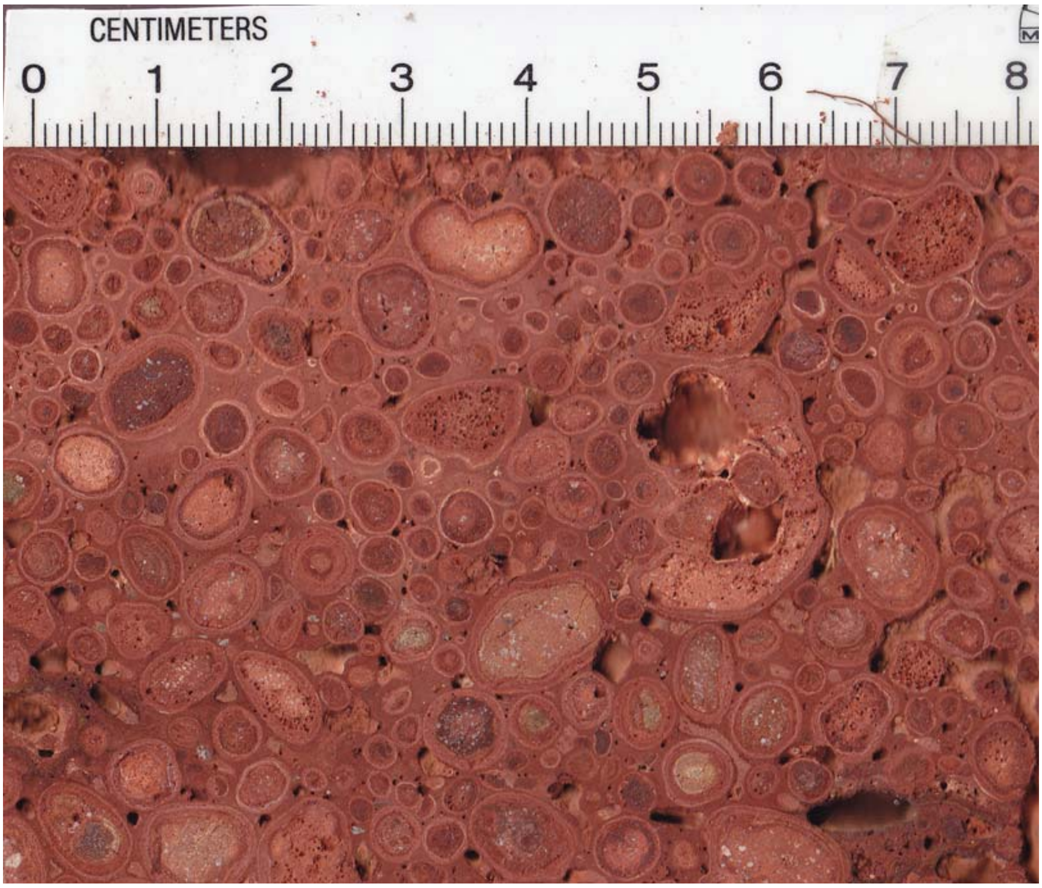
Bauxite is a pisolitic and concretionary ore of aluminium and iron hydroxides formed by lateritic processes. The ore is formed in alkaline conditions in a tropical climate from deep weathering processes over a considerable time period and involves the migration of rainwater through a porous aluminous rock. Bauxite comprises varying proportions of hydrous aluminium oxides, primarily the minerals gibbsite ($Al(OH_3)$), boehmite ($AlO(OH)$) and diaspore ($AlO(OH)$). Iron and silica are also commonly present in bauxite. Bauxite occurs in several forms; the most common are pisolites and round concretionary grains. Gibbsite and boehmite form almost all of the commercially worked aluminium ores (Photograph 19). The key issues in terms of bauxite quality are the alumina content and mineralogy, and total reactive silica content. The alumina content and mineralogy drive the amount of alumina and therefore aluminium that will ultimately be recovered from a given tonne of bauxite, whereas silica is an impurity that must be removed using caustic soda in the process of refining bauxite to alumina. The alumina mineralogy determines the ease with which the alumina can

Table 5. Bauxite deposits of Queensland

Deposit name	Size	Dry beneficiated bauxite resources (Mt)	Total recorded production beneficiated bauxite (includes metallurgical ore and abrasive-grade ore)
Pisolite Hills (including Musgrave and Area 2)	M	198.6	Nil
Bauxite Hills *(DSO from BH 1 and BH 6 only)	S S	43.3 (47)	Nil
Hey Point	S	2.5	Nil
North Coconut (Com Area, ER Area & HR Area)	S	73.2	Nil
South Johnstone		30	Nil
Escape River Area/Turtle Head Island	L	340	Nil
Aurukun Bauxite Project (Coconut Pod, Kokialah Area, Possum Pod, Tappelbang Pod, North Watson, CT Area and SG Area)	L	614.8	Nil
Skardon River *(DSO resource)	S S	50.3 (70.1)	Nil
Vrilya Point	M	100	Nil
Weipa Bauxite Mine (includes Ely and Andoom, Ducie-Wenlock)	L	3475	489.8 Mt
Binjour Bauxite	S	24.5	Nil
Toondoom (partly DSO)	S	3.5	Nil
Total		4847.4	**489.8 Mt**

*DSO = direct shipping ore; figures in brackets are not added to totals


ESCAPE RIVER AREA
TURTLE HEAD ISLAND
VRILYA POINT
SAM CREEK
SKARDON RIVER
DUCIE-WENLOCK
PISOLITE HILLS
ELY
AREA 2
WEIPA BAUXITE MINE
AURUKUN BAUXITE PROJECT
BLOCK 4-5
BLOCK 70-90
Bauxite
BINJOUR
MOUNT TAMBORINE



Photograph 19: Pisolitic bauxite from Weipa, Cape York.

be refined from the bauxite. Although the percentage of aluminium contained within gibbsite is about one third of that in boehmite, the lower grade gibbsite releases its aluminium more easily than boehmite and therefore costs less to refine and is a cheaper source of aluminium. Gibbsite ore can be treated at a lower temperature than boehmite ore (120°C compared with 170°C). Also, alumina liberation from gibbsite requires less caustic soda, which is a major cost item in the alumina refining process. Gibbsite and boehmite are white, but the presence of iron usually imparts a red earthy colour.

Bauxite is treated using the Bayer process, which involves heating in caustic soda. The aluminium trihydrate dissolves leaving a residue of insoluble iron and titanium oxides. The aluminium trihydrate ($Al_2O_3.3H_2O$) is dried to produce a white powder termed 'alumina'. The iron and titanium oxide residue is called 'red mud'. Two tonnes of bauxite yield one tonne of alumina. Aluminium is produced from alumina in a special electrolytic furnace called a Hall-Heroult cell. The cell is lined with carbon and filled with cryolite. Alumina dissolves in the cryolite when an electric current is passed through the mixture from carbon blocks suspended in the cell. The electric current breaks up the molecular structure of the alumina; molten aluminium collects at the base of the cell. Processing alumina into aluminium is very energy intensive, requiring ~14 000 DC kWh of electricity to produce 1 tonne of aluminium. Depending on the mineralogy of the ore, it takes 2.2–3.25 t of bauxite to produce one tonne of aluminium. Aluminium is supplied in rolled, extruded and forged shapes and castings.

Queensland's only operating bauxite mine is at Weipa. Bauxite occurs within the topmost of four recognised zones (ferricrete zone, mottled zone, pallid zone and saprolite), within the 20–30 m thick laterite weathering profile. The ferricrete zone comprises iron-cemented soil overburden (~0.5 m thick) and a 1–5 m thick bauxite layer underlain by a basal 1–2 m of ironstone.

The bauxite layer comprises uncemented to poorly cemented pisolites of gibbsite and boehmite with small amounts of kaolinite and quartz. The ratio of gibbsite to boehmite is ~4:1. The matrix, although bauxitic, has a high silica content (up to 12% total silica) in the form of sand and silt sized quartz grains. Silica is removed by wet screening during beneficiation. The basal ironstone layer consists of goethite and hematite nodules with varying amounts of kaolin and quartz. Ironstone is much harder than the overlying bauxite layer and forms the cut-off point for mining.

The Weipa mine contained proven ore reserves of 521 Mt bauxite at 52.1% Al_2O_3 and probable ore reserves of 989 Mt bauxite at 52.7% Al_2O_3 at the end of 2013. The total mineral resources (additional to the ore reserves), are measured resources of 109 Mt bauxite at 49.6% Al_2O_3, indicated resources of 1401 Mt bauxite at 51.3% Al_2O_3 and inferred resources of 455 Mt bauxite at 51.9% Al_2O_3 at the end of 2013.

Kaolin occurs in the pallid zone of the weathering profile as discontinuous lenses ~2–3 km long, 300 m wide and 4.5 m in average thickness overlying a thin aquifer.

Photograph 20: Andoom bauxite processing plant, (left) dump bridge hopper feeding bauxite into a scrubber and trammel; (centre) Andoom fines separation plant; (right) product conveyor and load out bin for train transport to Port of Weipa.

Extensive bauxite deposits lie to the north of the Weipa mining operation and include the Ducie–Wenlock (in the area bounded by the Wenlock and Ducie Rivers), Andoom and Ely deposits. The completion of the NE Weipa mine expansion has increased bauxite mining to a continuous two mine operation and has allowed Rio Tinto to process the low yield ore within the Andoom orebody (Photograph 20). The Ely deposit will be developed in conjunction with Rio Tinto's Weipa operations. The Weipa mine produced 21 560 315 t (25 276 338 t) of metallurgical grade bauxite in 2011–12 (2012–13).

The South of the Embley project is 40 km south of Weipa and 40 km north of Aurukun, western Cape York Peninsula. A feasibility study to develop a new bauxite mining operation with an estimated capital cost of US$1.5 billion that includes development of a new port and ship-loading facilities, barge or ferry facilities, mine-access road, power station, water infrastructure and a beneficiation plant has been completed, and an EIS has been submitted. Rio Tinto's new mine is planned to eventually replace the existing mining operations at East Weipa and Andoom and ensure continuity of bauxite supply to the two Gladstone alumina refineries. The Australian government conditionally approved plans in May 2013 to expand mining and extend the life of the Weipa mine for a further 50 years and it is understood Rio Tinto will decide in 2014 whether to expand operations at Weipa. Yet no mention of the South of Embley project was made in the ore reserve and mineral resource statements by Rio Tinto. Mentions in the local media suggest possible development of the South of Embley project in the near future.

The Skardon River bauxite project is about 100 km north of Weipa. Gulf Alumina Limited acquired the Skardon River bauxite project in October 2012, an operation originally set up for the production of high-grade kaolin for the paper, paint, concrete, and polymer, cosmetic, pharmaceutical and ceramic industries. A new kaolin product, a cement called 'kaocem', had been developed to supply the Asian market. Gulf Alumina has set aside the equipment pertaining to the kaolin project and will stockpile the kaolin. The Skardon River bauxite project will include rehabilitation of a decommissioned kaolin mine and use of existing infrastructure from this mine, including a haul road, airstrip and the Port of Skardon River as well as civil works associated with the village and power distribution. In December 2014, using a 20% $Si0_2$ cut-off, the direct shipping ore bauxite resource in dry tonnes was estimated at measured 29.9 Mt, indicated 32.1 Mt and inferred 8.1 Mt with an average grade of 50.3% Al_2O_3. and total $Si0_2$ 11.2% and a recovery of 61.7%. Skardon River bauxite is primarily gibbsite with low temperature processing qualities. The Project is anticipated to have 3 Mtpa bauxite of direct shipping ore (DSO) initially and could rise to 5 Mtpa subject to market conditions. The bauxite ore would be transported via existing haul roads to a crushing and stock pile facility at the Port of Skardon River. Bauxite products would be shipped from a new ship loading facility and transhipped to bulk carriers in deep water beyond the mouth of the river for export. Construction is planned to commence in 2015 and bauxite mining and shipping in 2016. The project life is expected to be 10 years. Chinese aluminium company Shandong Nanshan Aluminium Company Limited, have committed to an off-take of 100% of the bauxite produced at Skardon River, and to assisting with the project funding. Furthermore, Gulf Alumina Limited have identified exploration targets of 5–12 Mt additional resources at Skardon River.

The Vrilya Point deposit, 46 km southwest of Bamaga, comprises pisolitic bauxitic laterite of similar general appearance to that in the Weipa area, and differs from the southern areas in that the bauxite is quite strongly cemented and even indurated in places. Its inferred resource in a company report from 1983 was 100 Mt at ~44% Al_2O_3 and ~7% reactive SiO_2.

Cape Alumina Pty Ltd, a 50%-owned subsidiary of Metallica Minerals Ltd, has carried out extensive drilling of bauxite deposits in the Catfish Creek – Wenlock area, including the Pisolite Hills and Bauxite Hill projects, about 50 km northeast of Weipa. Bauxite mineralisation up to 5.5 m thick seems to be a continuation of the bauxite on the nearby Alcan and Comalco mining leases. The total resource delineated at the Pisolite Hills prospect in 2014 comprises a measured resource of 27.5 Mt at 54.4% Al_2O_3 and an indicated resource of 56.1 Mt at 53.5% Al_2O_3 and an inferred resource of 48.8Mt of bauxite at an average grade of 53.1% Al_2O_3. This would yield 88.9 Mt of bauxite on a dry-product basis at an average beneficiated grade of 53.1% Al_2O_3 and 12.3% SiO_2 of which there is 7.5% reactive silica at 150°C. Cape Alumina Limited's Pisolite Hills project was abandoned for environmental reasons in 2014.

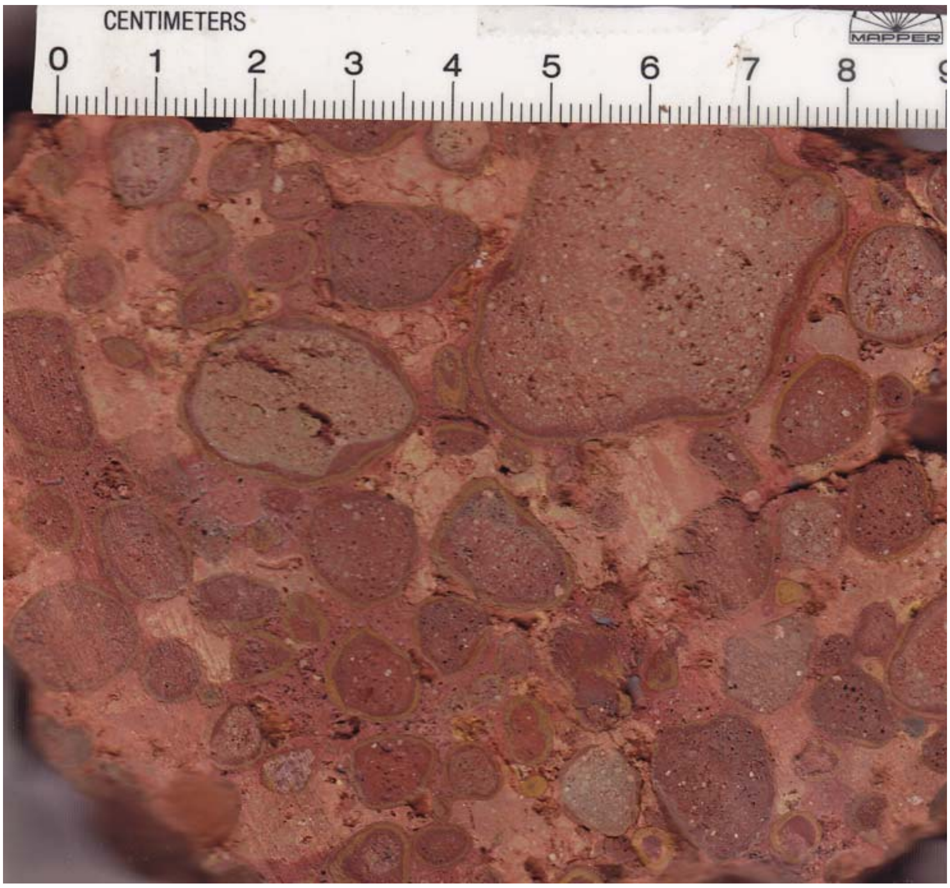
The Bauxite Hills deposit is 95 km north of Weipa and 5 km southeast of the port at Skardon River. The deposit, which was previously held by Cape Alumina Limited, was subject to a friendly takeover by MetroCoal Limited in November 2014 and subsequently changed its name to Metro Mining Limited in December 2014. Bauxite Hills comprises an inferred resource of 60.2 Mt of *in situ* bauxite to yield 41.3 Mt of bauxite on a dry-product basis at average beneficiated grade of 51.6% Al_2O_3 and 9.6% SiO_2 and 3.8 Mt of *in situ* bauxite to yield 2.0 Mt of bauxite on a dry-product basis at average beneficiated grade of 49.4% Al_2O_3 and 11.0% SiO_2. The assay results from the project's BH1 area have indicated the presence of two types of bauxite, an upper layer of mixed boehmite-trihydrate bauxite and an underlying layer of low monohydrate bauxite which is expected to be suitable for refineries operating at low temperature. In January 2015, Cape Alumina Limited announced an updated inferred resource of 22.1 Mt of direct shipping ore at 51.2% Al_2O_3 and 12.2% reactive silica (at 150 degrees centigrade) for the BH6 part of the prospect, and an inferred resource of 24.9 Mt of direct shipping ore at 51.7% Al_2O_3 and 9.0% reactive silica (at 150 degrees centigrade) for the BH1 part of the prospect. This ore could be exported directly and could underpin a reduced cost operation as there would be no requirement for a large beneficiation plant and significantly reduced water, energy and tailings dam requirements. Cape Alumina Limited had previously announced an *in situ* resource of 22.1 Mt at BH6 giving 15.1 Mt of beneficiated bauxite at 51.2% Al_2O_3 and 5.4% reactive silica.

Cape Alumina Pty Ltd sold a smaller bauxite deposit at Hay Point to Racle Resources Pty Ltd in November 2012. This deposit has an inferred resource of 3.8 Mt to yield 2.5 Mt of beneficiated bauxite at 55.3% Al_2O_3.

The Aurukun Bauxite deposits are located on the southeastern edge of the much more extensive Weipa bauxite province between 40 and 120 km south of Weipa, to the east of the Aurukun Mission settlement. The group of deposits comprise numerous bauxite resource bodies (Coconut Pod, Kokialah Area, Possum Pod, Tappelbang Pod, North Watson, CT Area and SG Area) referred to as Aurukun Bauxite Project. The bauxite occurrences are highly variable in consistency largely due to erosion. This project has been assessed for development by the Queensland Government under Restricted Area 315. Although the deposit has been re-evaluated recently and described by Chalco (Vigar, A J, Jiang, G, Morgan, M, MacDonald, G, Smith, L, Taylor, I, Recklies, M and Grobler, C, 2009) the actual resource estimate is confidential. An outdated resource estimate gave the deposit, north of the Watson River, as having a combined total measured, indicated and inferred resource of 284 Mt of bauxite at an average high temperature reactive silica content of 8% In late August 2014, the Queensland Government decided to appoint Glencore International AG as the preferred proponent of the Aurukun bauxite deposit. Glencore is working with the Queensland Government to finalise the commercial arrangements. Should a satisfactory agreement be reached, Glencore is expected to begin a feasibility study in 2015.

Three smaller areas outside the RA 315 (the Aurukun bauxite deposits) to the north (COM Area, ER Area and HR Area), held by Cape Alumina Limited under application (EPM15269) have an inferred resource of 73.2 Mt as reported in 1973 in a company report.

The South Johnstone bauxite project is about 20 km west of Mourilyan harbour. The bauxite mineralisation is developed as a thin surface layer on lava flows of the Atherton basalt. The inferred resource of part of the deposit is 30 Mt at 25.2% Al_2O_3 and 6.9% reactive SiO_2. Queensland Bauxite Limited has carried out a scoping study based on a shallow open cut and an initial 800 000 t operation. The company believes there is excellent potential for an early production start in late 2015. However, further drilling needs to be carried out and a mining lease applied for.



Photograph 21: Pisolitic bauxite from Binjour.

The Binjour bauxite project, about 20 km northwest of Gayndah, is held by Australian Bauxite Limited. The indicated resource is 15.5 Mt at 39.5% Al_2O_3 and 2.6% reactive SiO_2 and the inferred resource is 9.0 Mt at 38.0% Al_2O_3 and 3.8% reactive SiO_2 with an indicated and inferred high-grade core zone of 19.5 Mt at 39.6% Al_2O_3 and 2.6% reactive SiO_2. The bauxite in the resource area is consistently high quality and most is 'brown sugar' bauxite, being a superior quality, low-silica, gibbsite bauxite suitable for sweetening circuits in refineries (Photograph 21). The bauxite lies beneath a clay horizon (red mud overburden) near the top of a plateau that has been widely cleared for farming, although large parts are now left uncultivated because of the dry poor soils. There is considerable potential for more bauxite resources at Binjour.

As part of due diligence work, Australian Bauxite Limited also outlined an inferred resource of 3.5 Mt at 32.8% Al_2O_3 and 5.2% reactive SiO_2 with an average thickness of 4.9 m at the Toondoom mining lease 40 km southwest of Binjour. This resource includes a direct shipping bauxite deposit with an inferred resource of 1.7 Mt at 35.5% Al_2O_3 and 5.9% reactive SiO_2 with an average thickness of 2 m. The identification of the Toondoom resource gives the opportunity for potentially earlier production, than previously thought, should Australian Bauxite Limited purchase the deposit. Binjour potentially be in production by 2018 and a 50 year mine life is envisaged. The deposits are approximately 115 km from the Port of Bundaberg, which could be upgraded to allow for bulk exports. It is critical thought to find a suitable infrastructure option to carry a bulk commodity to port. These are being assessed as part of a joint industry-government project.

Base Metals: Copper

Australia is the fifth largest copper producer in the world and holds 12% of the world's resources. Queensland is Australia's largest copper producing state, and Queensland's major base metal deposits contain ~19.3 Mt of copper in known resources and reserves. In 2011–12 (2012–13), Queensland produced 1 062 953 t (919 512 t) of copper concentrates, 2532.3 t (1 922 t) of copper precipitates and 33 670 t (34 068 t) copper cathodes.

The world-class base metal terrain of the Mount Isa Province hosts deposits such as Mount Isa and Ernest Henry and places Queensland as a significant copper producer on the world stage. Exploration beneath shallow Mesozoic cover rocks fringing the outcropping part of the Orogen has identified several major mineral deposits. Significant discoveries have also been made beneath known outcrops and abandoned mine workings.

Major copper deposits within Queensland occur in four main mineralisation styles: brecciated sediment-hosted copper, breccia-hosted and structurally-controlled Proterozoic Cu and iron oxide-Cu-Au, volcanic-hosted massive sulphide and porphyry copper (Table 6).

1) Brecciated Sediment-Hosted Copper

Copper mineralisation in the Western Fold Belt Province of the Mount Isa Province is largely hosted by brecciated dolomitic, pyritic and carbonaceous sediments, or brecciated sandstone proximal to regional fault/shear zones. The Mount Isa copper deposit is the largest copper deposit in Queensland. Copper mineralisation at Mount Isa is hosted by 'silica-dolomite' rocks of the Urquhart Shale, adjacent to the lead-zinc lodes to the east of the Mount Isa Fault zone (Photograph 22).

The Mount Isa mine is one of the world's largest underground mining complexes and is managed by the Glencore subsidiary Mount Isa Mines as two separate businesses, copper and zinc. The Mount Isa copper mines comprise the Enterprise (3000 and 3500) and X41 (1100 and 1900, and in the new calculations includes the 500 orebody) underground orebodies (Photograph 23). The Enterprise mine is Australia's deepest mine with an internal shaft that reaches a depth of 1900 m. The current mining rate is 5.9 Mt per year while the copper concentrator has a capacity of 7.2 Mtpa. Glencore reported resources for the Enterprise orebodies as measured resource of 32.2 Mt at 1.93% Cu, an indicated resource of 13.1 Mt at 1.78% Cu and and inferred resource of 6.7 Mt at 1.66% Cu. Glencore also estimated the resources for X41 as measured resource of 33.3 Mt at 2.9% Cu, an indicated resource of 3.6 Mt at 2.52% Cu and an inferred resource of 0.7 Mt at 2.23% Cu. The open cut resource comprises a measured resource of 48 Mt at 1.46% Cu, an indicated resource of 82 Mt at 1.32% Cu and an inferred resource of 138 Mt at 0.89% Cu. Mining depletion, sterilisation and changes to mine design amounted to 13 Mt reduction of mineral resources and 9.4 Mt reduction in ore reserves.

The Mount Isa copper smelter produces copper anode from ore mined in the two Mount Isa underground copper mines and from the Ernest Henry open cut mine. Copper anode from the Mount Isa smelter (99.7% pure copper) is refined at Glencore Copper's Townsville copper refinery to produce 99.995% pure LME (London Metal Exchange) grade-A copper cathode. However, the copper smelting and refining activities will be closed by the end of 2016.

Other significant resources of this type in the Mount Isa Province include the Esperanza and Mammoth deposits (Mount Gordon mine) and Mount Oxide, 120 km north of Mount Isa. These deposits are within and adjacent to the Mount Gordon Fault Zone. The Mount Gordon operation 115 km north of Mount Isa, held by Aditya Birla Minerals Ltd, consists of the Mammoth underground mine and several separate orebodies (Photograph 24). The Mammoth underground mine was placed on care and maintenance in January 2009 but production re-commenced in May 2011, with a current production rate is of 1.2 Mtpa. Due to reduced copper metal prices Aditya Birla Minerals have put the mine on care and maintenance again in 2013. Mining of the Esperanza open cut was completed in November 2005 (Photograph 25). Development of Esperanza South underground mine was stopped in 2008 after developing 967 m and placed on hold. Copper concentrate is trucked to Cloncurry, railed to Townsville and then shipped to Hindalco Copper's Dahej copper smelting and refining facility in India. At 30 April 2014, the total measured resource was 15.44 Mt at 1.43% Cu; the indicated resource was 49.07 Mt at 1.43% Cu and the inferred resource 120.76 Mt at 1.19% Cu. Of this total, the separate Esperanza/Pluto deposits has an indicated and inferred resource of 16.3 Mt at 1.75% Cu and the Esperanza South deposit has an

Table 6. Major copper deposits of Queensland

Name	Size	Total recorded production	Contained metal in remaining resource	Principal mineralisation style	Host/ orebody province
Balcooma (some production reported under Thalanga and Mount Garnet Plants	M	33 909 t Cu 230 kg Au	39 848 t Cu 359 kg Au	Volcanic-Hosted Massive Sulphide	Thalanga/ Thalanga
Baal Gammon	M	Production included in Mount Garnet Plant figures	24 891 t Cu 94 388 kg Ag	Volcanic-Hosted Massive Sulphide	Hodgkinson/ Kennedy
Chinaman Creek Prospect	L		400 000 t Cu	Porphyry Cu	SEQVP/SEQVP
Coalstoun Lakes	M		245 614 t Cu	Porphyry Cu	Wandilla/ SEQVP
Cloncurry Copper Project (Great Australia, Jasper, Taipan, Paddock Lode, Victory-Flagship, Kangaroo Rat, Wallace South)	M	15 852 t Cu 41.4 kg Au	150 423 t Cu 4376 kg Au 490 t Co	Structurally- Controlled Proterozoic Iron Oxide-Cu-Au	Eastern Fold Belt/ Eastern Fold Belt
Einasleigh	S	8237 t Cu 4083 kg Ag 71.2 kg Au bullion	31 400 t Cu 13 800 kg Ag 1160 kg Au	Brecciated Sediment-Hosted Cu	Etheridge/ Etheridge
Eloise (including Sandy Creek East & West)	M	197 124 t Cu 55 143.4 t Cu conc. (Cu-Au-Ag) 41 288.4 kg Ag 3264.8 kg Au 266.3 kg Au bullion	128 592 t Cu 3331 kg Au 31 956 kg Ag	Structurally- Controlled Proterozoic Iron Oxide-Cu-Au	Eastern Fold Belt/ Eastern Fold Belt
Ernest Henry (includes Ernest Henry Underground)	L	1 348 006 t Cu 51 586.9 kg Au bullion	1 112 520 t Cu 58 938 kg Au	Breccia-Hosted Proterozoic Iron Oxide-Cu-Au	Eastern Fold Belt/ Eastern Fold Belt
Hero	M		100 000 t Cu	Breccia-Hosted Proterozoic Iron Oxide-Cu-Au	Western Fold Belt/ Western Fold Belt
Highway-Reward	M	173 092 t Cu 7395.5 kg Ag 3302.3 kg Au 1137 t Pb 2866 t Zn 29.3 kg Au bullion		Volcanic-Hosted Massive Sulphide	Thalanga/ Thalanga
Julivon Creek Prospect	M		54 600 t Cu 3850 t Mo	Porphyry Cu	Urannah Batholith/ Urannah Batholith
Kaiser Bill	M	2.3 t Cu 0.8 kg Ag	126 150 t Cu 97 500 kg Ag 1875 kg Au	Base metal skarn	Etheridge/ Etheridge
Kalman	M		164 610 t Cu 41 910 t Mo 8326 kg Au 40 800 kg Ag 110 000 kg rhenium	Proterozoic Structurally- Controlled Cu	Eastern Fold Belt/ Eastern Fold Belt
Lady Annie Project (Lady Annie Copper, Lady Brenda, Mount Kelly, Mount Clarke, Mount Kelly Fault, Anthill, Link, Anthill West, Flying Horse, Swagman)	L	107 322.4 t Cu	531 846 t Cu	Brecciated Sediment-Hosted Cu	Western Fold Belt/ Western Fold Belt

Table 6 (continued)

Name	Size	Total recorded production	Contained metal in remaining resource	Principal mineralisation style	Host/ orebody province
Las Minerale (Rocklands)	L	8 t Cu	313 800 t Cu 16 239 t Co 6330 kg Au 8 364 000 t magnetite	Structurally- Controlled Proterozoic Iron Oxide-Cu-Au	Eastern Fold Belt/ Eastern Fold Belt
Merlin and Mount Dore (including Little Wizard)	L	6 t Cu	787 383 t Cu 982 935 kg Ag 711 091 t Zn 15 231 kg Au 13 205 t Co 121 410 t Pb	Structurally- Controlled Proterozoic Iron Oxide-Cu-Au	Eastern Fold Belt/ Eastern Fold Belt
Monakoff	S	1.94 kg Au bullion 457.8 t Cu	23 600 t Cu 740 kg Au 348t U_3O_8	Structurally- Controlled Proterozoic Iron Oxide-Cu-Au	Eastern Fold Belt/ Eastern Fold Belt
Mount Cannindah	M	1030 t Cu 933.1 kg Au bullion	50 410 t Cu 81 990 kg Ag 1888 kg Au	Porphyry Cu	Yarrol/Yarrol
Mount Carlton Project (Silver Hill, Mount Carlton and Herbert Creek)	M	124 267.2 kg Ag 2050 t Cu 1404.7 kg Au	36 290 t Cu 417 724 kg Ag 29 584 kg Au	High Sulphidation Epithermal	Bowen Basin/ Bowen Basin
Mount Elliott (Hampden Consol, Swan)	L	146 825 t Cu 6 725.7 kg Au bullion	2 509 240 t Cu 145 267 kg Au	Structurally- Controlled Proterozoic Iron Oxide-Cu-Au	Eastern Fold Belt/ Eastern Fold Belt
Mount Garnet Copper Plant (production includes material from Balcooma and Dry River South and Mount Garnet Underground post 2003)	S	57 975 t Cu 13 600 kg Ag 192.8 kg Au	N/A	Volcanic-Hosted Massive Sulphide	Thalanga/Thalanga
Mount Gordon Project (includes Mammoth, Esperanza, Esperanza North and South)	L	455 057.3 t Cu 21 701 t Cu conc. 7973.1 kg Ag	2 353 819 t Cu	Brecciated Sediment-Hosted Cu	Western Fold Belt/ Western Fold Belt
Mount Isa Copper	G	7 647 785 t Cu 6 313 t Co 274 278.6 kg Ag 101 t Sb	5 049 290 t Cu	Brecciated Sediment-Hosted Cu	Western Fold Belt/ Western Fold Belt
Mount Margaret (E1 Camp)	L		87 320 t Cu 2542 kg Au	Structurally- Controlled Proterozoic Iron Oxide-Cu-Au	Eastern Fold Belt/ Eastern Fold Belt
Mount Morgan	L	360 616 t Cu 215 268 kg Au bullion 78 788 kg Au 36 842 kg Ag 568 000 t pyrite	20 400 t Cu 27 050 kg Au	Volcanic-Hosted Massive Sulphide?	Yarrol/ Yarrol
Mount Norma	M	651.5 t Cu 1596 t Cu sulphate precipitate 315.5 kg Ag	64 000 t Cu	Proterozoic structurally controlled Cu	Eastern Fold Belt/ Eastern Fold Belt
Mount Oxide	M	22 816.3 t Cu 893.4 kg Ag 4.5 kg Au	225 600 t Cu 131 520 kg Ag 6300 t Co	Brecciated Sediment-Hosted Cu	Western Fold Belt/ Western Fold Belt
Mount Watson (+ Hidden Treasure + Leichhardt Copper Prospect)	M	7438.1 t Cu	87 494 t Cu	Brecciated Sediment-Hosted Cu	Western Fold Belt/ Western Fold Belt

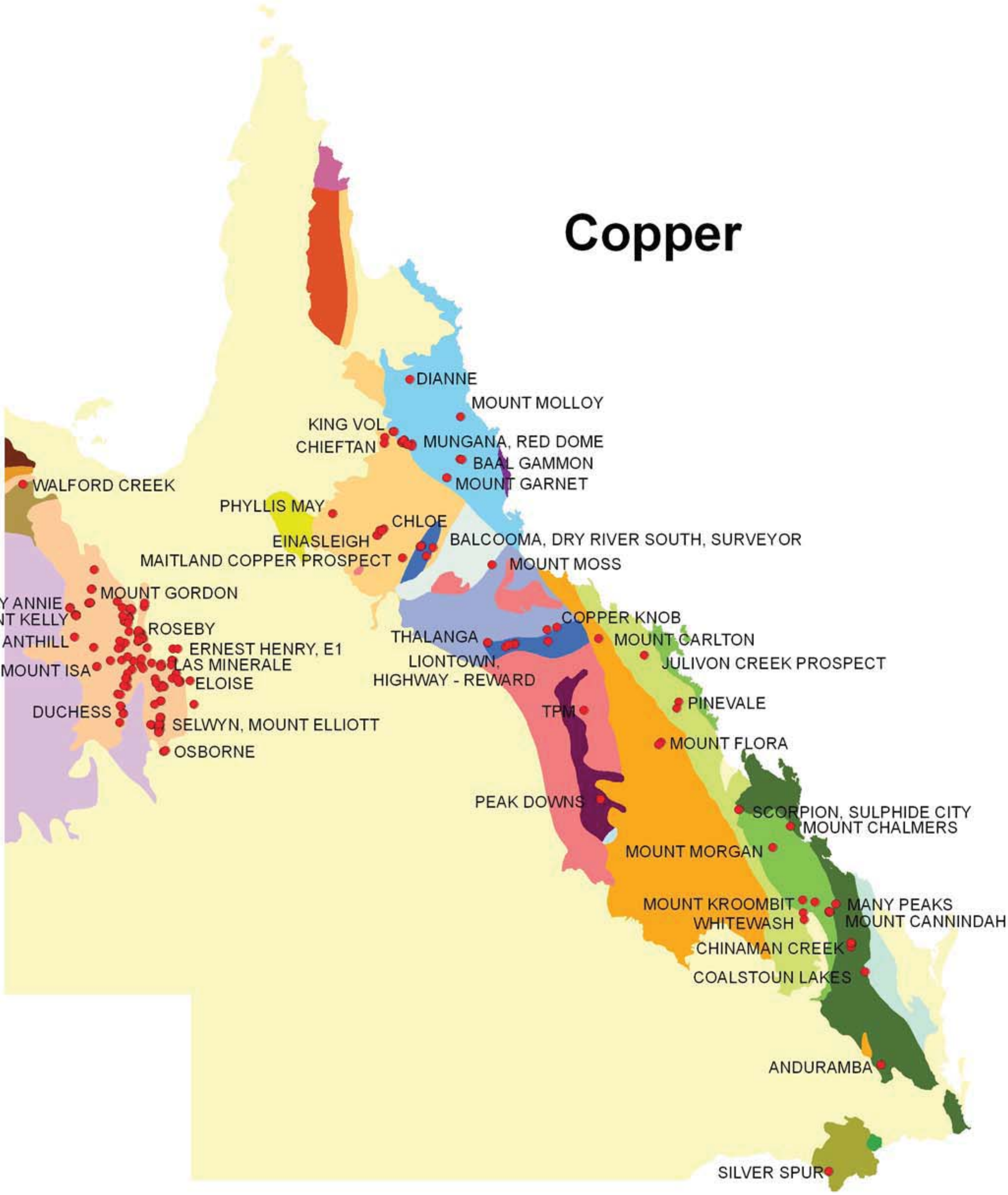
Table 6 (continued)

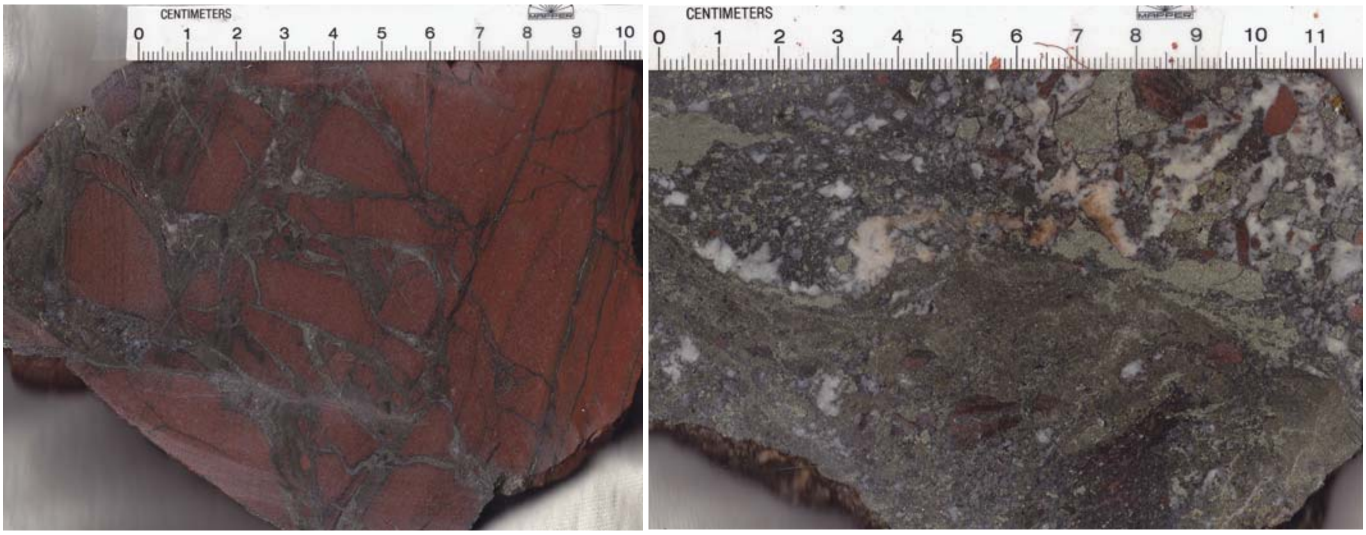
Name	Size	Total recorded production	Contained metal in remaining resource	Principal mineralisation style	Host/ orebody province
Mungana	M		94 346 t Cu 4620 t Zn 651 606 kg Ag 44 t Pb 34 376 kg Au	Porphyry Cu, base metal skarn	Hodgkinson/ Kennedy
Osborne (Osborne Underground and Kulthor)	L	538 467 t Cu 6540.7 kg Au 13 055.8 kg Au bullion	251 500 t Cu 16 820 kg Au 5 442 500 t magnetite	Structurally- Controlled Proterozoic Iron Oxide-Cu-Au	Eastern Fold Belt/ Eastern Fold Belt
Rebound	M		56 451 t Cu 750 kg Au	Structurally- Controlled Proterozoic Iron Oxide-Cu-Au	Eastern Fold Belt/ Eastern Fold Belt
Red Dome	M	36 059 t Cu 105 855 kg Ag 22 716 kg Au	164 060 t Cu 356 770 kg Ag 43 687 kg Au	Porphyry Cu, base metal skarn	Hodgkinson/ Kennedy
Roseby Copper Project (Bedford North, Bedford South, Blackard, Caroline, Charlie Brown, Great Southern, Ivy Ann, Ken Brown, Lady Clayre, Legend, Little Eva, Longamundi, Scanlan)	L	82.9 t Cu 0.2 kg Au 1.5 kg Ag	3 717 196 t Cu 38669 kg Au	Structurally- Controlled Proterozoic Iron Oxide-Cu-Au	Eastern Fold Belt/ Eastern Fold Belt
Starra line (includes Selwyn, Areas 222, 244, 251, 257, 276)	L	168 500.4 t Cu 32 143.1 kg Au bullion	124 840 t Cu 19 652 kg Au	Structurally- Controlled Proterozoic Iron Oxide-Cu-Au	Eastern Fold Belt/ Eastern Fold Belt
Surveyor	S	46 339 t Cu 508.9 kg Au 61 326 kg Ag 33 554 t Pb 125 367 t Zn	179 t Cu 221 kg Au 16 611 kg Ag 11 456 t Pb	Volcanic-Hosted Massive Sulphide	Thalanga/Thalanga
Thalanga (Vomacka, Orient, West 45) (Production from Balcooma and Surveyor after 2005 excluded)	M	188 900 t Cu conc. 20 277 t Cu 66.8 kg Au bullion	29 624 t Cu 625 kg Au	Volcanic-Hosted Massive Sulphide	Thalanga/ Thalanga
Trekelano-Inheritance	M	56 610 t Cu 368.9 kg Au 996.5 kg Au bullion 461.9 kg Ag		Structurally- Controlled Proterozoic Iron Oxide-Cu-Au	Eastern Fold Belt/ Eastern Fold Belt
White Range Project (McCabe, Vulcan, Greenmount, Kuridala, Sierra, Stuart, Desolation)	M	35.7 t Cu	243 967 t Cu 10 930 t Co 6158 kg Au	Structurally- Controlled Proterozoic Iron Oxide-Cu-Au	Eastern Fold Belt/ Eastern Fold Belt
Greater Whitewash Project (Whitewash, Whitewash South, Gordons Knob, Kiwi Carpet, John Hill/Ben Hur)	L		468 853 t Cu 453 590 kg Ag 69 479 t Mo	Porphyry Cu, base metal skarn	Connors/ Connors

Photograph 22: Massive copper mineralisation (mostly chalcopyrite) from the 3000 ore body at Mount Isa Copper Mine.

Photograph 23: The Enterprise copper mineralisation within the 3000 ore body, over 1 mile below surface, Mount Isa Copper Mine (pictured F. von Gnielinski).

Copper


DIANNE
MOUNT MOLLOY
KING VOL
CHIEFTAN
MUNGANA, RED DOME
BAAL GAMMON
MOUNT GARNET
WALFORD CREEK
PHYLLIS MAY
CHLOE
EINASLEIGH
BALCOOMA, DRY RIVER SOUTH, SURVEYOR
MAITLAND COPPER PROSPECT
MOUNT MOSS
LADY ANNIE
MOUNT GORDON
MOUNT KELLY
ROSEBY
ANTHILL
ERNEST HENRY, E1
MOUNT ISA
LAS MINERALE
ELOISE
DUCHESS
SELWYN, MOUNT ELLIOTT
OSBORNE
COPPER KNOB
THALANGA
MOUNT CARLTON
LIONTOWN,
HIGHWAY - REWARD
JULIVON CREEK PROSPECT
PINEVALE
TPM
MOUNT FLORA
PEAK DOWNS
SCORPION, SULPHIDE CITY
MOUNT CHALMERS
MOUNT MORGAN
MOUNT KROOMBIT
MANY PEAKS
WHITEWASH
MOUNT CANNINDAH
CHINAMAN CREEK
COALSTOUN LAKES
ANDURAMBA
SILVER SPUR



Photograph 24: (left) Chalcopyrite mineralisation in brecciated metasediments from the Mammoth underground mine; (right) massive chalcopyrite breccia from the Mammoth underground mine.

Photograph 25: The Esperanza open cut, currently used as mine water storage (panorama view).

indicated and inferred resource of 32.40 Mt grading 1.16% Cu. Greenstone, a new deposit to the east of Mammoth, has a combined measured, indicated and inferred resource of 7.02 Mt at 1.18% Cu. Another orebody termed H Lens which lies between Esmeralda/Pluto and the main Mammoth ore body has an inferred resource of 12.53 Mt at 1.29% Cu.

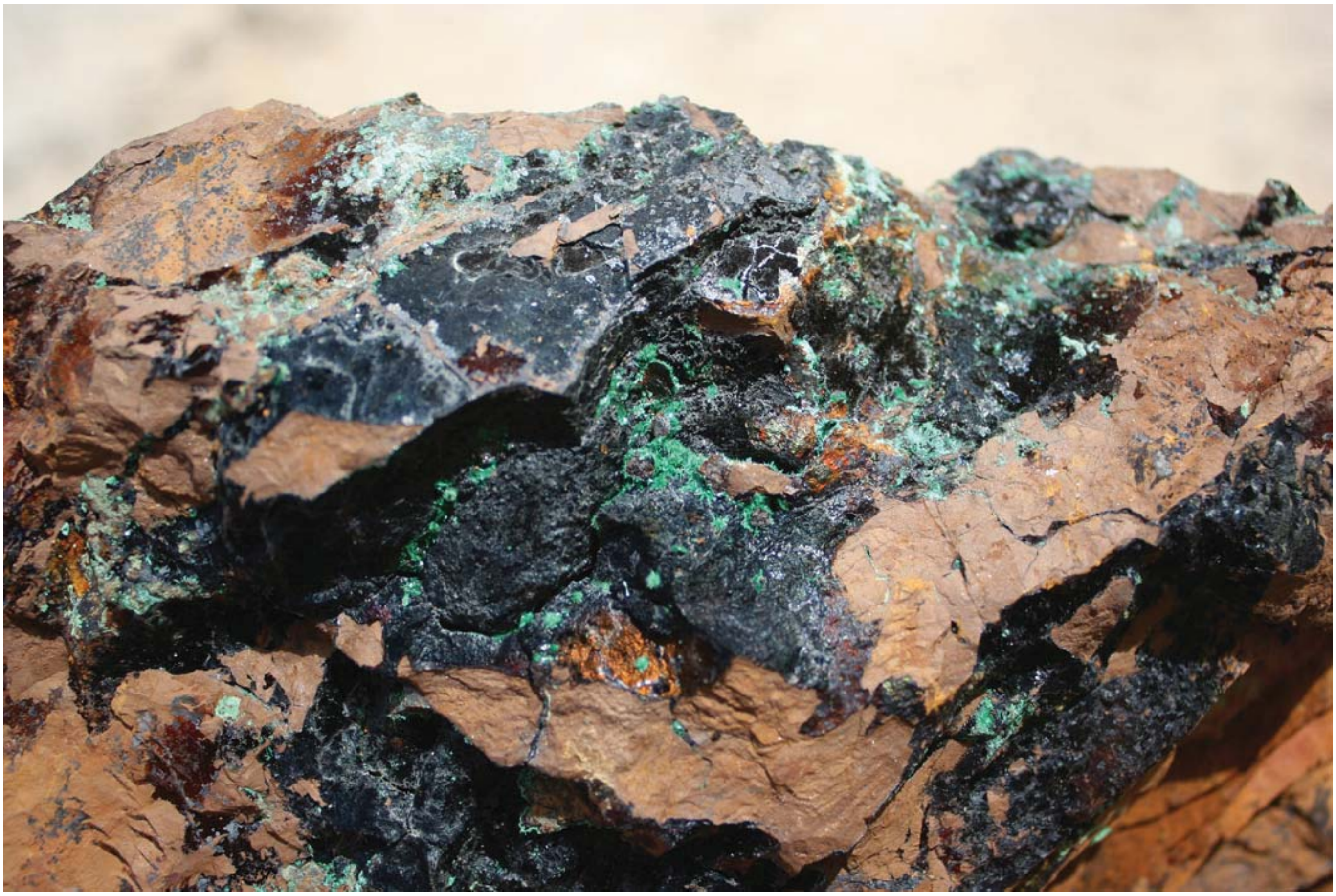
The Lady Annie mine, 100 km north-northwest of Mount Isa, consists of a plant, mine and camp at Mount Clark, and a 17 km haul road north-northwest to Lady Annie. The mine is 40 km from the existing power and water supplies at Mount Gordon, and this infrastructure has aided the development. The mine is currently owned by CST Mining Group, who resumed copper production in September 2010. They have completed a ramp up of capacity at the solvent-extraction and electrowinning cathode production plant at almost 30 000 tpa of LME grade-A copper cathode in the same year (Photograph 26). The previous owner, CopperCo Ltd, commenced copper cathode production from breccia- and fault-hosted oxide resources at Mount Clarke and to a lesser extent Lady Annie, 100 km north of Mount Isa, in 2007. The company went into voluntary administration in November 2008. In 2012, new global mineral resource estimates were released for the oxide, transitional and sulphide zones for the various deposits in the area, comprising Lady Annie (Photograph 27), Lady Brenda, Mount Clarke, Flying Horse, Anthill, the Link, Anthill West, Lady Colleen, McLeod Hill and Swagman. From December 2014, about 10% of the ore fed to the crushing plant consisted of Lady Annie transition ore. The addition of transition ore produced a more consistant ore grade but also increased the calcium grade and acid consumption. To mitigate the effects of the high calcium grade on production, a number of processing improvements were made. CST Mining is also aiming to develop the Anthill deposit which is 40 km south of Mount Clark and has a mining lease application over the deposit. Golder Associates refined a mineral resource estimate for CST Mining in May 2014. The mineral resource estimates were updated for the oxide, transitional and sulphide zones for the various deposits in the area, comprising Lady Annie (Photograph 28), Lady Brenda, Mount Clarke, Flying Horse, Anthill, Lady Colleen, McLeod Hill and Swagman. The total measured oxide resources are 6.7 Mt at 0.67% Cu, measured transition ores are 5.6 Mt at 0.67% Cu and the total measured sulphide ores are 2.1 Mt at 0.95% Cu. The total indicated oxide resources are 12.4 Mt at 0.59% Cu, indicated transition ores are 12.0 Mt at 0.72% Cu and the total indicated sulphide ores are 13.6 Mt at 0.86% Cu. The total inferred oxide resources are 1.0 Mt at 0.38% Cu, inferred transition ores are 2.4 Mt at 0.52% Cu and the total inferred sulphide ores are 11.1 Mt at 0.69% Cu. All figures were calculated using a cut-off grade of 0.3% Cu. The May 2014 figures also included proven reserves at Lady Annie (Photograph 29), which were 250 000 t of oxide at 1.04% Cu and 150 000 t of transition at 1.36% Cu and the proven oxide reserves at Mt Kelly were 1.22 Mt at 0.67% Cu and 590 000 t of transition at 0.67% Cu. The probable reserves at Lady Annie were 230 000t of oxide at 1.03% Cu and 350 000 t of transition at 1.26% Cu and the probable oxide reserves at Mt Kelly were 220 000 Mt at 0.95% Cu and 220 000 t of transition at 1.17% Cu.

Photograph 26: (left) Lady Annie electrowinning cathode production plant; (right) copper product ready for shipment.

Photograph 27: Lady Annie open cut.

Matrix Metals Ltd refurbished the Mount Cuthbert solvent extraction-electrowining (SX-EW) treatment plant, 90 km northwest of Cloncurry, and brought its Leichhardt (Mount Watson) deposit, 24 km north of Mount Cuthbert, into production in 2007 at a rate of 5500 tpa cathode copper. In November 2008, the previous operator, Matrix Metals Limited, went into voluntary receivership. In February 2009 the operation was placed on care-and-maintenance. Cape Lambert Iron Ore Limited successfully bid for the operations, and onsold the project to Malaco Mining in July 2013. In February 2014 Malaco produced the first copper cathode after re-commissioning the plant and has stated that the heap leach pad has 3.6 Mt of ore for 16 800 t of copper which gives an average grade of 0.466% copper. The recently re-commissioned copper cathode processing plant has a proven capacity of 9000 tpa copper metal, with potential to further increase capacity via modular expansions. Malaco plans to mine the Mount Watson pit at a rate of about 1.5 Mtpa grading about 0.85 per cent copper. The company envisages a project life of about 10 years. Glencore is the offtake partner for the product — Grade A plate. Leichhardt has a total resource of 8.09 Mt at 0.98% Cu at an 0.5% copper cut-off grade. Other deposits that could provide feedstock are Mount Earl, Mount Wonder, Tewinga and Boomerang. Significant sulphide mineralisation has been intersected at depth below the oxide ore at Leichhardt.

The Mount Oxide project is located about 140 km north of Mount Isa. Perilya Limited considered it is unlikely Mount Oxide can be developed as a 'standalone' operation at current metal prices and the project development timeline has been delayed. Other opportunities for the Mount Oxide deposit are also being reviewed. The indicated resources for sulphide and transition ore



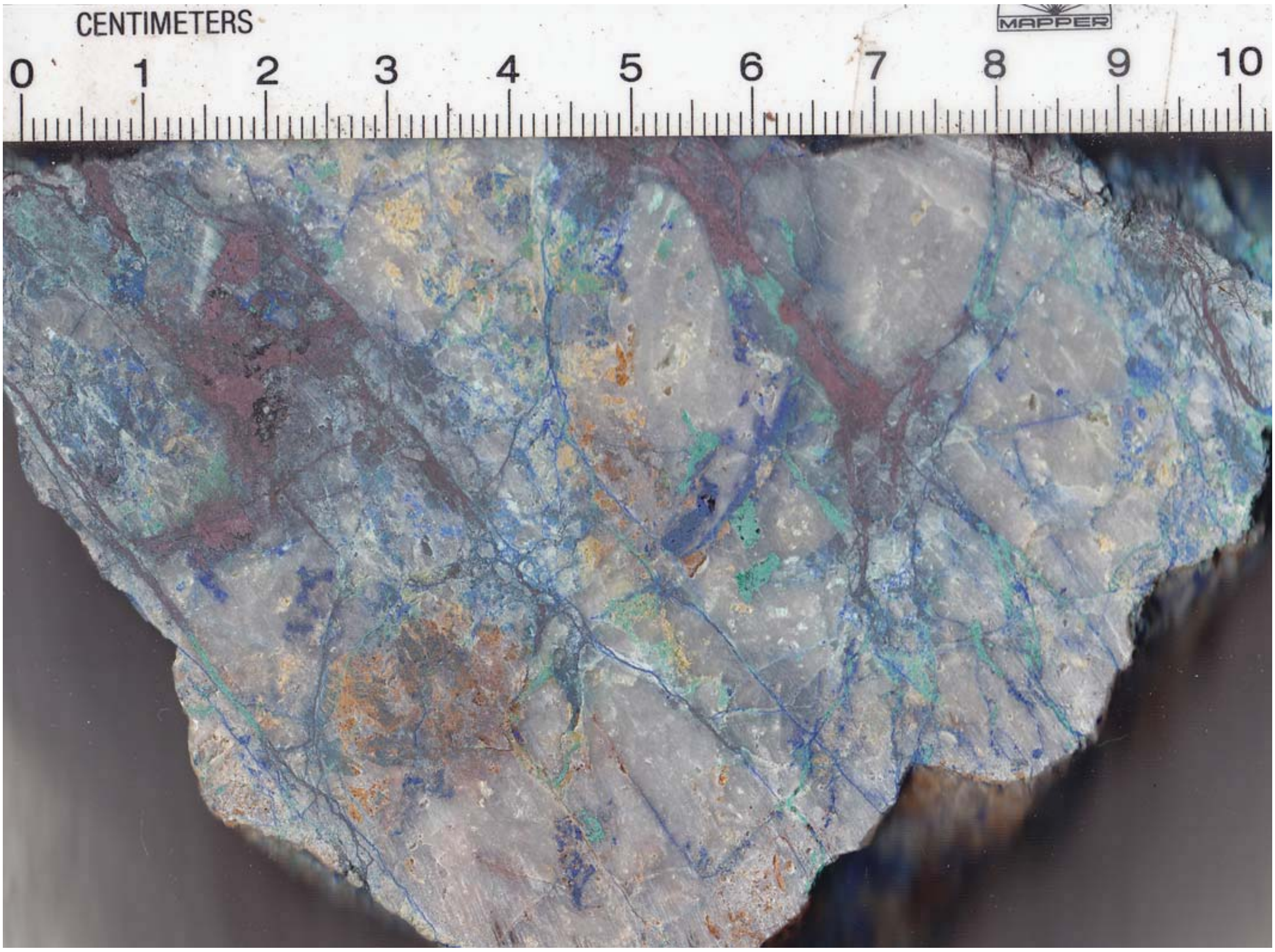
Photograph 28: Cuprite and secondary malachite mineralisation from the oxide zone at Lady Annie.

Photograph 29: Transition zone copper mineralisation from Mount Kelly – Flying Horse.

are 11.1 Mt at 1.6% Cu and 9.6 g/t Ag and the inferred resources are 4.8 Mt at 1.0% Cu and 5.2 g/t Ag at 0.5% Cu cut off. The transitional ore, which consists of chalcocite, cuprite and malachite, accounts for 15% of the resource (Photograph 30). Significant cobalt mineralisation exists outside the copper mineralisation in the resource area, mainly on the margins of the shallow domain in a zone of high pyrite content. At a cut-off grade of 0.1% Co, there is 4.5 Mt at 0.14% Co in the resource area (Photographs 31 and 32). Zhongjin Lingnan Mining (HK) Company Limited acquired Perilya Limited in December 2013, but there has been no announcements on any further developments.

The Einasleigh project, about 70 km southeast of Georgetown, incorporates the Einasleigh and Kaiser Bill copper deposits, beside the Broken-Hill-style Jackson, Chloe and Railway Flat zinc, lead and silver deposits. The project was sold by Kagara Mining to Snow Peak Mining in early 2013 as part of a larger package, which in January 2015 reverted back to Consolidated Tin Mines Limited. The Einasleigh deposit consists of high-grade copper mineralisation which is a structural extension of that mined in the old workings (Photograph 33 [left]) and has the potential to be mined by underground methods. Kaiser Bill, 6 km to the west, consists of thick, moderate-grade copper mineralisation and is open-pittable. At Einasleigh, indicated resources are 0.5 Mt at 4% Cu, 0.2 g/t Au and 18 g/t Ag and inferred resources are 0.6 Mt at 1.9% Cu, 0.1 g/t Au and 8 g/t Ag. At Kaiser Bill, indicated resources are 13.5 Mt at 0.8% Cu, 0.1 g/t Au and 6 g/t Ag and inferred resources are 1.5 Mt at 0.9% Cu, 0.1 g/t Au and 11 g/t Ag (Photograph 33 [right]). At Chloe, indicated resources are 3.3 Mt at 4.7% zinc, 2.1% lead, 52 g/t silver, 0.2% copper, and inferred resources (including Stella) are 1.3 Mt at 5.3% zinc, 1.8% lead, 51 g/t silver, 0.3% copper.

Photograph 30: Mount Oxide open cut.



Photograph 31: Cuprite and malachite mineralisation from Mount Oxide.

Photograph 32: Copper Bush (Polycarpia Glabra), a distinctive low bush which grows in clumps in areas were other plants appear absent. Its presence indicates >300ppm Cu in soil and rock.

Photograph 33: (left) Old workings in the Einasleigh area; (right) copper malachite gossan from the Einasleigh copper workings (image courtesy David Carmichael, DNRM).

2) Iron Oxide–Copper–Gold (IOCG)

Structurally-controlled copper–gold and iron-oxide copper gold mineralisation occurs mainly in the Eastern Fold Belt Province of the Mount Isa Province. Deposits in these systems are associated with relatively high temperature, iron- (magnetite and/or hematite) rich hydrothermal alteration systems that are spatially and temporally related to felsic plutons of the Williams-Naraku and Wonga Batholiths and have a variety of forms, including vein networks, breccias, disseminations and replacements. They are localised in dilatant zones of structures active during pluton emplacement and cooling and are hosted by oxidised sedimentary and volcanic packages. These host rocks include banded iron formation and ironstone, carbonaceous slate and phyllite, metasiltstone, schist and ferruginous arenite, with metamorphic grades ranging from greenschist to upper amphibolite facies.

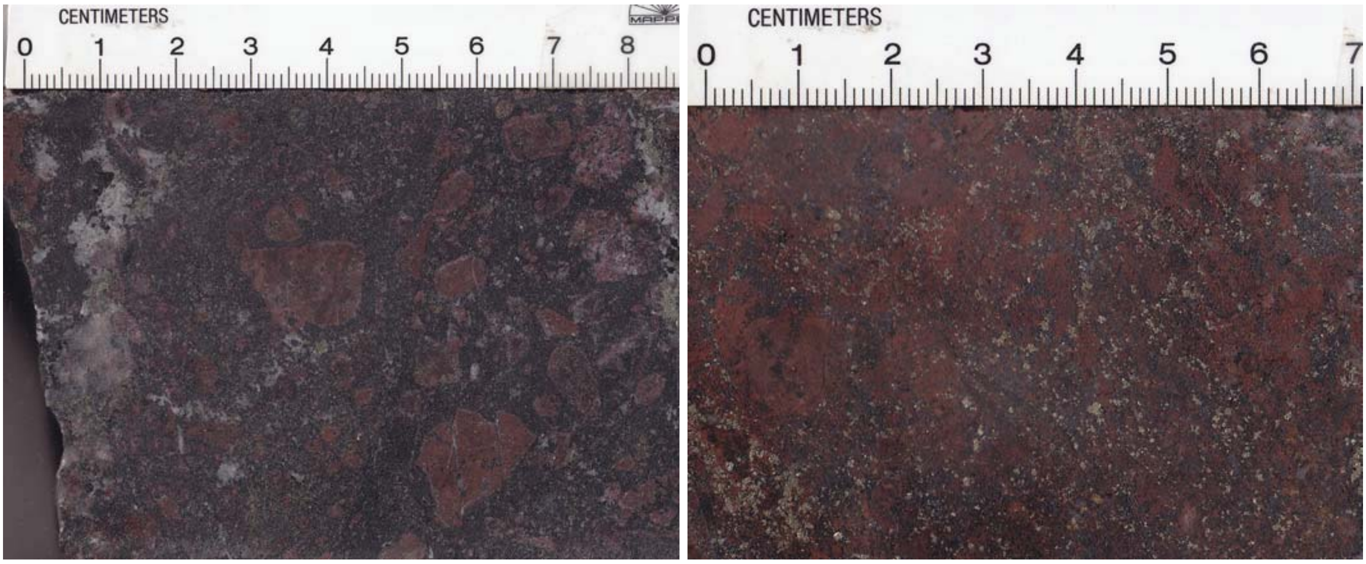
Alteration systems containing the Cu-Au mineralisation are characterised by Fe-rich calc-silicate (calcic amphibole + pyroxene, + carbonate + scapolite) assemblages along with alkali feldspar + biotite-bearing parageneses. This alteration fills dilatant sites such as veins and breccias and is commonly magnetite-rich, giving rise to strong positive magnetic anomalism.

Ernest Henry, Osborne, Kulthor, Selwyn (the Starra Line deposits), Eloise and Las Minerale are the major copper–gold deposits of this style in the Eastern Fold Belt Province. Primary iron-rich mineral associations vary from oxidised (*e.g.* magnetite at Ernest Henry and Osborne and hematite at Selwyn) to reduced (*e.g.* pyrrhotite at Eloise). Ernest Henry is hosted in variably altered, brecciated felsic volcanic rocks with primary mineralisation forming a magnetite-carbonate gangue. Magnetite makes up 20–25% of the primary ore.

Production at the Ernest Henry copper–gold mine, which is located 37 km northeast of Cloncurry, commenced in 1998. The open cut mine had operated from October 1997 until December 2011 and is approximately 1.5 km across at its widest point and 530 m deep. Close to 700 Mt of material was mined throughout the mine's life (Photograph 34). The operation was transitioned from an open cut to an underground mine in late 2011. The underground mine is based on a proved and probable ore reserve of 74.2 Mt at a grade of 1.04% Cu, 0.53 g/t Au (measured resource 9.2 Mt at 1.34% Cu, 0.69 g/t Au, indicated resource 72.6 Mt at 1.24% Cu, 0.65 g/t Au and inferred resource 9 Mt at 1.1% Cu, 0.6 g/t Au) (Photograph 35). The magnetite resource reported together with the 2011 resource figures has been removed from the resource estimation by Glencore after a business review resulted in the suspension of magnetite production in July 2013.

Osborne is a mid-sized copper–gold underground mine located 195 km southeast of Mount Isa. Barrick Gold Corporation operated the underground mine between 1995 and 2010, also supplementing ore from the Inheritance and Trekelano deposits trucked 130 km. Ivanhoe Australia Limited (later Inova Resources) acquired Osborne in October 2010 and recommenced operations February 2012. In that time Ivanhoe Australia also developed the Kulthor deposit, 2 km from Osborne. A strategic review identified that the Osborne operation would provide the best return by operating for at least the initial planned four year mine life to 2015 (Photograph 36). Chinova Resources Limited acquired all tenements from Inova in 2014. Chinova Resources is wholly owned by Shanxi Donghui Coal Coking & Chemicals Group Co. Ltd. The revised plan utilised ore from the Osborne, Kulthor and Starra 276 underground mines only. Mining at Osborne is expected to cease around August 2015. Ore production from Starra 276 commenced in March 2013 and Chinova Resources Limited finished the mining there in mid-August 2014. The Osborne underground resource

Photograph 34: Mine truck at Ernest Henry mine (Image courtesy Simon Crouch, GSQ).



Photograph 35: Copper magnetite mineralisation at Ernest Henry.

Photograph 36: (left) Osborne plant with headframe and conveyor belts; (right) Osborne copper mineralisation.

Photograph 37: Osborne open cut with underground portal at the base of the pit.

was estimated at 2.1 Mt at 1.5% Cu and 0.9 g/t Au (measured resource), 0.8 Mt at 1.2% Cu and 0.9 g/t Au (indicated resource) and 0.5 Mt at 1.2% Cu and 0.9 g/t Au (inferred resource). The Osborne open cut has a total resource of approximately 2.5 Mt at 0.7% Cu and 0.6 g/t Au (Photograph 37). In September 2012, the resource at Kulthor was upgraded to include adjustment for mining depletion to September 2012. The measured and indicated resource is 7.4 Mt at 1.6% Cu and 1.0 g/t Au. The inferred resource is 5.4 Mt at 1.3% Cu and 0.9 g/t Au. In their September 2013 quarter, Inova announced that an update to the Kulthor resource is imminent following successful drilling results, but since that time Chinova took over operations and there has been no resource update reported by them.

Photograph 38: Starra 257 open cut showing steeply dipping massive hematite bands within the Starra Line stratigraphy. Laminated hematite quartz ironstone and fine hematite mica schist are the main rock types.

The Starra 276 mine is about 120 km south of Cloncurry, and is part of Chinova Resources deposits, including Mount Dore, Mount Elliot and Starra 222. The Starra 276 orebody is one of five high-grade gold–copper orebodies on which a series of open cut and underground mines were developed over a 6 km trend, the Starra Line, by previous owners, like Selwyn Mines (Photograph 38). The metasediments hosting the orebodies are laminated hematite quartz ironstone and fine hematite mica schists. Starra 257 produced 2000t Cu and 3173kg Au from 690 000t of ore by open cut mining from 1987 to 1990; it also produced 5000t Cu and 2022kg Au from 466 000t of ore by underground mining from 1990 to 1998. The indicated resource at Starra 276 was estimated at 7.3 Mt at 1.1% Cu and 0.8 g/t Au and the inferred resource was 4.3 Mt at 1.0% Cu and 0.9 g/t Au, using a cut-off grade of 0.5% Cu equivalent, excludes previously mined material. Chinova Resources have now completed mining this deposit in August 2014. The Starra 222 indicated resource is 5 Mt at 0.6% Cu and 1.1 g/t Au.

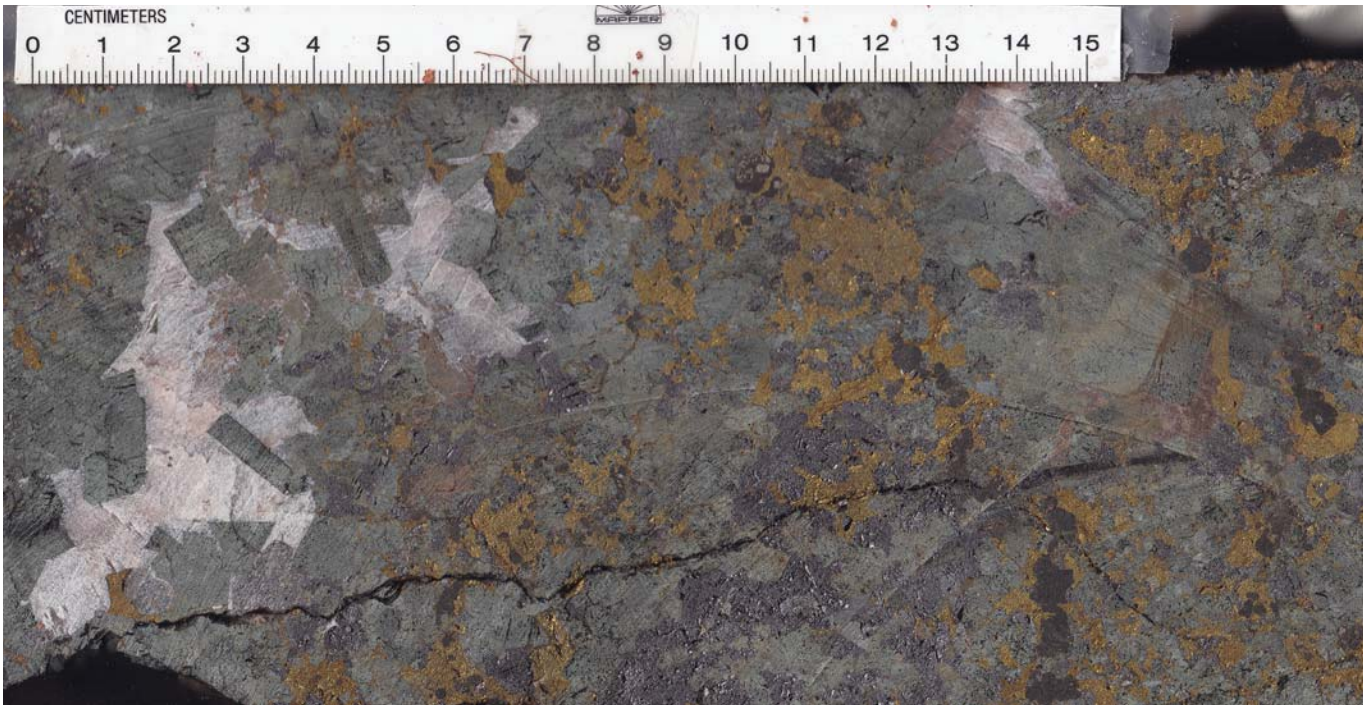
Chinova Resources also hold Mount Dore, about 147 km southeast of Mount Isa. Copper mineralisation occurs within brecciated metasediments and schists of the Kuridala Formation and is associated with dilational zones along the Mount Dore Fault zone. A pre-feasibility study to develop an open cut mine on the shallow leachable copper zone to produce cathode copper using heap leach and SX–EW technology was completed. The open cut indicated resource based on a 0.25% Cu cut off is 70 Mt at 0.6% Cu and 0.1 g/t Au. The underground indicated resource based on a 1.5% Cu cut off is 0.2 Mt at 1.2% Cu and 0.3 g/t Au. It is concluded that the project requires further analysis before progressing with further studies.

Mount Elliott, about 100 km south of Cloncurry, is one of the largest copper-gold mineralised systems discovered in Australia (Photograph 39 [left]). The project which is held by Chinova Resources since 2014, comprises several mineralised zones near the old Mount Elliott mine including the South-west Anomaly (SWAN), Mount Elliott (Photograph 39 [right]), South-west Elliott (SWELL) and Corbould zones. Long recognised as having the potential to provide a long-life mine with an on-site milling facility, a surprising outcome of the scoping study is that the original Mount Elliott underground mine could be mined by open cut independently of the SWAN resource and provide a feed source for a further 4 years to the Osborne mine. The proposed open cut has a mining inventory of 7.8 Mt at 1.51% Cu and 0.75 g/t Au (Photograph 40).

Amethyst Castle, another prospect held by Chinova Resources, about 9 km southwest of SWAN and Mount Elliott, consists of iron–oxide copper–gold–uranium mineralisation (Photograph 41), similar in style to that encountered at SWAN.

The White Range project, centred on Kuridala, 60 km south of Cloncurry, and held by Queensland Mining Corporation Limited, comprises three major deposits located at Greenmount, Kuridala and Young Australian with significant copper oxide resources that may be amenable to acid leaching (Photograph 42). Several satellite deposits include Mount McCabe, Vulcan and Desolation.

Photograph 39: (left) Mount Elliott historical plant and workings; (right) Mount Elliott open cut.



Photograph 40: Sulphide mineralisation in coarse gabbro.

Matrix Metals, completed a bankable feasibility study based on the production of 15 000 tpa of cathode copper and a mine life of about seven years in July 2006, but receivers and managers were appointed to the company in November 2008. Subsequently Queensland Mining Corporation Limited acquired White Range in July 2010. The total resource of the White Range project is 28 Mt at 0.84% Cu. The largest deposit, Greenmount, has a total resource of 12.7 Mt at 0.9% Cu 0.33g/t Au and 0.06% Co. Greenmount has a measured resource of 1.2 Mt at 1.30% Cu, 0.50g/t Au and 0.07% Co, an indicated resource of 7.7 Mt at 0.80% Cu, 0.30g/t Au and 0.06% Co and an inferred resource of 3.8 Mt at 0.60% Cu, 0.20 g/t Au and 0.04% Co. The resource is dominated by oxide copper to 30m depth and transitional copper (dominated by chalcocite) to the proposed pit floor at 100m vertical depth. The total measured, indicated and inferred transitional and oxide resources at Vulcan are 1.5 Mt at 0.65% Cu and 0.02% Co, at Mt McCabe are 2.6 Mt at 1.07% Cu and 0.03% Co and at Desolation are 1.9 Mt at 0.7% Cu, 0.25g/t Au and 0.05% Co. The Kuridala deposit has a measured resource of 2.5 Mt at 0.90% Cu, 0.20g/t Au and 0.02% Co, an indicated resource of 3.0 Mt at 0.80% Cu, 0.20g/t Au and 0.02% Co and an inferred resource of 1.7 Mt at 0.70% Cu, 0.20 g/t Au and 0.03% Co. The Young Australian has an indicated and inferred resource of 2.1 Mt at 0.95% Cu and 0.01% Co. Queensland Mining Corporation Limited are looking to upgrade and expand the resource base by conducting further exploration. They are also considering including recovery options for the gold and cobalt in future development plans.

The Eloise underground copper mine, which is located 65 km southeast of Cloncurry and owned by FMR Investments, reopened in early 2011 after being on care and maintenance since late 2008. The orebody is pipe-like with a strike length of some 180 m and a depth extent beyond 2000 m. The mine is now over 1300 m deep, with haulage of the high-grade ore by decline. The mill is capable of sustaining a rate of 600 000 tpa. The probable ore reserves quoted in 2009 were 2.4 Mt at 2.6% Cu, 9.3 g/t Ag and 0.7 g/t Au. Additional inferred resources in a shear-hosted copper-gold system were reported by Breakaway Resources in 2013 for Sandy Creek

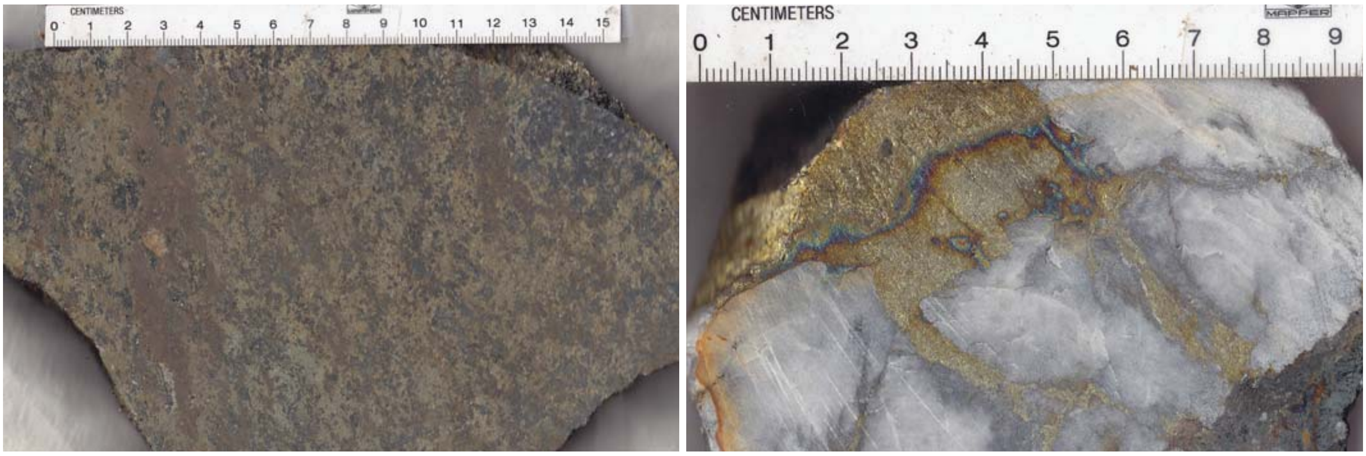
Photograph 41: Iron-oxide copper–gold–uranium mineralisation from Amethyst Castle copper prospect.

Photograph 42: (left) Historical Hampden-Kuridala workings; (right) leached sulphide mineralisation and comb quartz from Hampden-Kuridala workings.

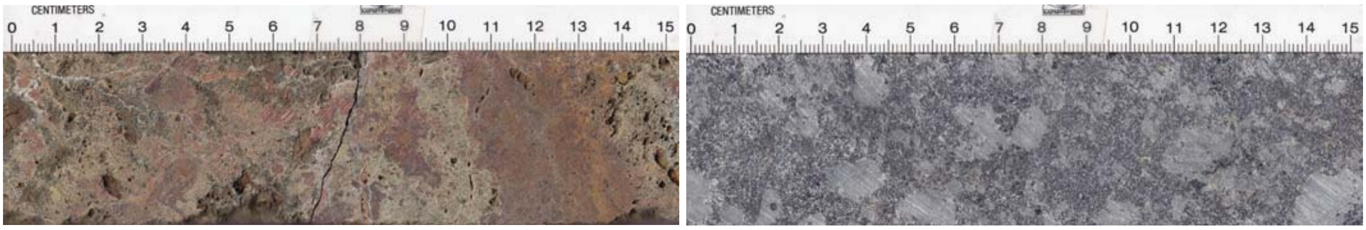
2.0 Mt at 1.32% Cu and 0.30 g/t Au (Photograph 43). The Eloise Copper project tenements (plus others) were acquired by Minotaur through its all-scrip take-over of the then-listed Breakaway Resources Ltd late in 2013.

In 2014 Minotaur Exploration Limited announced the discovery of significant copper, zinc, gold (and minor silver) mineralisation in massive sulphides at the Artemis prospect 20 km west of the Eloise mine and 350 m away from the Sandy Creek prospect. A separate private joint venture partner may earn up to 50% of the project. Minotaur has accelerated its exploration programme and is aiming to complete a 50 hole diamond drill hole program totalling 20,000 m in the 2014 financial year. Minotaur regards the mineralisation style at Eloise as analogous to that at the Eloise mine and is testing for the down plunge and strike extent of the mineralisation as well as other targets.

Las Minerale is the main deposit within the Rocklands group of copper-dominant deposits 17 km west-northwest of Cloncurry. This group of deposits was discovered by CuDeco Limited in 2006, in an area of shallow copper and known copper mineralisation at



Photograph 43: Copper mineralisation from the Eloise underground mine.



Photograph 44: (left) Native copper mineralisation from the Las Minerale deposit; (right) chalcocite mineralisation from the Las Minerale deposit.

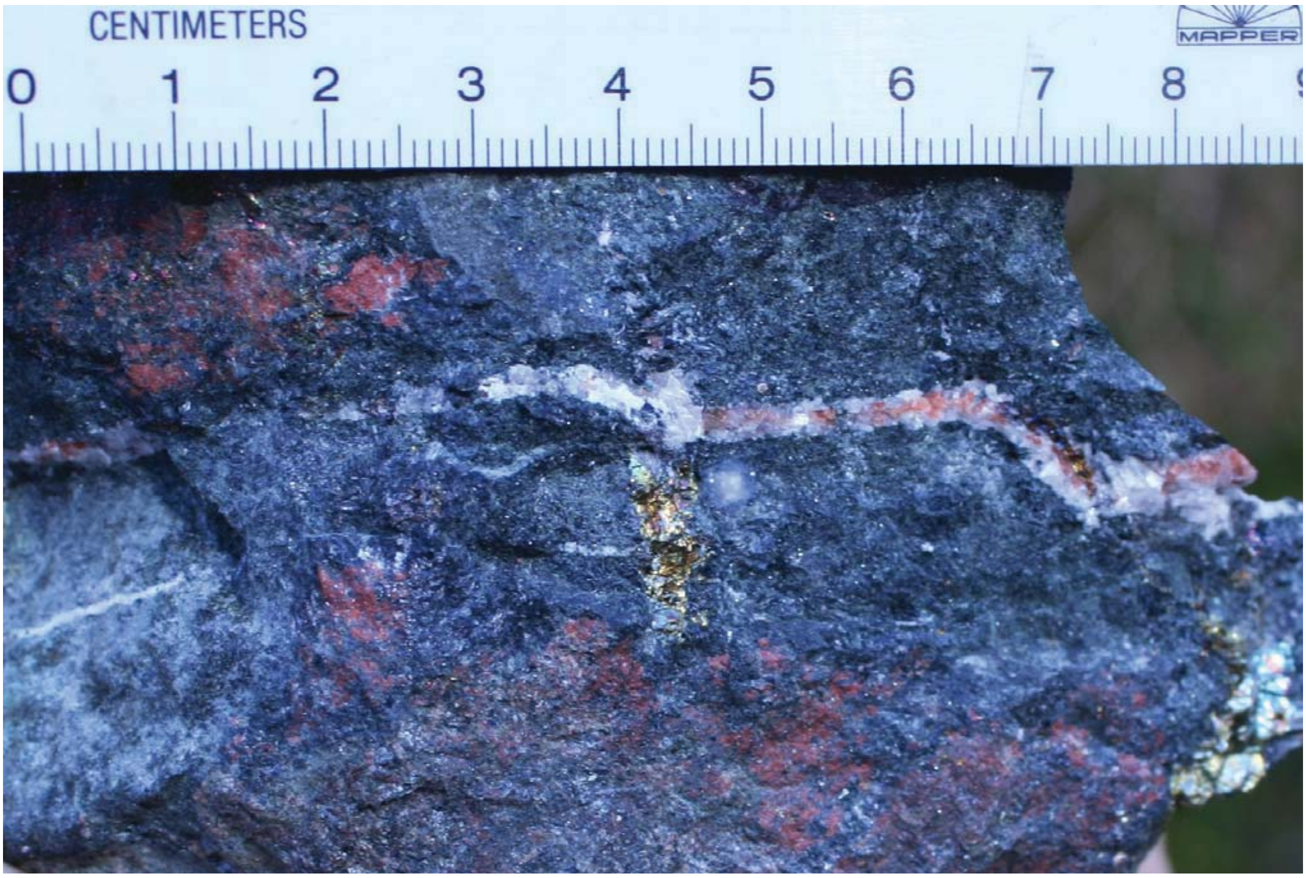
Double Oxide (earlier name for Las Minerale). Preliminary mining was also carried out at Rocklands South orebody, that displays similar mineralisation characteristics as Las Minerale, as well as at Meridian and Central Rocklands. Separate orebodies that have been identified are Rainden, Fairfield and Solsbury Hill. Las Minerale has a large supergene zone that continues from surface to 170 m deep in places, containing significant resources of coarse native copper and high-grade chalcocite (Photograph 44). The Rockland group of clustered, sub-parallel-striking ore-bodies will be collectively mined over the first 10 years of planned mining operations by CuDeco Limited. The open cut mining at Las Minerale has commenced in 2014. The excavation is designed to access 5000 t of coarse native copper to be used for the commissioning of the Rocklands three stage crushing circuit and the ore stockpiled pending completion of the plant. A throughput of 3 Mtpa is anticipated, which is estimated to produce 480 000 t of concentrate. The company has also arranged with Glencore Plc to supply 20 000 t of ore from Rocklands for toll-treatment at its Ernest Henry processing plant, and the results reported as surpassing epectations. Both parties may consider a long-term supply of ore from the Rocklands mine. The company also made its first shipment for smelter testwork of native copper concentrate produced from the Rocklands mine in November 2014 to a Chinese buyer. The process design for the recovery of the sulphide ore is conventional floatation and the mill will deliver four products, copper-gold sulphide concentrate, magnetite concentrate (94% magnetite), cobalt-bearing pyrite concentrate (about 1% cobalt, 50% sulphur) and native copper concentrate (96% Cu). In February 2014 CuDeco quoted a total resource for the Rocklands project at 30.5 Mt at 1.01% Cu, 0.21 g/t Au and 466 ppm Co at a cut-off grade of 0.80% Cu equivalent. This figure includes a measured resource of 19 Mt at 1.23% Cu, 0.22 g/t Au and 504 ppm Co, an indicated resource of 11 Mt at 0.68% Cu, 0.19 g/t Au and 405 ppm cobalt and an inferred resource of 0.5 Mt at 0.54% Cu, 0.12 g/t Au and 413 ppm Co. Additionally a magnetite only inferred resource was quoted for the Rocklands project at 10% magnetite cut-off of 328 Mt at 0.02%Cu, 70 ppm Co, 0.01 g/t Au and 26.6% magnetite yielding approximately 47 Mt of contained magnetite.

CuDeco Ltd also continues to intersect highly significant shallow gold, silver, tellurium and uranium mineralisation at the Wilgar prospect (Photograph 45) adjacent and to the north of the company's Rocklands copper project. The deposit would seem to be a new style of mineralisation in Queensland, but most likely associated with structurally-controlled iron oxide–copper–gold mineralisation. Noteworthy is the presence of rare earth element mineralisation at this deposit.

Smaller deposits of this style are localised along major shears and faults throughout the Eastern Fold Belt Province, with or without associated ironstone bodies. Examples include Monakoff, Mount Margaret (E1), Mount Roseby, Great Australia, Trekelano (Photograph 46), Greenmount, Mount McCabe and Mount Dore.

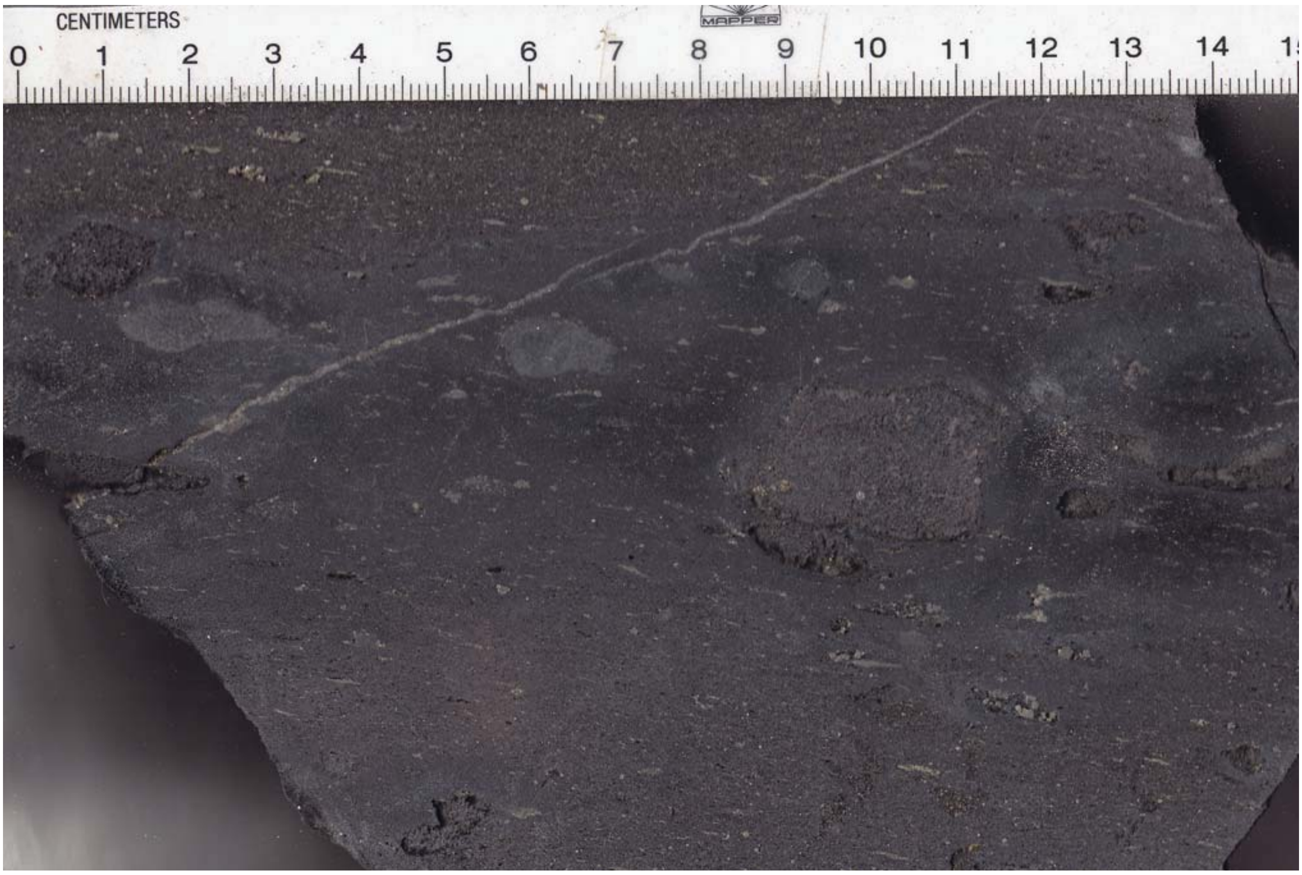
The iron-oxide copper gold systems Monakoff and Mount Margaret (E1) are part of the Mount Margaret Mining Project, and are 8 km east and 21 km south of the Ernest Henry mine respectively. They are held by Xstrata Copper following acquisition from Exco Resources NL in mid-2011. Open cut mining commenced at Mount Margaret (Photograph 47) in July 2012 and the first ore production was processed at Ernest Henry in September 2012. Over a five-year mine life, Mount Margaret is expected to produce about 140 000 t of copper, 2353 kg of gold and 560 000 t of magnetite in concentrate. The ore is transported to the Ernest Henry mine for processing through the existing concentrator. Following the merger of Glencore and Xstrata to create Glencore Xstrata Plc (now known as Glencore Plc) Glencore suspended magnetite production in July 2013 and closed some of the Mount Margaret (E1) pits. In 2013 Glencore reported resources and reserves for the Mount Margaret Mining Project without magnetite values. A probable and proved reserve of 0.7 Mt at 1.0% Cu and 0.32 g/t Au was estimated for E1 (Photograph 48). At Monakoff the 2012 probable

Photograph 45: Historical open cut at Wilgar prospect.



Photograph 46: Sulphide (chalcopyrite) mineralisation from the Trekelano open cut.

Photograph 47: The E1 open cut at Mount Margaret.



Photograph 48: Copper and magnetite mineralisation from Mount Margaret (E1).

reserve was removed from the listing. The total resources at E1 are 11 Mt at 0.75% Cu and 0.22 g/t Au and include a measured resource of 5.4 Mt at 0.74% Cu and 0.21 g/t Au and an indicated resource of 5.6 Mt at 0.76% Cu and 0.23 g/t Au. Additionally a small inferred resource for E1 of 0.6 Mt at 0.8% Cu and 0.2g/t Au was reported (figures substantially reduced from the 14 Mt reported in 2012). At Monakoff Glencore reported indicated resources of 2.4 Mt at 0.95% Cu and 0.3 g/t Au and inferred resources of 0.1 Mt at 0.8% Cu and 0.2g/t Au. The Mount Margaret Mining Project was completed in early 2014. Economic mineralisation at E1 occurs as breccia-hosted mineralisation within the footwall volcanics at E1 North, and as strata-bound, replacement style mineralisation within the sedimentary units at E1 North, Central, South and East. The E1 resources are constrained to the latest economic pit designs and were reported as three groups: E1 North, South and East. Following an extensive review of the E1 complex Glencore have excluded E1 South and East from the current ore reserves. The expiry of relevant tenements for E1 is 31 December 2032. At Monakoff all resources have been excluded from Glencore's current ore reserves. The expiry date for the Monakoff tenements is 31 October 2032.

The Roseby project, 65 km northwest of Cloncurry and adjacent to the Dugald River project, is held by Altona Mining Limited. The mineralisation at Roseby comprises four iron oxide – copper-sulphide deposits (Little Eva, Bedford, Ivy Ann and Lady Clayre), and several copper oxide deposits with associated stratabound native copper. The total resource over the four copper-gold sulphide deposits is 123.4 Mt at 0.55% Cu and 0.10 g/t Au of which the most advanced prospect, Little Eva, has an estimated total resource of 100.3 Mt at 0.54% Cu and 0.09 g/t Au (Photograph 49). A definitive feasibility study has been completed based on a large open cut at Little Eva with a strip ratio of 1.8:1. Ore would be processed at an adjacent 7 Mtpa processing plant, processing ore from all four iron oxide copper-gold deposits. Since March 2014, Altona has pursued sale, partnering, corporate and financing oportunities to fund development. The total copper resource for the seven copper oxide deposits is 265.8 Mt at 0.57% copper 0.05 g/t gold of which the most advanced deposit, Blackard, has an estimated total resource of 76.4 Mt at 0.62% copper. The deposits contain both copper sulphide ore in fresh rock and native copper ore in overlying weathered rocks. Sulphide ores could be readily treated in the Little Eva processing plant. Native copper ores could also be treated at Little Eva, but at lower recoveries of about 50 to 60%.

Photograph 49: Copper mineralisation at the Little Eva prospect. (Note sample in right hand photograph, placed on outcrop expression identified by presence of Copper Bush plant).

The Great Australia mine is adjacent to Cloncurry and held by CopperChem Ltd, a private company that is 93.4% owned by Washington H. Soul Pattinson and Company Limited (Photograph 50). The current operation commenced in 2004 using a copper sulphate plant to treat the oxide ore (Photograph 51). A copper concentrate plant to treat the sulphide ore (Photograph 52) commenced operation in the third quarter of 2011. At full capacity the facility will be able to mill 700 000 tpa. The indicated resource at the Great Australia was estimated by Exco as 1.4 Mt at 1.53% Cu, 0.13 g/t Au and the inferred resource is 800 000 t at 1.57% Cu, 0.14 g/t Au. In May 2013, CopperChem's resources around the production facility totalled 5.89 Mt at 0.94 % copper and 0.12 g/t gold. They comprised reserves of 60,000 t at 1.4 % copper and 0.1 g/t gold at the Great Australia, 284 000 t at 0.93% copper and 0.03 g/t gold at the Orphan Shear, 72 000 t at 1.51 % copper and 0.11 g/t gold at Taipan and 426 000 t at 1.04 % copper and 0.52 g/t gold at Notlor. The resources which are exclusive of the reserves were quoted as 3 Mt at 1.06 % copper and 0.08 g/t gold at the Great Australia, 241 000 t at 1.0 % copper and 0.03 g/t gold at the Orphan Shear, 2.22 Mt at 0.74 % copper and 0.11 g/t gold at Taipan and 426 000 t at 1.04 % copper and 0.52 g/t gold at Notlor (these figures were quoted as non-JORC compliant). The levels of native copper present in the ore have impacted the plant's performance and the company has mined the Orphan Shear, 150 m along strike to the northeast of the Great Australia open cut with a view to improving copper sulphide production. This mining operation was completed in 2013. After the takeover of Exco Resources in late 2012 by Washington H. Soul Pattinson and Company Limited, additional copper resources at Mount Colin, Taipan (Photograph 53), Kangaroo Rat, Wallace South, Victory Flagship and Salebury have become available as potential feedstock for the two copper processing plants in the Cloncurry area.

The Mount Colin deposit is midway between Cloncurry and Mount Isa, and development was expedited with Washington H. Soul Pattinson and Company Limited to fast-track production. Open cut mining commenced in December 2013, underground mining development started in early 2014 to produce the sulphide ore. In April 2012 Exco updated Mount Colin's indicated resource to

Photograph 50: Great Australia open cut.

Photograph 51: Chrysocolla, cuprite and quartz mineralisation from the oxidised zone at Great Australia mine.

Photograph 52: Sulphide (chalcopyrite) mineralisation from Great Australia mine.

Photograph 53: Taipan open cut.

1.042 Mt at 3.04% Cu and 0.42 g/t Au and the inferred resource to 880 000 t at 2.09% Cu and 0.41 g/t Au. Because of drought the company entered into an agreement with Glencore to treat the sulphide ore from Mount Colin at Mount Isa from March 2014. As a result of utilising toll treatment, the copper concentrator at Cloncurry was placed on care and maintenance. The company will review the option to restart the copper concentrator at Cloncurry or move it to one of the upcoming project areas.

In the Cloncurry area additional structurally-controlled iron oxide–copper–gold deposits are at Taipan, Kangaroo Rat, Wallace South, Victory Flagship, Salebury, Bosca/Bosca South and Canteen. Inferred Resources, which were delineated by Exco Resources using a 0.5% copper cut-off, at Kangaroo Rat are 1.26 Mt at 1.29% Cu and 0.63 g/t Au, at Taipan 1.46 Mt at 0.8% Cu and 0.1 g/t Au, at Victory Flagship 196 000 Mt at 1.2% Cu and 1.4 g/t Au and at Wallace South using an 0.5 g/t gold cut-off, 1.0 Mt at 1.6 g/t Au. The indicated resource at Salebury is 1.1 Mt at 0.9% Cu and 0.54 g/t Au and the inferred resource is 219 300 t at 0.75% Cu and 0.46 g/t Au. Mining of these deposits is expected to be sequenced to optimise the opportunity to utilise both the oxide and sulphide processing facilities in parallel.

The structurally-controlled iron oxide–copper–gold Turpentine deposit is located approximately 90 km north of Cloncurry and is owned by Washington H. Soul Pattinson and Company Limited. The sulphide mineralisation is hosted within Proterozoic metasedimentary and mafic rocks. In April 2012 Exco estimated an overall (indicated and inferred) resource of 5.64 Mt at 0.94% Cu and 0.2 g/t Au for Turpentine, which belongs to the Hazel Creek project. Other deposits in this project include Eight Mile Creek, Quail Creek and Turpentine South.

The Kalman copper molybdenum prospect, 60 km southeast of Mount Isa, was discovered in 2006 by Kings Minerals NL and is now held by Hammer Metals Limited. Wide zones of copper, molybdenum, gold and rhenium were identified in a major shear zone along the Pilgrim Fault (see 'molybdenum and rhenium' section).

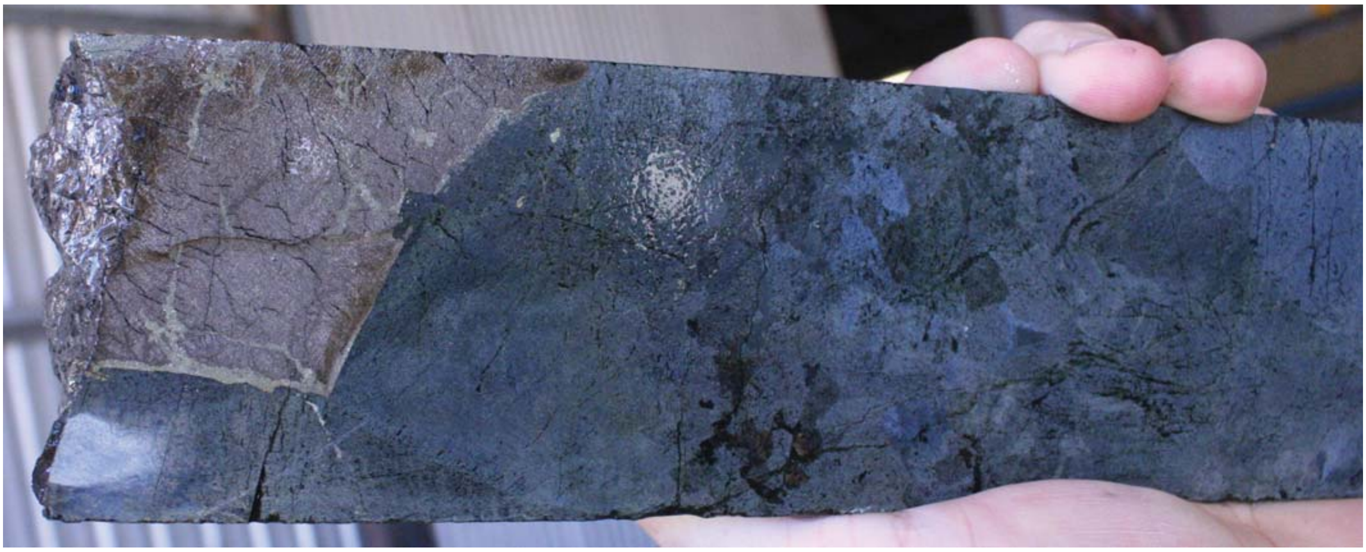
The Overlander North and South deposits, owned by Hammer Metals Limited, are located 60 km southeast of Mt Isa and about 6 km west from the Kalman deposit. The mineralisation consists of steeply dipping high grade copper and cobalt lodes within a low grade mineralisation envelope as part of a possible structurally controlled iron-oxide copper-gold system. A strong 'red rock' alteration is characteristic for these deposits. In 2014 Hammer Metals have acquired the deposits from Midas Resources Limited and reported a combined (indicated and inferred) resource 1.157 Mt at 1.2% Cu and 0.039% Co (at 0.7% Cu cut-off). Additional iron-oxide copper-gold deposit targets have been delineated in December 2014 at Andy's Hill, Dronfield and Hammertime prospects but further work is pending.

At Elaine Dorothy, 6 km south of Mary Kathleen along the Mary Kathleen shear, China Yunnan Copper Australia Limited (70%) and Goldsearch Limited (30%) have discovered a multi-element mineralised system containing variable and quite high grades of copper, cobalt, gold, rare earths and uranium over significant widths. The structurally-controlled copper-cobalt-gold mineralisation is hosted in garnet granulites, pyroxenites (Photograph 54) and calc-silicates of the Corella Formation (Photograph 55). The inferred resource is 27.7 Mt at 0.53% copper and 0.08 g/t gold using a 0.25% copper cut-off. A separate mineralisation event, the rare earths and associated uranium-thorium mineralisation, overlaps with the copper-cobalt-gold mineralisation, is not included in the copper resource estimate. The uranium and rare earth mineralisation is discussed in the 'uranium' and rare earths' sections. At the nearby Elaine South deposit, an inferred resource of 83 000 t at 280 ppm U_3O_8 and 3200 ppm total rare earth oxides at a cut-off of 200 ppm U_3O_8 was calculated in March 2010.

The Barbara copper-gold project, 50 km northeast of Mount Isa, comprises several shear-related copper deposits. Washington H. Soul Pattinson and Company Limited is funding a feasibility study through to a decision to mine under an agreement with Syndicated Metals, with a view to treatment of ore through the CopperChem Ltd processing facility at Cloncurry. Production is expected to commence from an open cut mine in early 2016 and the project is being remodeled with a view to an underground mine beneath the initial open cut. The companies are targeting a five to a seven year mine life. Metallurgical test work has exceeded the scoping study assumptions of 90 per cent copper recovery for sulphides and 65 per cent copper recovery for oxides. The indicated resource for the Barbara deposit is 3.25 Mt at 1.7% Cu, 0.15% Au 2.76 g/t Ag and 281 g/t Co and the inferred resource is 1.49 Mt at 1.3% Cu, 0.16% Au 2.17 g/t Ag and 369 g/t Co. The Lillymay deposit has an inferred resource of 225 295 t at 2.3% Cu and 0.02 g/t Au. The Blue Star deposit, 20 km to the south-southeast of Barbara, has inferred resources of 177 000 t at 2.31% Cu and 0.27 g/t Au and is not subject to an agreement.

ActivEx Limited discovered several structurally-related iron-oxide copper gold deposits within their Cloncurry copper project, south of Cloncurry. The mineralisation around Florence Bore North and Florence Bore South 1 is located within the Quamby-Malbon Tectonic Zone, along the margins of the Wimberu Granite surrounding metasediments of the Malbon Group. Chalcopyrite appears to be the main mineral at depth with oxidised copper minerals closer to the surface. Gold appears to be associated with the coper minerals. Earlier reports have also recorded cobalt and rare earth minerals present. In January 2015 ActivEx reported a new combined (inferred) resource estimate for Florence Bore North and Florence Bore South 1 at a cut-off grade of 0.5% Cu. The inferred resource is 1.61 Mt at 0.77% Cu and 0.15 g/t Au. Cobalt and rare earth elements were omitted in this calculation, but the earlier TREO information is mentioned in the 'yttrium and rare earth elements' section.

Since 2013, Red Metal Limited has had some considerable exploration success at Maronan, 120 km north of the Cannington mine. The exploration has identified two separate styles of mineralisation, bedded lead-silver mineralisation partially overprinted by structurally controlled and copper-gold mineralisation. The silver-lead mineralisation is of a similar style to Cannington and the copper-gold mineralisation can be compared with the mineralisation style at the Eloise and Osborne mines. Red Metals interpret the deposit environment as a banded iron formation with extensive venting on a seafloor. A large system of zoned facies was identified including an ore sulphide facies at the core, an iron sulphide facies as part of an intermediate zone, and an iron oxide facies at a



Photograph 54: Drill core from Elaine Dorothy; a very-coarse pyroxenite with chalcopyrite and pyrrhotite mineralisation.

Photograph 55: Drill core from Elaine Dorothy; Well-banded calc-silicate with chalcopyrite vein mineralisation.

distal range. The iron formations, iron sulphides and lead sulphide mineralisation are deposited in deep water perhaps similar to the environments where 'White Smokers' or 'Black Smokers' vent on the seafloor today. The ore sulphide facies (silver-lead-zinc) display galena-sphalerite-carbonate, galena-carbonate and galena-sphalerite-pyrrhotite mineralisation. The iron sulphide facies display pyrrhotite-carbonate and pyrrhotite-calc-silicate. The iron oxide facies display magnetite-quartz, magnetite-calc-silicate and magnetite-carbonate mineralisation.

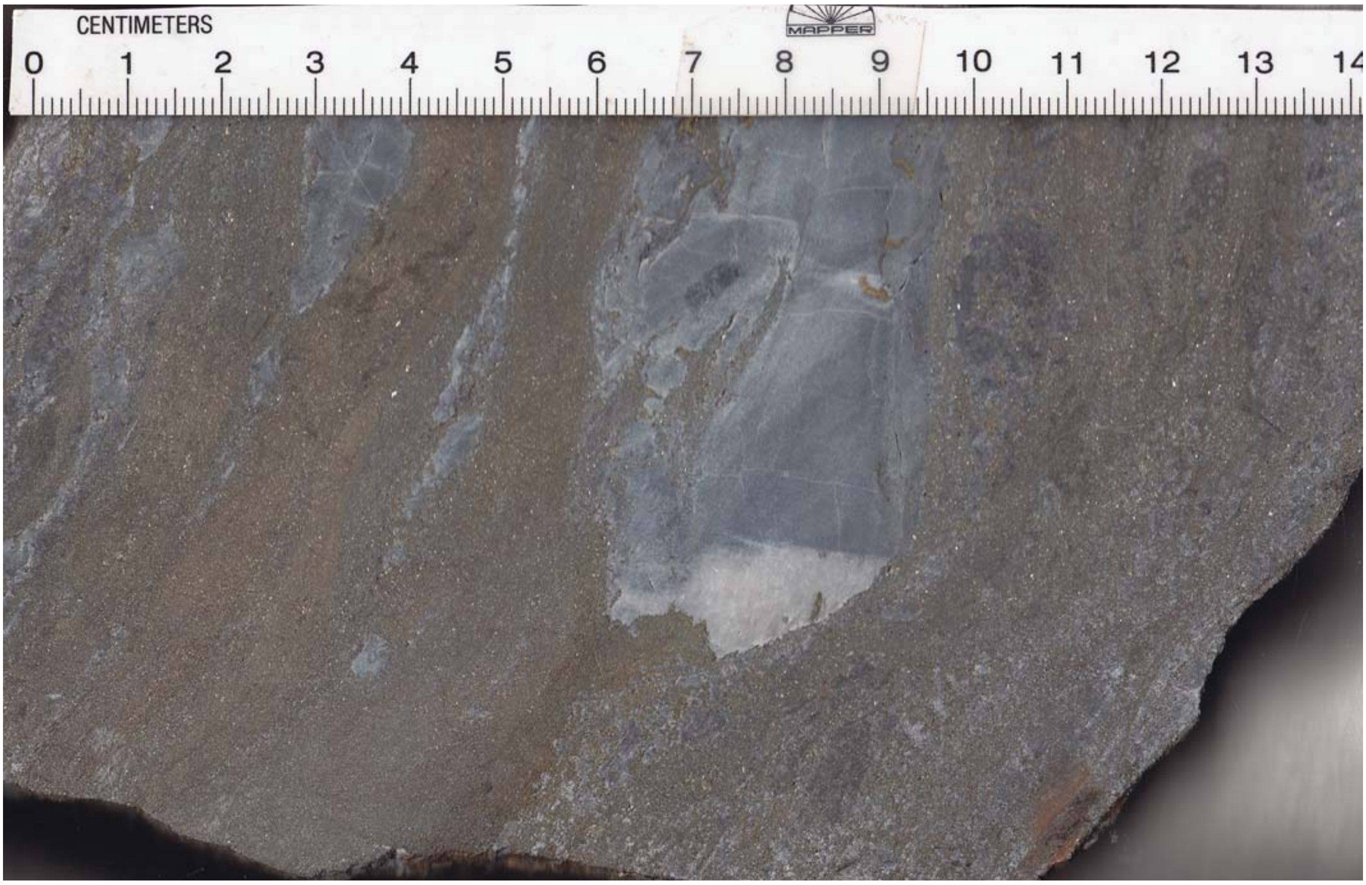
Discovery of deposits such as Ernest Henry, Osborne, Eloise and Mount Margaret (E1) beneath thin cover of the Eromanga and Carpentaria Basins on the eastern edge of the Mount Isa Province was largely due to advancements in geophysical techniques, as well as better targeting based on improved understanding of these systems.

3) Volcanic-hosted massive sulphide (VHMS)

Major volcanic-hosted massive sulphide copper deposits within Queensland are generally of medium size and occur predominantly within the Late Cambrian to early Ordovician rocks of the Thalanga Province in northern central Queensland. Examples of significant medium-sized copper sulphide deposits include Thalanga, Highway-Reward, Dry River South, Balcooma and Surveyor. Several smaller VHMS deposits, such as Mount Molloy and Dianne, occur in north Queensland.

Thalanga and Highway-Reward are hosted by the Seventy Mile Range Group of the Thalanga Province. The Thalanga deposit, although zinc rich, contained significant copper and has a tabular geometry, with rhyolitic volcanic rocks in the footwall and dacite and andesite in the hanging wall of the open cut.

The Thalanga mill was reactivated by Kagara Mining in 2006 to treat copper ore from Balcooma and was refurbished to treat Vomacka ore from late October 2010. Development of the Vomacka open cut 500 m from Thalanga commenced on 21 July 2010 and mining was completed in mid-January 2012. A further 178 000 t of transitional material grading 2.6% Zn, 0.8% Pb, 1.1%



Photograph 56: Massive sulphide (pyrite, chalcopyrite) mineralisation from Highway-Reward mine.

Cu, 0.3 g/t Au and 25 g/t Ag remains. Kagara Mining appointed voluntary administrators on 30 April 2012 following operational difficulties within the company and the assets are currently being sold by PCF Capital Group. The Highway-Reward deposit consists of pipe-like, copper- and gold-rich massive sulphide (pyrite, chalcopyrite) orebodies (Photograph 56) in rhyolitic to dacitic lavas and volcaniclastic rocks. Production from Highway-Reward stopped in 2005 after all resources were considered to be mined out (Photograph 57). Red River Resources Limited acquired the Thalanga operation at the end of October 2014 and has set a target of restarting production at the end of 2015 (see more information on Thalanga in "base metals: silver-lead-zinc' section).

The Balcooma, Dry River South and Surveyor deposits (Photograph 58) occur in the Balcooma Metavolcanic Group in the eastern part of the Georgetown Inlier. Metapelite lenses within a thickly bedded meta-arenite sequence host the Balcooma deposit. Mineralisation is rich in copper and contains significant zinc, lead, silver and gold. The deposits in the Balcooma Metavolcanic Group are interpreted as being about the same age as the deposits in the Seventy Mile Range Group. Kagara Mining commenced zinc, lead and silver mining at Surveyor in 2003 and underpinned development by successful exploration. During 2005–06 the Dry River South underground zinc, lead and silver mine was developed (Photograph 59) and the company commenced an open cut mine at the nearby copper-dominant Balcooma deposit. Since then, copper was the most important commodity for the company and in late 2008 the Dry River South and the polymetallic Balcooma underground mines were suspended. In September 2009 the transition to production from an underground copper mine at Balcooma was made (Photograph 60). Most of the copper ore from Balcooma was trucked some 300 km for treatment to a second mill at Thalanga. Mining was suspended at Balcooma in April 2012. At 5 September 2012, the proven and probable copper reserves at Balcooma were 194 000 t at 1.9% Cu, and the polymetallic reserve at Balcooma was 27 000 t at 9.2% Zn, 5.3% Pb and 0.6% Cu. The measured indicated and inferred copper resources at Balcooma are 412 000 t at 2.1% Cu and the polymetallic resources 1.532 Mt at 4.7% Zn, 1.7% Pb and 1.3% Cu. At 5 September 2012, the remaining dominantly inferred resources at Dry River South are 730 000 t at 6.9% Zn, 2.5% Pb, 0.9% Cu, 0.6 g/t Au and 62 g/t Ag. There is a further indicated oxide resource at New Surveyor East of 179 000 t at 6.4% Pb, 0.1% Cu, 1.2 g/t Au and 93 g/t Ag.

The Mount Morgan Au-Cu orebody occurs in a belt of Middle Devonian volcanics and sediments forming a roof pendant in a Late Devonian tonalite intrusion in the Yarrol Province. Although genesis has long been controversial, Mount Morgan is now generally regarded as being an end-member of the general class of VHMS deposits. This world-class deposit sustained almost continuous mining between 1882 and 1990, producing 215 268 kg of gold bullion and 78 788 kg of fine gold, 360 616 t of Cu and 36 842 kg of silver from 50 Mt of ore (including treatment of tailings). Further exploration at Mount Morgan has defined only limited extensions to the mineralisation (Photograph 61).

Photograph 57: Highway-Reward open cut.

Photograph 58: Panorama view of the Surveyor open cut with underground portal and waste dump refill on right of view.

Photograph 59: Ore carted out of Dry River South pit (image courtesy DNRM).

Photograph 60: (left) Balcooma copper underground portal; (right) Balcooma underground massive copper mineralisation (mostly chalcopyrite).

Photograph 61: Mount Morgan historical plant and open cuts; from left: open cut, historical chimney, sulphide mineralisation and overall view.

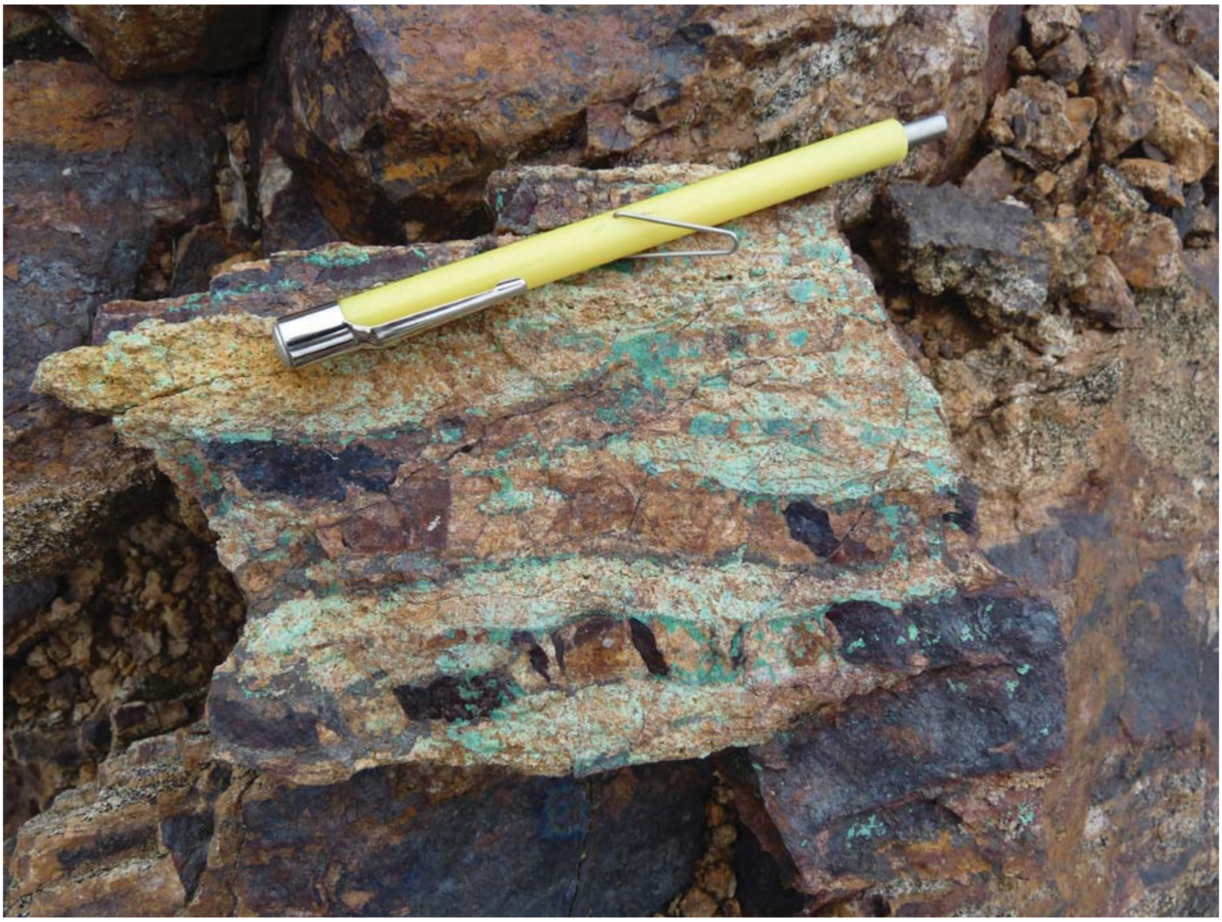
The Mount Morgan gold tailings project has been held by Norton Gold Fields Limited since November 2007 but in 2014 was sold to Carbine Resources. A feasibility study has confirmed the technical and economic viability of establishing a project processing tailings and mullock over 8 years .The 8 year project life is based on an indicated resource (at 30 June 2012) of 2.487 Mt at 1.59 g/t Au and 0.16% Cu and an inferred resource of 5.861 Mt at 1.07 g/t Au and 0.14% Cu. An additional mineral inventory of more than 4 Mt is expected to be sourced from former mine waste material. Tailings test work by Carbine Resources has successfully resulted in a 81 per cent reduction in cyanide consumption using the selective removal of copper prior to gold recovery, a significant increase in gold extraction to 78%, 56% of the copper and 91% recovery of pyrite to a saleable high-grade concentrate. Flowsheet optimisation work and resource drilling are to be carried out prior to a preliminary feasibility study in 2015.

In early 2013 Aeon Metals Limited discovered a new deposit about 35 km west of Monto, the 7B Copper-gold project, identified via distinct magnetic anomalies, historical stream sediment sampling and known structural features, and interpreted as a significant volcanogenic polymetallic (Cu-Au-Mo) mineralisation. Current interpretation of observations from drill core indicates a possible Cu-Au-Mo style of mineralisation. Indicator minerals like sphalerite, galena, pyrite, barite, and chalcopyrite are in the halo of such deposits. Drill results to date include up to 4.92% Cu, up to 4.79 g/t Au, silver up to 68 g/t Ag and 2.47% Zn.

4) Porphyry copper

The most significant porphyry copper style deposit in Queensland is at Coalstoun Lakes, where Late Permian diorite-monzonite porphyry stocks and large breccia pipes of the South-East Queensland Volcanic and Plutonic Province intrude altered sedimentary and volcanic rocks (Good Night beds) of the Wandilla Province. Mineralisation at Coalstoun Lakes is subeconomic due to its low copper grade (inferred resource of 85.6 Mt at 0.29% Cu). Several weakly mineralised porphyry systems have been recognised along the east coast of Queensland, *e.g.* Booubyjan, Chinaman Creek, Mount Cannindah. ActivEx held Booubyjan showed broad zones of copper mineralisation along porphyry lithocaps indicating a possible major buried intrusive system with a best intercept of 88m @ 0.47% Cu and 0.49% Au (Photographs 62 and 63). More recently another area has been outlined near Monto and has several deposits grouped within the Greater Whitewash project.

The Greater Whitewash project is about 30 km west of Monto. The operators of this project, Aeon Metals Limited, have recognised a structural corridor striking south over 20 km, which include the Kiwi Carpet, John Hill, Gordon's, Whitewash, Whitewash South and Windmill deposits. The structure continues south over the Wingfield prospect and the Sandy Creek prospect, which are on tenure joint ventured with Rio Tinto. In general the deposits are classed as polymetallic (molybdenum, copper, silver) structurally-

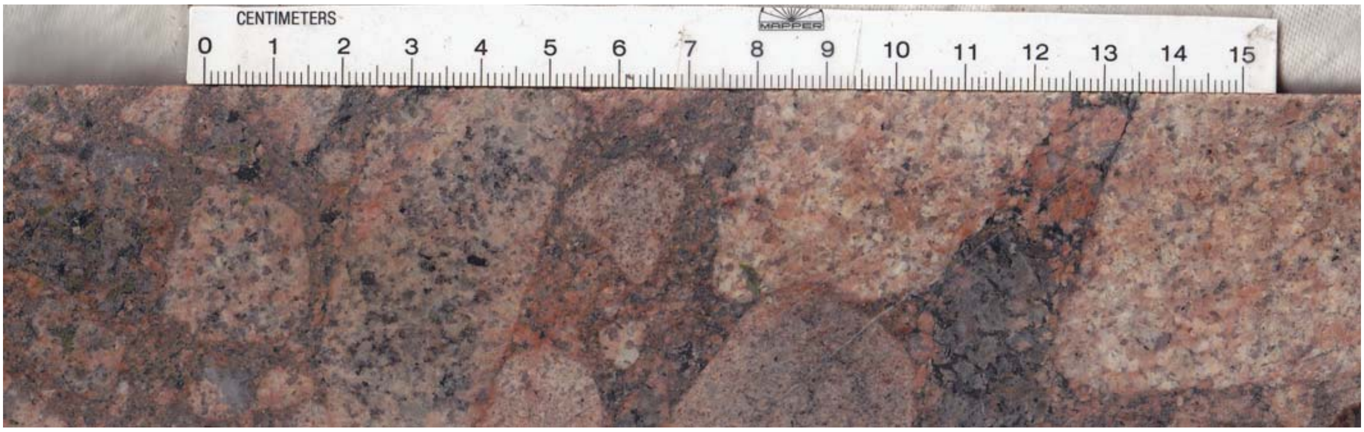


Photograph 62: Copper mineralised vein system from the Kiwi Prospect at Booubyjan (image courtesy Doug Young, ActivEx).

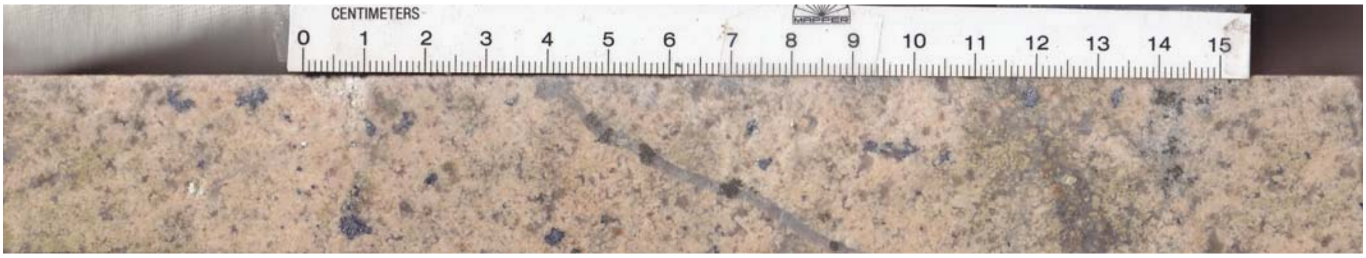
Photograph 63: Copper mineralisation in drill core (KAKD1, 98m) from the Kiwi Prospect, Booubyjan (image courtesy Doug Young, ActivEx).

controlled porphyry intrusions with sheet-veined molybdenite–chalcopyrite–quartz mineralisation, copper dominant at Whitewash and Whitewash South (Photograph 64). The mineralisation is hosted within porphyry intrusions and granite within the Wingfield Granodiorite in the Rawbelle Batholith (Photograph 65). Gordon's deposit, which is due north of Whitewash, is hosted by three principal geological zones. The main body represents a vertically attenuated pipe-like body, which extends off a mineralised porphyritic granite carapace at depth (Photograph 66). The molybdenite mineralisation within the pipe-like body was observed as abundant disseminations within pegmatite, massive quartz and pegmatite breccia. The 'Whitewash-style' sheeted-vein networks within the granodiorite wallrocks lie immediately adjacent to the intrusive pipe and carapace. They comprise dense laminated quartz-molybdenite-chalcopyrite veins. A 3D model highlighted these three major zones which were subsequently used to constrain the resource estimate for Gordon's.

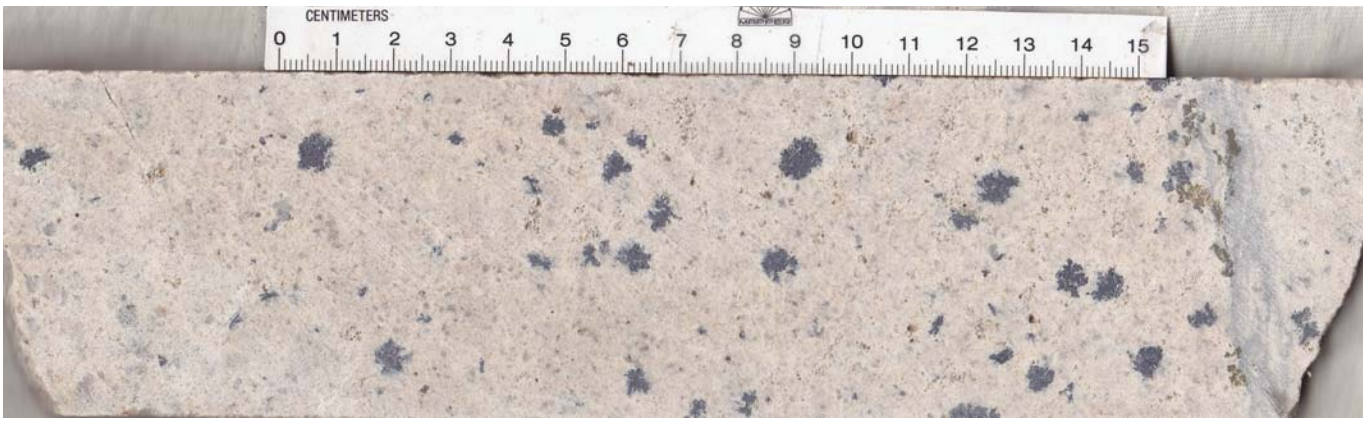
Further north along the structural corridor more deposits have been delineated, e.g. Kiwi Carpet (discovered by CRA in 1962 and drilled by Kennecott in the 1970s) and the John Hill deposit, discovered in May 2012. Kiwi Carpet and John Hill are about 15 km and 12.5 km north of Whitewash respectively, and are held by Aeon Metals. John Hill has similar polymetallic disseminated mineralisation to Greater Whitewash, but copper is clearly the dominant metal (Photograph 67). The presence of an extended chalcocite supergene zone is also identified at John Hill. Due to the proximity to Greater Whitewash, the John Hill deposit has the potential to add substantially (open cut tonnes and copper grade) to the economics of a centralised Greater Whitewash processing plant. In 2014 Aeon Metals Limited recognised the John Hill deposit being part of a large mineralised copper system with the presence of an extended chalcocite supergene zone. This significant copper-dominant polymetallic porphyry-style mineralisation is now recognised as the Ben Hur project, 10 km north of Greater Whitewash. The maiden inferred resource using a cut-off grade



Photograph 64: Milled breccia with polymictic clasts of granite and granodiorite in fine molybdenum-rich matrix Wingfield Granodiorite of the Rawbelle Batholith, Whitewash South prospect.



Photograph 65: "Miesels" porphyry with molybdenum rosettes and chalcopyrite veinlets within the Wingfield Granodiorite of the Rawbelle Batholith, Gordons prospect, Whitewash Project.



Photograph 66: Porphyry with molybdenum rosettes and some chalcopyrite within the Wingfield Granodiorite of the Rawbelle Batholith, Gordons prospect, Whitewash Project.

Photograph 67: Biotite porphyry with disseminated copper and molybdenum and fine quartz veinlets in Wingfield Granodiorite of the Rawbelle Batholith, John Hill prospect.

of 0.24% Cu is 62 Mt at 0.3% Cu, 0.012% Mo and 1.3 g/t Ag, of which some 10 Mt occur in a chalcocite enrichment zone. The dominant part of this resource comprises the John Hill deposit.

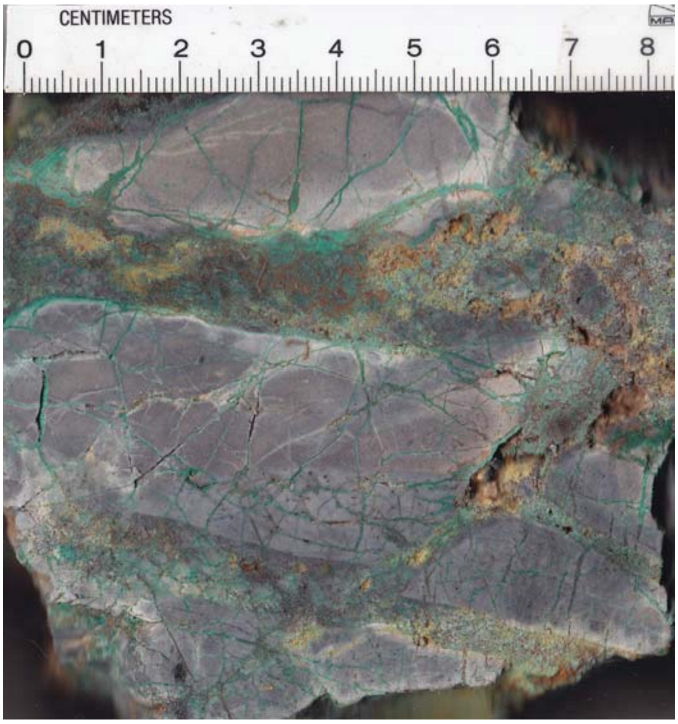
Aeon Metals Limited has outlined an indicated and inferred resource of 242 Mt grading 604 ppm molybdenum equivalents (molybdenum, copper and silver). An MDL application was approved over the Greater Whitewash resource and bulk sampling and corresponding pilot plant work can follow preliminary metallurgical testing. The metallurgical testing has provided encouraging results with the possibility of substantially upgrading the mineral content at a coarse stage of processing, which in turn should reduce the material needed to fine grind. Flotation tests have shown excellent recoveries for molybdenum (93%), copper (96%); silver (85%) and tungsten can also be recovered.

5) Intrusive-related copper

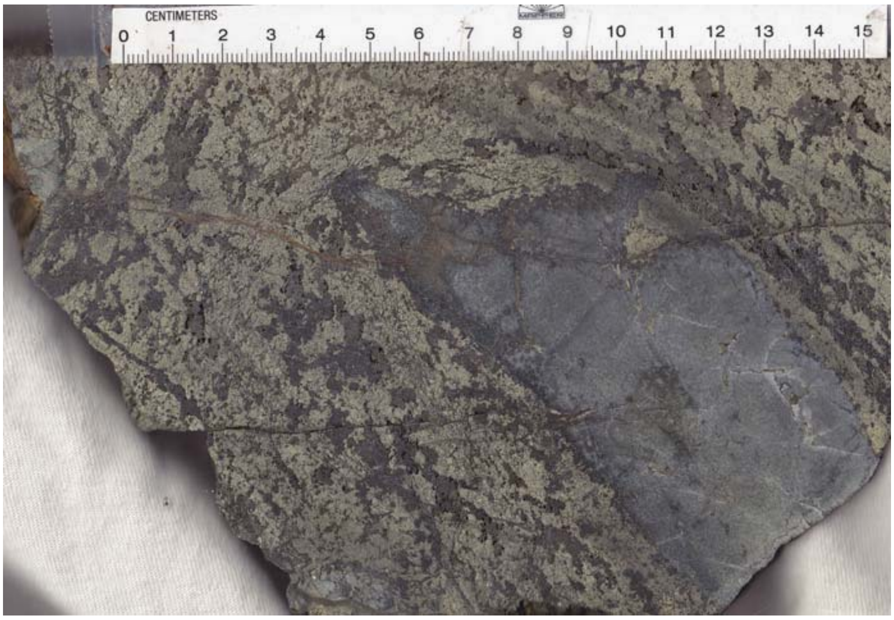
Intrusion-related gold (copper) systems also occur in the Hodgkinson Province in north Queensland. Significant mineralisation at Red Dome and Mungana associated with skarns and their related porphyry intrusions are held by Mungana Goldmines Limited. The Mungana gold ore body is adjacent to the Mungana polymetallic mine, operated by Kagara Mining up to April 2012. Currently Mungana polymetallic mine is under care and maintenance and Mungana Goldmines have completed the acquisition of the Kagara assets in August 2014.Red Dome has a measured, indicated and inferred resource of 69.2 Mt at 0.24% Cu, 0.63 g/t Au and 5.2 g/t Ag (October 2011 figures). Construction of a concentrator at Mungana, designed to treat 650 000 t of polymetallic ore per year, commenced in May 2008 but was suspended in late 2008 because of the global financial crisis. As a result, the Mungana ore was trucked to Mount Garnet. In September 2012 the indicated resource for the Mungana base metal skarn was 44 000 t at 10.5 g/t Zn, 0.1% Pb, 1.9% Cu, 0.9 g/t Au and 124 g/t Ag. The related porphyry system has a measured, indicated and inferred resource of 48.7 Mt at 0.19% Cu, 13.3 g/t Ag and 0.7 g/t Au (October 2011 figures).

The Baal Gammon deposit, 7 km west of Herberton, is held by Consolidated Tin Mines Limited. In May 2011, the previous owners Monto Minerals entered into an agreement with Kagara Mining for Kagara to explore for all metals excluding tin and to mine and process the ore in the Mount Garnet copper plant. At September 2012 the probable reserve was 317 000 t at 2.8% Cu and 90 g/t Ag and the indicated and inferred resource 2.01 Mt at 0.8% Cu, 33 g/t Ag. Kagara Mining commenced open cut mining at Baal Gammon in September 2011 and processed the ore at Mount Garnet. When the operation was suspended in April 2012 Kagara Mining had removed all transitional ore and was poised to access the high-grade sulphide orebody (Photographs 68 and 69). In December 2012, Kagara Mining (administrators appointed) sold their north Queensland central region assets which included the Baal Gammon deposit to Snow Peak Mining Pty Ltd. Snow Peak Mining under Consolidated Tin Mines management commenced mining Stage 1 of the Baal Gammon mine in March 2014 with the ore treated at the companies Mount Garnet plant. At that time, a stockpile of 6368 t of broken ore grading 2.86% Cu and 67.87 g/t Ag was on the ROM pad at the Baal Gammon mine site awaiting trucking to Mount Garnet. Production was subsequently suspended in April 2014 following heavy rainfall associated with Cyclone Ita and the mine placed on care and maintenance. Consolidated Tin Mines Limited have signed an asset sale agreement with Snow Peak Mining in October 2014 to purchase the Mount Garnet plant and all tenements associated with Snow Peak's holdings including the Baal Gammon mine. The latest resource figures for Baal Gammon were quoted in September 2012 in the asset sales offer for Kagara Mining (in liquidation). The indicated resource is 1.98 Mt at 0.8% Cu and 33 g/t Ag and the inferred resource is 31 000 t at 0.6% Cu and 18 g/t Ag. Tin and Indium were quoted in previous resource estimates but omitted here.

The Tartana deposit located 40 km northwest of Chillagoe, held and operated by Solomons Mines Pty Ltd, is not obviously related to intrusive rocks like King Vol and Montevideo. It is possible that Tartana, which is a low grade deposit in calcareous sediments within the Chillagoe Formation, represents an original sedimentary deposit of the type which was remobilised and concentrated following granitic intrusion. Solomons Mines Pty Ltd is reputed to have produced some of the world's best copper sulphate product



Photograph 68: Secondary malachite mineralisation in brecciated metasediments from Baal Gammon.

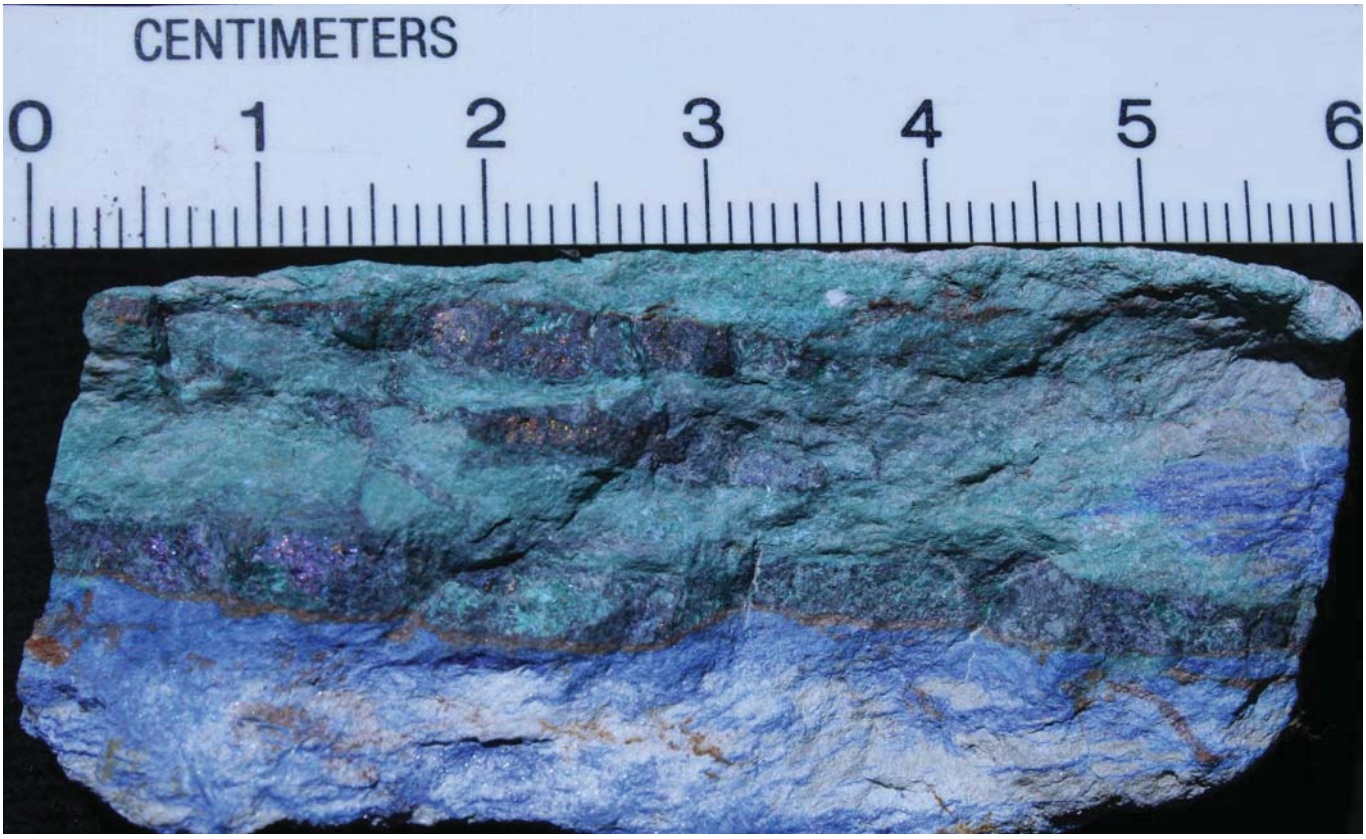


Photograph 69: Sulphide mineralisation (mostly chalcopyrite) from Baal Gammon.

from Tartana oxidised ore (Photograph 70). Oxidised copper minerals were mined and processed by acid leaching to recover copper sulphate (pentahydrate) crystals. The plant produced copper pentahydrate mainly for the zinc-refining industries, but also for uses as a chemical (as a fungicide, herbicide and pesticide) and in wood preservation. There is potential for the production of primary copper sulphide but at the moment the mine is on care and maintenance and the operator is working elsewhere (Photograph 71).

6) Skarns

Mount Moss is a skarn-related magnetite deposit, 105 km northwest of Townsville, which was acquired by Curtain Brothers Queensland Pty Limited in 2005. Details on magnetite production are recorded in the 'Ironstone and magnetite; section. The mine also has potential for the production of copper and perhaps zinc as secondary products, which is also associated with the skarn mineralisation.



Photograph 70: Tartana oxidised copper ore (malachite and azurite).

Photograph 71: Tartana Copper Mine (© The State of Queensland).

Base Metals: Silver–Lead–Zinc

Queensland is Australia's largest producer of silver, lead and zinc, hosting several world-class silver–lead–zinc mines. These are all within the Paleoproterozoic–Mesoproterozoic rocks of the Mount Isa Province. Numerous smaller deposits occur within the Mount Isa Province and within rocks of the Tasman Orogenic Zone and Etheridge Province. Queensland's known reserves and resources contain >72 740 t of silver, >30.5 Mt lead and >53.3 Mt zinc.

In 2011–12 (2012–13), Queensland produced 672 036 t (1 463 180 t) of lead concentrate and 1 916 243 t (1 208 435 t) of zinc concentrate in gold bullion. The metal content from both concentrates included 429 783 t (421 549 t) of lead, 1 442 378 kg (1 473 580 kg) of silver and 1 008 416 t (971 425 kg) of zinc.

Major Ag–Pb–Zn deposits within Queensland occur in five main mineralisation styles: sediment-hosted Ag–Pb–Zn, Broken Hill type, volcanic-hosted massive sulphide, zinc skarns and epithermal Ag–Au deposits (Table 7).

Table 7: Major Ag-Pb-Zn deposits of Queensland

Name	Size	Total recorded production	Total contained metal in remaining resource	Principal mineralisation style	Host/ orebody province
Altia	M		229 245 t Pb 233 070 kg Ag 28 407 t Zn	Broken Hill Type	Eastern Fold Belt/ Eastern Fold Belt
Balcooma some production reported under Thalanga and Mount Garnet plants	M	31 806.3 kg Ag 63 327 t Zn 1 575 t Pb	49 362 kg Ag 74 290 t Zn 26 514 t Pb	Volcanic-Hosted Massive Sulphide	Thalanga/Thalanga
Cannington	G	17 514 357.1 kg Ag 3 837 692.8 t Pb 1 041 217.7 t Zn (+ 41 932 t Zn concentrates)	12 896 000 kg Ag 3 815 220 t Pb 2 423 440 t Zn	Broken Hill Type	Eastern Fold Belt/ Eastern Fold Belt
Century	G	6 930 475 t Zn 2 129 342.5 kg Ag 924 821 t Pb	1 087 200 t Zn 749 700 kg Ag 510 100 t Pb	Sediment Hosted	Western Fold Belt/ Western Fold Belt
Dugald River	G		7 421 600 t Zn 2 010 400 kg Ag 1 155 200 t Pb 79 200 t Cu 880 kg Au	Sediment Hosted	Eastern Fold Belt/ Eastern Fold Belt
Einasleigh Project (Jackson, Chloe, Railway Flat) - Ag values from Einasleigh and Kaiser Bill included	S		243 100 kg Ag 84 600 t Zn 39 200 t Pb	Broken Hill Type	Etheridge/ Etheridge
Eveleigh Zn Prospect	M		225 000 t Zn	Broken Hill Type?	Etheridge/ Etheridge
George Fisher (North and South)	G	Production included with that of Mount Isa Silver-Lead Mine	North: 12 108 010 t Zn 5 702 660 t Pb 9 066 840 kg Ag South: 4 851 433 t Zn 3 174 222 t Pb 6 244 938 kg Ag	Sediment Hosted	Western Fold Belt/ Western Fold Belt
Grevillea	M		Resource figures are confidential	Sediment Hosted	Western Fold Belt/ Western Fold Belt
King Vol	M	369 t Pb 0.3 t Cu 257 kg Ag	356 110 t Zn 89 541 kg Ag 17 050 t Pb 20 030 t Cu	Skarn	Kennedy/ Hodgkinson
Lady Loretta	L	20 496.4 t Zn 11939.9 t Pb 18 749.4 kg Ag	2 462 600 t Zn 877 400 t Pb 1 427 200 kg Ag	Sediment Hosted	Western Fold Belt/ Western Fold Belt

Table 7 (continued)

Name	Size	Total recorded production	Total contained metal in remaining resource	Principal mineralisation style	Host/ orebody province
Mount Carlton Project (Silver Hill and Mount Carlton)	M	124 267.2 kg Ag 2050 t Cu 1404.7 kg Au	416 250 kg Ag 36 290 t Cu 25 264 kg Au	Epithermal vein	Bowen Basin
Mount Garnet (Underground - pre 2003)	S	13 623.9 t Zn 29 500 kg Ag 12 798.9 t Cu	40 070 t Zn 11 144 kg Ag 2869 t Cu	Volcanic-Hosted Massive Sulphide	Thalanga/Thalanga
Mount Garnet Polymetallic Plant (production includes material from Balcooma and Dry River South and Mount Garnet Underground post 2003)	S	225 250 t Zn 34 565 t Pb 67 120 kg Ag 514.4 kg Au 26 165 t Cu	N/A	Volcanic-Hosted Massive Sulphide	Thalanga/Thalanga
Mount Isa Silver-Lead Mine includes production from George Fisher North and George Fisher South	G	19 498 376 kg Ag 9 184 446 t Zn 8 157 886 t Pb 9439 t Cu 5087 t Cd 2566 t Sb 328 t Co 839 594 t S (Pre 1996–1997 and post 2005 production do not record Cu, Cd, Sb, Co or S produced)	15 550 610 t Zn 13 008 280 t Pb 27 467 450 kg Ag	Sediment Hosted	Western Fold Belt/ Western Fold Belt
Mungana	M		4620 t Zn 44 t Pb 651 606 kg Ag 94 346 t Cu 34 376 kg Au	Base Metal Skarn	Hodgkinson/ Kennedy
Pegmont	M		306 713 t Pb 130 981 t Zn	Broken Hill Type	Eastern Fold Belt/ Eastern Fold Belt
Surveyor	S	61 326 kg Ag 33 554 t Pb 125 367 t Zn	16 611 kg Ag 11 456 t Pb	Volcanic-Hosted Massive Sulphide	Thalanga/Thalanga
Thalanga (Vomacka, Orient, West 45) (Production from Balcooma and Surveyor after 2005 excluded)	M	158 100 t Pb conc. 624 000 t Zn conc. 878 t Pb 1998 t Zn 1195.8 kg Ag	163 563 t Zn 125 837 kg Ag 53 540 t Pb	Volcanic-Hosted Massive Sulphide	Thalanga/Thalanga
Twin Hills (and Mount Gunyan)	M	32 219.4 kg Ag 18.5 kg Au	1 164 733 kg Ag 1008 kg Au	Epithermal Ag-Au	Texas/Texas
Walford Creek	M		136 500 t Zn 104 000 t Pb 162 500 kg Ag 39 000 t Cu 4550 t Co	Brecciated sediment-hosted	Western Fold Belt/ Western Fold Belt


Silver - lead - zinc
DIANNE
KING VOL
NIGHTFLOWER
MUNGANA
ISABEL
MOUNT GARNET
WALFORD CREEK
RED DAM
EVELEIGH ZINC PROSPECT
INTERNATIONAL
KAISER BILL
CHLOE
BALCOOMA
CENTURY
KIDSTON
GREVILLEA
MOUNT MOSS
MOUNT OXIDE
LADY LORETTA
SOAPSPAR
COPPER KNOB
DUGALD RIVER
GRANITE CASTLE
MOUNT CARLTON
GEORGE FISHER/HILTON
THALANGA
MESOZOIC BASINS
MOUNT ISA
LIONTOWN
PAJINGO
ALTIA, ELOISE
WIRRALIE
SILVER PHANTOM
TALLY HO
MARAMUNGEE
PEGMONT
CANNINGTON
TWIN HILLS (309)
SULPHIDE CITY
MOUNT CHALMERS
MOUNT MORGAN
MOUNT KROOMBIT
SILVER STAR
MOUNT CANNINDAH
CRACOW
MOUNT PERRY
COPPER MINE
BAN BAN ZINC LODE
ANDURAMBA
FINNEY'S PB-AG MINE
SILVER SPUR

1) Sediment-hosted Ag–Pb–Zn

The majority of major silver–lead–zinc resources within Queensland are in the Mount Isa Province and are of the sediment-hosted Ag–Pb–Zn mineralisation style. Significant examples include the world-class Black Star and Isa open cut (Mount Isa), Century, George Fisher North and George Fisher South (Hilton) orebodies, advanced prospects such as Lady Loretta and Dugald River, and prospects such as Grevillea and Walford Creek. Century is the world's second-largest zinc mine, producing about 5% of the world's zinc.

Generally, sediment-hosted Ag–Pb–Zn mineralisation comprises stratiform to stratabound basinal accumulations of sulphide and sulphate minerals interbedded with euxinic marine sediments. Sulphides commonly form banded sheet or lens-like tabular orebodies up to a few tens of metres thick. Deposits are typically hosted by the fine-grained sediments of the Western Fold Belt Province and occur within at least four different stratigraphic levels. Mineralisation at Dugald River is an important exception, being hosted by carbonaceous shales of the Eastern Fold Belt Province.

Mining at the Glencore Plc deposit Black Star started in 2004 with a mine life expected to 2016. Growth options at feasibility stage in the vicinity of the Black Star open cut are extensions to the south, Black Star South, Black Rock and Rio Grande open cuts (Photograph 72). The Mount Isa zinc–lead concentrator has been expanded to 8 Mtpa throughput and the company's intension is to ensure full use of the concentrator from its various mines (Photograph 73). The lead–zinc ore is treated to produce a zinc concentrate and a lead concentrate, which is smelted to produce crude lead. The zinc concentrate is filtered and sold to zinc smelters in Townsville and around the world. The crude lead bullion is exported and refined at Glencore Zinc's refinery in the United Kingdom to produce high-quality lead, lead alloys and silver. Glencore have separated the Black Star open cut resource estimates from the Isa Open cut resource estimates. In December 2013 Glencore reported 23 Mt at 4.6% Zn, 3.1% Pb and 61 g/t Ag for Black Star (measured and indicated resource) and another 1.3 Mt at 5% Zn, 3% Pb and 60 g/t Ag (inferred resource). The Isa Open cut was estimated to 257 Mt at 3.6%Zn, 2.8%Pb and 60 g/t Ag (measured and indicated resource) and 170 Mt at 3% Zn, 2% Pb and 40 g/t Ag (inferred resource).

Photograph 72: Panorama view of the Black Star open cut with the Mount Isa mine infrastructure in the background (image courtesy DNRM).

Glencore Plc also mines lead and zinc ore from George Fisher North, George Fisher South (Hilton) and Handlebar Hill (Photographs 74 and 75). From June 2013, the annual production rate of 3.5 Mtpa has been gradually expanded and was expected to reach 4.5 Mtpa in 2014. This expansion project involved the development of a second hoisting shaft. Resources for these deposits were reported by Glencore in December 2013: George Fisher North has a measured and indicated resource of 88 Mt at 8.6% Zn, 3.9% Pb and 64 g/t Ag and an inferred resource of 57 Mt at 8% Zn, 4% Pb and 60 g/t Ag. George Fisher South (Hilton) has a measured and indicated resource of 39 Mt at 8.2% Zn, 5.5% Pb and 110 g/t Ag and an inferred resource of 17 Mt at 7% Zn, 5% Pb and 100 g/t Ag (Photographs 76 and 77). Handlebar Hill (open cut primary) has a measured and indicated resource of 6.5 Mt at 6.3% Zn, 2.0% Pb and 34 g/t Ag and an inferred resource of 1.2 Mt at 5% Zn, 2% Pb and 20 g/t Ag. Handlebar Hill (open cut oxide) has a measured and indicated resource of 0.6 Mt at 0.4% Zn, 7.7% Pb and 84 g/t Ag.

The Lady Loretta deposit is 115 km northwest of Mount Isa. The underground mine is held and operated by Glencore Plc, following the buyout in February 2011 of interest by Cape Lambert Lady Loretta Pty Ltd. Because the ore is similar to the George Fisher ore in its genesis and metallurgical properties, it is planned to treat this ore through the Pb–Zn Mount Isa process plant. First ore production at Lady Loretta commenced in September 2012 and full-scale commercial mining will begin in 2013. In 2014 Glencore estimated the measured and indicated resource for Lady Loretta at 13 Mt at 16% Zn, 5.7% Pb and 98 g/t Ag and an inferred resource of 1.5 Mt at 13% Zn, 5% Pb and 90 g/t Ag. A 10 to 11 year mine life is anticipated and a maximum depth of 510 m will then be reached.

Photograph 73: Aerial view of the Mount Isa mine, showing the copper and lead zinc smelter operations (image courtesy DNRM).

Photograph 74: Headframe of George Fischer Mine.

Photograph 75: Underground entry to the George Fischer Mine with access to the North and South deposits.

Photograph 76: Folded sphalerite and galena bands in metasediments in the George Fischer underground mine.

Photograph 77: Banded sphalerite and galena mineralisation in metasediments from George Fischer mine.

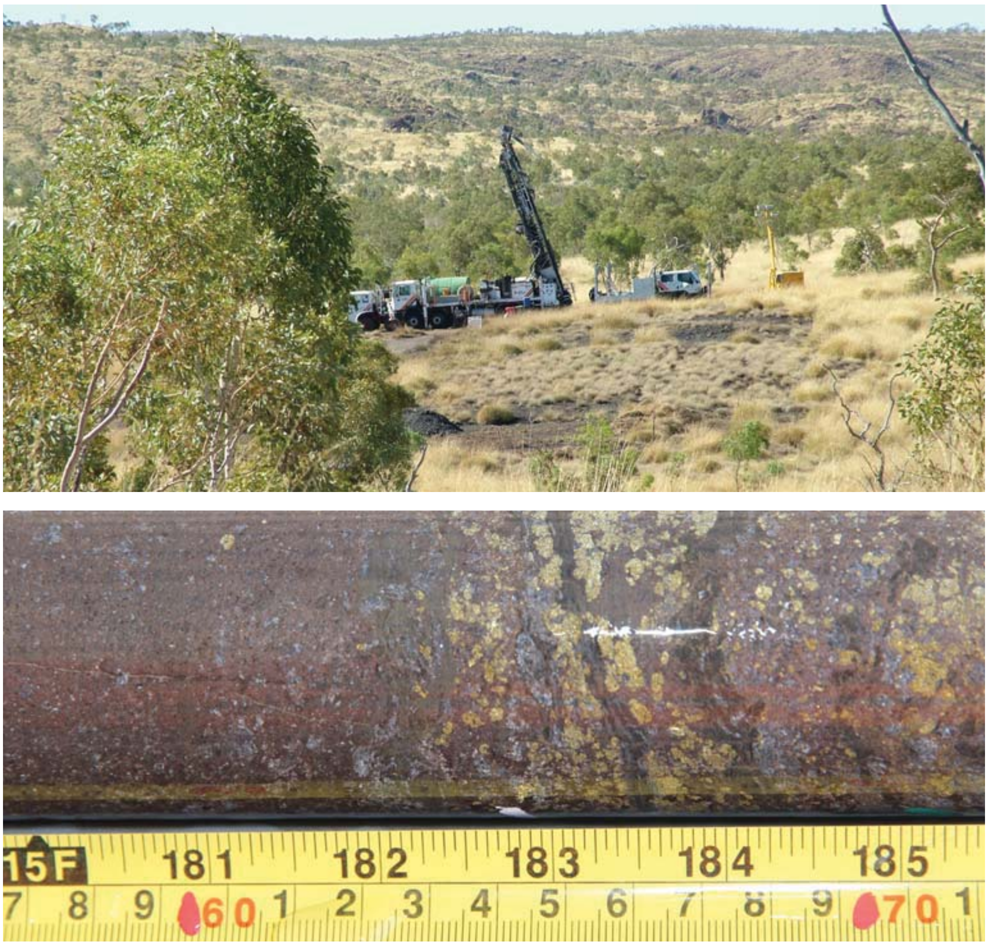
Photograph 78: Aerial photograph of the Century operations (image courtesy DNRM, 2005).

Photograph 79: Century zinc-lead-silver plant operations (Queensland Mineral and Petroleum Review, 2001).

The Century zinc-lead-silver open cut mine, 250 km north-northwest of Mount Isa, is held and operated by MMG Limited (Photograph 78). Zinc and lead concentrate production started in late 1999 and last production is expected in 2016. The current mining rate is over 5 Mtpa of ore. In 2014 MMG Limited reported combined resources (indicated and inferred) for Century open cut as 8.4 Mt at 9.3% Zn, 1.7% Pb and 41 g/t Ag. The measured resources were moved to the stockpiles and are estimated at 1.1 Mt at 5.7% Zn, 2.3% Pb and 51g/t Ag. An additional 0.5 Mt of indicated and inferred resources at 11.6% Zn, 1.1% Pb and 48 g/t Ag were estimated from Century Eastern Fault Block. Another inferred resource at Silver King was estimated at 2.7 Mt at 6.9% Zn, 12.5% Pb and 121 g/t Ag. Recoveries in the zinc concentrate are 71% zinc and 57% silver and recoveries in the lead concentrate are 63% lead and 8.5% silver. Century's ore (Photograph 79) is concentrated on site and then pumped along a 304 km underground slurry pipeline to a port facility at Karumba, on the Gulf of Carpentaria, where it is dewatered before shipment to smelters overseas.
The Century mine is currently in a transition period as it prepares for the end of open cut zinc production in the third quarter of 2015. Rehabilitation planning has already commenced, and MMG's intention is to return the lease to its pre-mining use as an

Photograph 80: *Dugald River underground development portal (image courtesy of MMG Ltd).*

Photograph 81: (top) Exploration drilling at Dugald River (image courtesy David Carmichael, DNRM); (bottom) high grade massive breccia and slaty breccia hosted zinc-lead-silver mineralisation from Dugald River (image courtesy of MMG Ltd).



area suitable for light cattle grazing. MMG also continues to examine growth options to utilise Century's extensive infrastructure within a 50 km of the Century mine site and will keep the plants in a state of operational readiness for several years after the end of production. A scoping study to recover zinc from the tailings is nearing completion with a pre-feasibility study and definitive feasibility study the next steps. It is understood that a tailings recovery operation could potentially prolong the life of the operation by a further 15 to 20 years with first production in 2019. The cost of power will be critical as the process is energy intensive and will be at least double the current 45 megawatts of power used. One possible option is improved availability of gas from the Northern Territory.

The Dugald River zinc-lead-silver project, 65 km northwest of Cloncurry, is one of the world's largest undeveloped zinc deposits. The owner, MMG Limited, is developing an underground mine (Photograph 80) accessed by two declines (North and South) to produce about 2 Mt per year of Zn, Pb and Ag, but also including some minor Cu (Photograph 81). The combined resource for Dugald River Primary Zinc is estimated at 55.2 Mt at 13.4% Zn, 2.1% Pb and 36 g/t Ag with a inferred copper resource (Dugald River

Primary Copper) of 4.4 Mt at 1.8% Cu and 0.2 g/t Au (June 2014). Because of complexities in the Dugald River ore body extensive trial stoping and geotechnical analysis has been carried out since March 2014, to determine the optimal mining method including stope design and productivity assumptions. As at the third quarter 2014, a total of 13 out of 22 trial stopes had been successfully mined and backfilled. Stope spans between 15m and 30m have proven stable for the geotechnical conditions encountered, and a geological and geotechnical program is now underway to review the findings in relation to the entire ore body. Mine life of more than 20 years is envisaged. The ore body remains open at depth. Processing Dugald River ore using existing infrastructure at Century mine remains a future option for the project. Another option is to transport zinc and lead concentrate by road to Cloncurry and re-arrange to use the rail load-out facility at Cloncurry.

Red Metals Limited hold an advanced exploration project at Maronan, 120 km north of the Cannington mine. The earlier bedded silver-lead mineralisation is of a similar style to Cannington and is overprinted by a structurally controlled copper-gold mineralisation.

The Walford Creek prospect, about 300 km north-northwest of Mount Isa and 135 km west of Burketown, was originally owned by Aston Copper Pty Limited. Aeon Metals acquired Walford Creek in April 2014. Subsequently the company has actively explored the area with a view to increasing the current total resource of 48.3 Mt at 0.39% copper 0.83% lead 0.88% zinc 20.4g/t silver and 731ppm cobalt. Walford Creek East, owned by Red Metal Limited has potential to form high grade part of deposit.

2) Broken Hill style

Broken Hill style Ag–Pb–Zn mineralisation occurs as sheet-like, tabular orebodies of stratabound to stratiform lead and zinc sulphide minerals in iron- and manganese-rich volcano-sedimentary rocks that are locally highly deformed, commonly within high-grade metamorphic rocks (Photographs 82 and 83). Cannington and Pegmont are the major examples of Broken Hill style mineralisation in Queensland. Cannington is the world's largest-tonnage and lowest-cost single mine producer of silver and lead. It comprises two underground mines (north and south Cannington). It produces about 6% of the world's silver in form of a silver-rich lead concentrate and a zinc concentrate, which are largely hauled to a rail-loading facility at Yurbi near Cloncurry, and railed to the Port of Townsville for export. Cannington and Pegmont both occur within strongly deformed and metamorphosed rocks of the Eastern Fold Belt Province of the Mount Isa Province. Mineralisation at Cannington is hosted by a garnetiferous psammite sequence within a migmatitic quartzo-feldspathic gneiss terrain. Underground mining at Cannington started in 1997 from the deeper and higher-grade Southern Zone, and capacity has been increased in several phases from its original design throughput of 1.5 Mtpa to currently 3.4 Mtpa. As of July 2014, Cannington had a reserve life of 9 years, although Cannington is was scheduled to cease operations in 2020. Mine life is extended by means of an open cut mine over the shallower northern underground operations. BHP Billiton Minerals Limited estimated at 30 June 2014 proved ore reserves at the underground mine of 18 Mt, at 239 g/t Ag, 6.38% Pb, 3.72% Zn and probable ore reserves of 2.7 Mt, at 240 g/t Ag, 6.15% Pb, 4.01% Zn. The total resource as at 30 June 2014 is 60 Mt, at 5.57% Pb, 3.5% Zn and 197 g/t Ag as underground accessible sulphide mineralisation and 16 Mt at 3.01% Pb, 2.06% Zn and 70 g/t Ag as open cut accessible sulphide mineralisation. BHP Billiton (BHP) has a current business strategy of spinning off around $US14 billion in unwanted assets, including the Cannington mine, to another corporate entity to be named South32.

The nearby Pegmont mineralisation is a stratabound, banded, graphitic magnetite–quartz–fayalite lode associated with galena–sphalerite–gahnite zones, comparable to mineralisation at Cannington (Photograph 84). The resources at Pegmont have not been upgraded since 2000 and the Pegmont Mines Limited website (2012) quotes them as current. In 2011 the resources for Pegmont were revised to include indicated and inferred resources estimated at a combined 8.9 Mt at 3.4% Pb and 1.5% Zn. No updates were given in 2014.

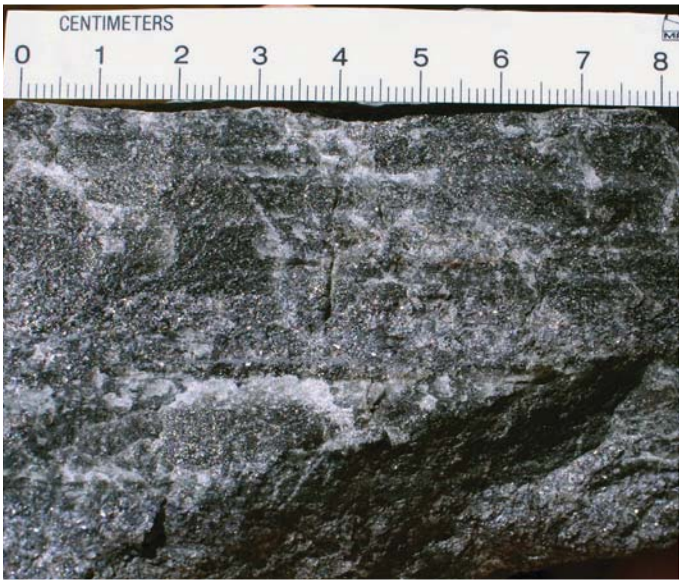
Breakaway Resources Ltd has discovered Broken Hill style mineralisation under cover at the Altia Prospect, north of Cannington. This prospect comprises two mineralised lenses with inferred resources of 5.78 Mt at 3.97% Pb, 0.49% Zn and 40.32 g/t Ag.

Several smaller deposits within the Etheridge Province of the Georgetown Inlier, including Jackson, Railway Flat, Stella and Chloe (Mount Misery) and the Eveleigh Zinc Prospect, have similarities to Broken Hill style mineralisation. These smaller deposits are stratabound concentrations of iron and base metal sulphides, commonly associated with epidote- to diopside-bearing quartzite, quartzofeldspathic granofels and gneiss of the Einasleigh Metamorphics.

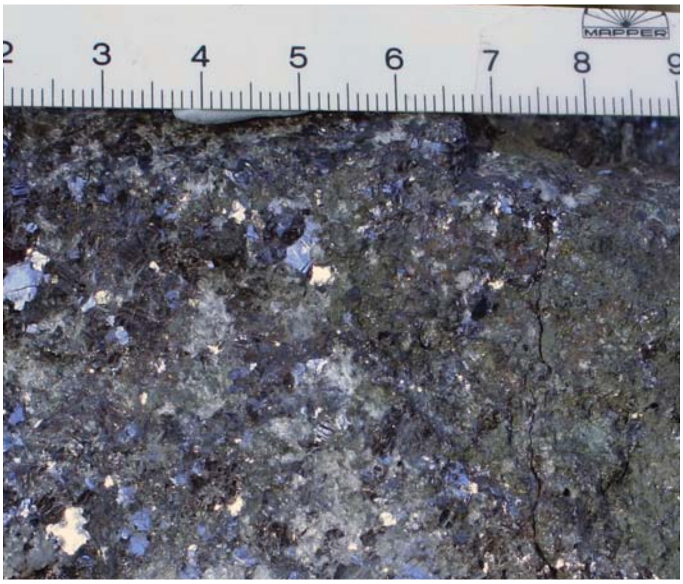
The Einasleigh and Kaiser Bill copper deposits and the Jackson, Chloe and Railway Flat zinc–lead–silver deposits are part of the Einasleigh project. The Einasleigh project, about 70 km southeast of Georgetown, was acquired by Kagara Mining from the previous holder, Copper Strike Limited in late 2011 with the intention of forming part of the company's future mining plans. The project was sold to Snow Peak Mining in early 2013. The Jackson, Stella and Chloe deposits have a combined indicated resource of 3.3 Mt at 0.2% Cu, 52 g/t Ag, 4.7% Zn and 2.1% Pb and an inferred resource of 1.3 Mt at 0.2% Cu, 51 g/t Ag, 5.3% Zn and 1.8% Pb. These resources could be developed as open cuts.

3) Volcanic-hosted massive sulphide (VHMS)

Volcanic-hosted massive sulphide Ag–Pb–Zn deposits in Queensland occur predominantly within early Paleozoic rocks of the Thalanga Province and Greenvale Province in north Queensland. Two significant VHMS Ag–Pb–Zn deposits have been defined, namely Thalanga and Balcooma. Both deposits are zinc rich and of medium size, with significant associated copper and minor gold mineralisation. Smaller examples occur elsewhere in north Queensland.



Photograph 82: Stratiform lead and zinc mineralisation from Cannington underground mine.



Photograph 83: Lead (galena) mineralisation from Cannington underground mine.

Photograph 84: Manganese (zinc) gossan at Pegmont.

The Thalanga deposit, previously held by Kagara Mining, occurs within Late Cambrian to early Ordovician rocks of the Seventy Mile Range Group in the Charters Towers area. Thalanga has a tabular, blanket-type geometry, with rhyolitic volcanic rocks in the footwall and dacite and andesite in the hanging wall. The main deposit was interpreted as zinc and silver-dominant volcanogenic massive sulphide mineralisation. In October 2014 Red River Resources Limited acquired the operations including the plant site (Photograph 85), Vomacka (Photograph 86), Orient, Liontown, Waterloo, West 45 (Photograph 87) and Thalanga Far West from Kagara Mining (in liquidation). The West 45 deposit is about 2 km from the Thalanga mill and has a resource estimate of 591 000 t at 8.3% Zn, 3.5% Pb, 0.6% Cu, 69 g/t Ag and 0.3 g/t Au, with 99% of the resource in the indicated category. In January 2015 Red River Resources announced a new maiden resource for Thalanga Far West with a combined (measured, indicated and inferred) resource of 1.158 Mt @ 1.7% Cu, 1.9% Pb, 5.8% Zn, 0.2 g/t Au and 49 g/t Ag at a >5% Zn equivalent cut-off. In relation to Thalanga, there is the potential for mining to be systematically carried out at the Orient, Waterloo and Liontown polymetallic deposits. The resource estimate for the Orient deposit is 540 000 t at 7.9% Zn, 1.8% Pb, 0.9% Cu, 44 g/t Ag and 0.19 g/t Au with about 90% in the indicated category and the remainder inferred. The indicated and inferred transitional and fresh polymetallic resources at Waterloo are 707 000 t at 11.0% Zn, 0.8% Cu, 1.6% Pb, 0.4 g/t Au and 24 g/t Ag. Liontown has resources of 1.845 Mt at 7.5% Zn, 2.4% Pb, 0.6% Cu, 28 g/t Ag and 0.55 g/t Au. Red River Resources Limited acquired the Thalanga operation at the end of October 2014 and has set a target of restarting production at the end of 2015. Production will commence with West 45 where about nine months of drive development was carried out and about 3000 t of ore was treated before work was suspended in March 2012. The company will conduct detailed studies to determine the order of further production centers and is reviewing the JORC 2004 resources. As announced in their latest release in January 2015 a revised announcement of a resource for West 45 is pending.

The Balcooma deposit is held by Kagara Mining (including the satellite deposits of Dry River South and Surveyor One). It is in the eastern part of the Georgetown Inlier, and is hosted by metapelite lenses within a meta-arenite sequence of the Balcooma Metavolcanic Group (Photograph 88). The unit consists of bimodal but predominantly felsic volcaniclastic rocks and lavas. Mineralisation is thought to be about the same age as the deposits in the Seventy Mile Range Group. During 2005–06 the Dry River South underground zinc, lead and silver mine was developed and Kagara Mining commenced an open cut mine at the nearby

Photograph 85: Thalanga processing plant viewed from the ROM pad near the primary crusher.

Photograph 86: Vomacka open cut.

Photograph 87: The West 45 underground portal.

Photograph 88: Early exploration drilling in the Balcooma area, around 2003 (image courtesy Simon Crouch, GSQ).

copper-dominant Balcooma deposit. Since then, copper was the most important commodity for the company and in late 2008 the Dry River South and the polymetallic Balcooma underground mines were suspended. At 5 September 2012, the remaining dominantly inferred resources at Dry River South are 730 000 t at 6.9% Zn, 2.5% Pb, 0.9% Cu, 0.6 g/t Au and 62 g/t Ag. There is a further indicated oxide resource at New Surveyor East of 179 000 t at 6.4% Pb 0.1% Cu, 1.2 g/t Au and 93 g/t Ag. The transition to production from an underground copper mine at Balcooma was made in September 2009. From December 2006 most of the copper ore from Balcooma was trucked some 300 km for treatment to a second mill at Thalanga, 60 km southwest of Charters Towers. Ore from the zinc operations was treated at the Mount Garnet mill, and from late 2009, Balcooma copper ore had also been treated at the Mount Garnet copper plant following an upgrade of capacity. Zinc concentrates were trucked from Mount Garnet to the Sun Metals Zinc Refinery in Townsville for refining, and copper and lead concentrates were exported. The Kagara Mining operations at Thalanga and Balcooma were placed on care and maintenance and their exploration activities were largely curtailed to the end of 2012.

4) Zn skarn

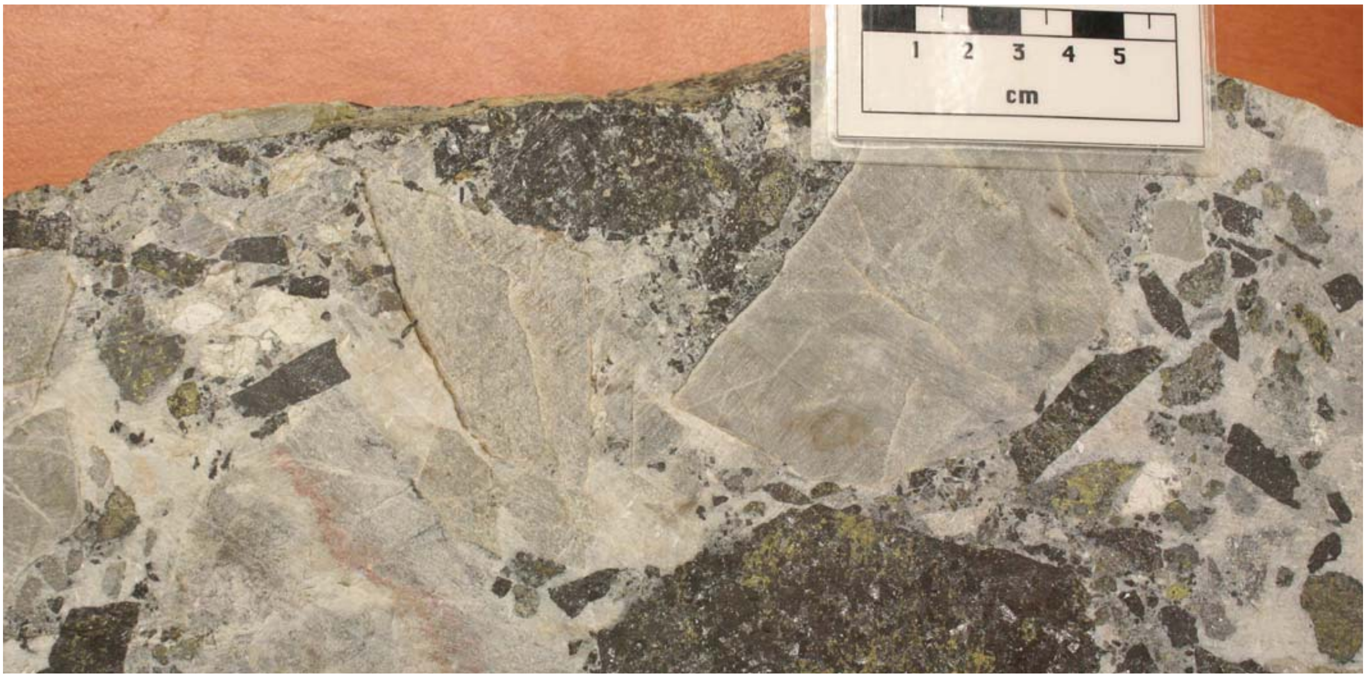
Significant skarn style zinc mineralisation occurs at Mount Garnet in north Queensland. Resources consist of magmatitic ore associated with calcitic garnet hornfels in the Chillagoe Formation of the Hodgkinson Province. Mineralisation is thought to be associated with late Carboniferous igneous activity of the Kennedy Province. Numerous smaller skarn deposits were mined in this region during the early part of the 20th century.

Kagara Mining commenced Ag–Pb–Zn mining at Mount Garnet, and at the Surveyor mines 125 km south-southwest of Mount Garnet, in 2003 and subsequently underpinned development by successful exploration, and more recently by the acquisition of properties near production centres. Underground mining at Mount Garnet commenced in February 2009 and the mine was placed on care-and-maintenance in late 2011 (Photograph 89). Kagara appointed voluntary administrators in April 2012 following operational difficulties. At 5 September 2012, the remaining measured resources at Mount Garnet are 100 000 t at 10.1% Zn, 0.6% Cu, and 22 g/t Ag. There is a further dominantly indicated resource at Mount Garnet of 568 000 t at 5.3% Pb, 0.4% Cu and 16 g/t Ag. Snow Peak Mining, a major shareholder of Consolidated Tin Mines Limited specific purpose was to gain access to the Kagara Mt Garnet plant for future use in the companies tin projects. In early 2013 Snow Peak purchased the assets centered on Mount Garnet. Snow Peak under Consolidated Tin Mines management recommenced processing of the copper ore and polymetallic ore at the Mount Garnet plant in March 2014. Currently the production rate is about 10 000 tonnes per week. During the September 2014 quarter, 33,000 t were also extracted from crown pillars at the Mount Garnet mine. Consolidated Tin has signed an asset sale agreement for the Mount Garnet mining and processing operations and mining tenements in October 2014.

Photograph 89: Mount Garnet open cut operations, around 2009 (image courtesy Simon Crouch, GSQ).

The Mungana deposit is hosted within the Chillagoe Formation north of Chillagoe. The Mungana orebody consists of high-grade zinc-rich polymetallic skarn-related mineralisation (Photograph 90), which appears to be overprinted by low-grade gold ore related to gold veining in a porphyry system. Some of the gold ore that has been mined to access the base metal mineralisation has been stockpiled for future processing. The Mungana underground mine (Photograph 91), 15 km northwest of Chillagoe, commenced production in September 2008 and ceased in April 2012, when Kagara Mining appointed voluntary administrators. Construction of a concentrator at Mungana, designed to treat 650 000 t of polymetallic ore per year, commenced in May 2008 but was suspended in late 2008 because of the global financial crisis. As a result, the Mungana ore was trucked to Mount Garnet. At 5 September 2012 the indicated resource was 44 000 t at 10.5 g/t Zn, 0.1% Pb, 1.9% Cu, 0.9 g/t Au and 124 g/t Ag. The Griffiths Hill copper zone immediately east of the Red Dome open cut (Photograph 92) at Mungana was discovered in 2010. This deposit includes a small inferred zinc resource of 50 000 t at 6.9% Zn, 0.3% Cu and 12.0 g/t Ag. Plans for a decline from the Mungana underground mine are currently on hold. On the 4th of August 2014, Mungana Goldmines Limited completed the acquisition of Kagara's Chillagoe gold and zinc assets in North Queensland.

The King Vol ore body is another skarn deposit hosted within the Chillagoe Formation north of Chillagoe and the Munguna deposit. This deposit also comprises high-grade zinc-rich polymetallic skarn-related mineralisation. Kagara Mining had scheduled production from the King Vol deposit, 23 km northwest of Mungana. Kagara Mining had completed extension and in-fill drilling at King Vol (Photograph 93). The current resource includes a probable reserve of 1.3 Mt at 11.2% Zn, 0.7% Cu and an inferred resource



Photograph 90: Skarn breccia with zinc-rich polymetallic mineralisation from Mungana mine.

Photograph 91: Drilling the underground zinc ore body at Mungana mine.

Photograph 92: Portal of Mungana underground zinc mine.

Photograph 93: Silicified breccia with minor sulphides from King Vol drilling.

of 2.0 Mt at 14% Zn and 0.8% Cu. No further work was carried out on this deposit since Kagara Mining went into liquidation. Mungana Goldmines Limited acquired this deposit from Kagara in August 2014. In January 2015 Mungana Goldmines reported that King Vol has a combined (indicated and inferred) resource of 2.99 Mt at 11.9% Zn, 0.6% Pb, 0.8% Cu and 29.9 g/t Ag.

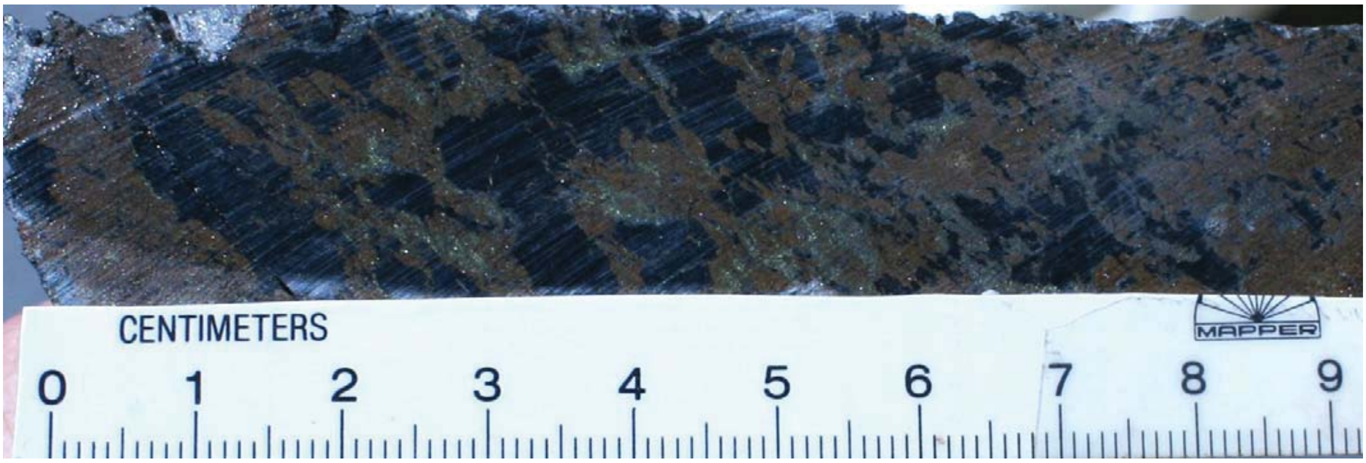
A high grade skarn-associated zinc dominant copper mineralised zone has been discovered at the Redcap project 5 km northeast of Mungana, which comprises the Victoria, Queenslander and Morrisons lodes and numerous prospects. Victoria contains an inferred resource of 3.44 Mt at 5.1% Zn, 1% Cu, 0.1 g/t Au and 22 g/t Ag and includes a higher grade inferred resource of 948 000 t at 7.3% Zn, 1.6% Cu and 30 g/t Ag. Morrisons contains an inferred resource of 1.93 Mt at 5.4% Zn, 0.6% Cu, 0.3% Pb, 21 g/t Ag and 0.1 g/t Au and Queenslander contains an inferred resource of 1.57 Mt at 4.4% Zn, 0.5% Cu, 0.2% Pb and 12 g/t Ag. In addition, the Montevideo deposit contains an inferred resource of 718 4 Mt at 7.7% zinc, 0.2% lead and 7.2 g/t silver and the Penzance deposit an inferred resource of 312 000 t at 2.6% zinc, 0.1% lead, 2.5% copper, 0.2 g/t gold and 48 g/t silver. All these depsits are held by Mungana Goldmines Limited since August 2014.

A small zinc skarn occurs in the Gympie Province at Ban Ban in southeast Queensland.

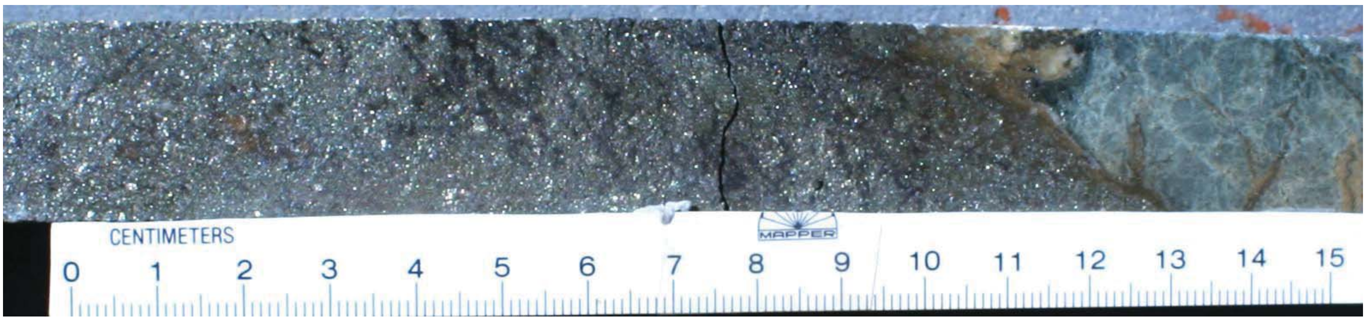
5) Epithermal Ag-Au

The Twin Hills silver deposit, 200 km southwest of Brisbane and 8 km east-southeast of Texas, comprises low sulphidation epithermal style mineralisation with similarities to the major silver mining districts in southwestern USA and Mexico. Silver mineralisation occurs as pyrargyrite and native silver hosted by fine-grained volcaniclastic rocks of the Texas Province that have been affected by intense silicification and K-metasomatism (Photograph 94). Macmin Silver Limited commenced open cut mining in early 2007 but appointed voluntary administrators in November 2008 largely because of operational problems. Silver recovery was by heap leach methods and electrowinning to produce silver powder. Alcyone Resources Limited commenced silver production at Twin Hills using a Merill Crowe silver recovery circuit in July 2011. In June 2013, Alcyone reported a proven and probable ore reserve totalling 4.66 Mt at 56 g/t Ag at Twin Hills, which is expected to underpin a mine life of about 5 years. The total mineral resource, which includes the ore reserve, is 8.365 Mt at 51.7 g/t Ag. The Mount Gunyan deposit, which is 4 km northeast of Twin Hills, has a measured, indicated and inferred resource of 3.94 Mt at 55 g/t Ag. Positive results from an initial scoping study at Mount Gunyan have indicated that 2.405 Mt of ore grading 56.6 g/t Ag is available for ore feed, thus extending the mine life beyond 7 years. There is also potential for massive sulphide mineralisation at depth in Mount Gunyan. Alcyone have other base metal targets like the Hornet prospect with identified copper mineralisation (Photograph 95). In March 2014 Alcyone Resources Ltd placed the Twin Hills mine in care and maintenance and administrators were appointed in November 2014.

Conquest Mining Ltd has discovered significant high sulphidation epithermal silver mineralisation at the Silver Hill, 45 km northwest of Collinsville in northern central Queensland in 2006. In 2012 Evolution Mining Limited acquired the Mount Carlton



Photograph 94: Silver mineralisation from Silver Spur.



Photograph 95: Massive copper mineralisation from Hornet.

Photograph 96: Banded open space fill alunite-sphalerite-pyrite-enargite veins from V2, within the Mount Carlton Project.

Photograph 97: Banded to colliform acanthite (silver sulphide) and stromeyerite (silver copper sulphide) in quartz-kaolin-dickite altered epiclastic to volcaniclastic sediments from A39, within the Mount Carlton Project

silver gold project (Silver Hill deposit), near Collinsville. The deposit comprises silver, gold and some copper, primarily as copper arsenic sulphides, silver arsenic sulphides and some native gold (within pyrite), that occurs exclusively in rhyodacitic volcanics (within the Lizzie Creek Volcanics). The Mount Carlton project comprises two discrete zones: the large gold dominant V2 deposit (Photograph 96) and the smaller, silver rich A39 deposit (Photograph 97). The V2 deposit is flat-lying and 20–180 metres below surface, and is 70 m thick with a 500 m by 500 metre areal extent (Photograph 98). A39 is a fault controlled silver dominant breccia mineralisation (including baryte). The two deposits are 200 m apart. At December 2013 probable open cut reserves at A39 using a cut-off grade of 53 g/t Ag were 410 000 t at 295 g/t Ag and 0.31% Cu and indicated resources were 55 000 t at 260 g/t Ag and 60 000 t at 0.26% Cu with 260 000 t at 72 g/t Ag in the stockpiles. Probable open cut reserves at V2 using a cut-off grade of 0.35 g/t gold were 7.11 Mt at 3.0 g/t Au, 22 g/t Ag and 0.28% Cu and proved resources in the stockpiles, 190 000 t at 1.6 g/t Au, 19 g/t Ag, 0.16% Cu. In addition to the stockpiles, the indicated open cut resources at V2 which include the reserves are 10.4 Mt at 2.4 g/t


Photograph 98: (left) Specimen from discovery outcrop of A39; (right) A39 open cut, Mount Carlton Project (image courtesy V. Lisitsin, GSQ).

Au, 23 g/t Ag and 0.27% Cu and the inferred underground resource at V2 770 000 t at 4.7 g/t Au, 15 ppm Ag and 0.33% Cu, using an 2.5 g/t Au cut-off grade. The first concentrate from the A39 deposit was produced from the 800 000 tpa plant in March 2013 and commercial mining commenced in July 2013. The A39 open cut is nearing completion and some deposit extensions may be developed via underground access. At full production the annual gold production is expected to be around 55,000 ounces and the initial mine life for Mount Carlton is 12 years. Gold-silver-copper concentrate from V2 and silver-copper concentrate from A39 is exported to smelter customers in China via Townsville. Metallurgical recoveries are dependant on ore-type material properties and grade. The current and estimated future recoveries at V2 are 89% for gold 91% for silver and 91% for copper and at A39, 88% for silver and 92% for copper. Previous reported Zn resources have been omitted by the mining company due to metallurgical recovery problems.

Gallium

No official production figures for gallium are recorded in Queensland. As gallium is commonly found in association with zinc mineralisation and with bauxite, Queensland is likely to be a significant producer of this strategic metal. As gallium is not an element that is usually assayed for, its actual distribution is poorly known. Prior to 2000 gallium was mentioned as a by-product included in the zinc-concentrates exported by MIM Holdings from their Mount Isa operations, but this practice was discontinued following the purchase of MIM Holdings by Xstrata. Although gallium is commonly found in association with zinc mineralisation and bauxite it is not separated from either commodity prior to export.

Gallium is considered a 'critical' element as it is currently only produced globally as a by-product of processing zinc and bauxite ores. Production of the element is therefore 'at risk' because its supply is totally dependent on prices of these other commodities.

No gallium production is currently reported from refining operations in Australia. Gallium was produced around 1990 to 1997 at Pinjarra in Western Australia from the Bayer process stream at Alcoa's Pinjarra Alumina refinery. The Bayer process stream involves dissolving bauxite in caustic soda for the purpose of extracting aluminium. In this process gallium is also extracted from the bauxite and dissolved in the caustic soda stream as (a 15% solution of) gallium chloride.

Aside from the likely presence of gallium in the zinc bearing and bauxite deposits of Queensland, gallium is known to occur in conjunction with antimony in quartz veins at the Missant deposit near Irvinebank, where assays were reported to contain up to 5 ppm Ga. On this basis further potential exists for gallium mineralisation associated with other antimony(-gold) and tin deposits in the Hodgkinson Province of north Queensland.

Gold

Australia is the third largest gold producing nation in the world, with Queensland the third largest producer in Australia. Queensland's total gold resources and reserves stand at >1268 t. Since the early gold rushes of the late 19th century, total documented gold production in Queensland has been >7000 t. Queensland's significant current gold producers are Pajingo, Ernest Henry, Mount Rawdon, Cracow and Ravenswood. Queensland's gold production in 2011–12 (2012–13) totalled 25 206.5 kg (18 224 kg) gold bullion, with a metal content of 13 477 kg (10 620 kg) Au and 8087 kg (7 158 kg) Ag. Alluvial gold bullion recorded an additional 55.6 kg (44 kg) for the 2011–12 (2012–13) production (Photograph 99).

Gold mineralisation occurs in a diverse range of deposit styles and geological provinces in Queensland, ranging from the large, historically important, alluvial goldfields of north Queensland to the Proterozoic iron oxide–copper–gold deposits of the Mount Isa Province. The main gold mineralisation styles recognised in Queensland include: orogenic gold deposits, intrusion-related

Photograph 99: Casting gold bullion (Queensland Mineral and Petroleum Review, 2002).

gold deposits, epithermal deposits, iron oxide copper gold deposits, volcanic-hosted massive sulphide, skarns, shear hosted hydrothermal deposits and alluvial deposits (Table 8).

1) Orogenic gold deposits

Orogenic deposits are generally high-grade, gold-bearing quartz veins that formed from hydrothermal solutions at high temperatures (180–700°C) and at substantial depths (2–20 km). The important historical goldfields in Queensland characterised by orogenic quartz veins include the Hodgkinson, Palmer, Charters Towers, Croydon and Etheridge fields.

In the Hodgkinson and Palmer Goldfields, slate-belt gold-quartz veins are thought to have formed from metamorphic fluids produced during devolatilisation of the sediment pile. Fluids were channelled to dilational sites in fault/shear zones within metasediments of the Hodgkinson Formation (Hodgkinson Province). The Hodgkinson Basin project, held 100% by Territory Minerals Pty Ltd, comprises the Northcote district (24 km west of Mareeba), and also the wholly owned South Palmer goldfield (103 km west-northwest of Mareeba), as well as several smaller satellite deposits. The Anglo Saxon mine, discovered in 1886, was the most productive lode gold mine in the Palmer River area (Photograph 100). The ore occurs in shear zones with shallow (10 m) oxidation profile of sediment-hosted pyrite – arsenopyrite mineralisation containing very fine gold. Identified gold resources at Northcote and Tregoora and the smaller Atric and Reedy–Hurricane deposits, as at 30 June 2011, comprise a total of 11.4 Mt at 1.7 g/t Au. These are composed of measured resources 1.51 Mt at 2.2 g/t Au, indicated resources 5.59 Mt at 1.7 g/t Au, and inferred resources 4.31 Mt at 1.5 g/t Au. In addition, antimony mineralisation as stibnite at Northcote has been discussed earlier under the heading 'Antimony'.

Orogenic gold vein deposits also occur at Charters Towers. Mineralisation at Charters Towers is of Devonian age and is related to Pama Province intrusive activity (Photograph 101). Historically, Charters Towers is one of Australia's richest goldfields, having produced more than 187 107 kg of gold throughout the life of the field. Citigold Corporation Limited poured the first gold from its Imperial (Warrior) mine (Photograph 102) in November 2006 and produced 525.3 kg of Au and 381.4 kg of Ag. The Imperial mine area refers to the 25 square kilometres area that incorporates the Warrior mine as well as several other reefs, one of the current focuses being the Sons of Freedom reef. Citigold Corporation Limited are examining the potential for an open cut near the Imperial mine following several high-grade drill results. The area comprises highly fractured and disaggregated cross-cutting quartz veins and alteration zones. The inferred resource for the Southern area incorporating the Imperial deposit is 11 Mt at 14 g/t Au and 9 g/t Ag. The inferred resource for the Central area is 14 Mt at 14 g/t Au and 9 g/t Ag. The total probable ore reserves for the overall Charters Towers project are 800 000 t at 13 g/t Au at a 7 g/t Au cut-off. The probable ore reserve is derived from, and not additional to, the indicated mineral resource. Total indicated mineral resources for the Charters Towers project are 3.18 Mt at 7.6 g/t Au and 5.1 g/t Ag. Of about 80 major reefs in and around the city of Charters Towers, 22 are included to date in the Company's resource estimate with the defined resources generally starting at 100 m from surface to a vertical depth of 1200 m (Photograph 103). The main east–west reef systems are the Brilliant, the Day Dawn, the Mexican, the Queen and the Sunburst, extending over a strike

Gold

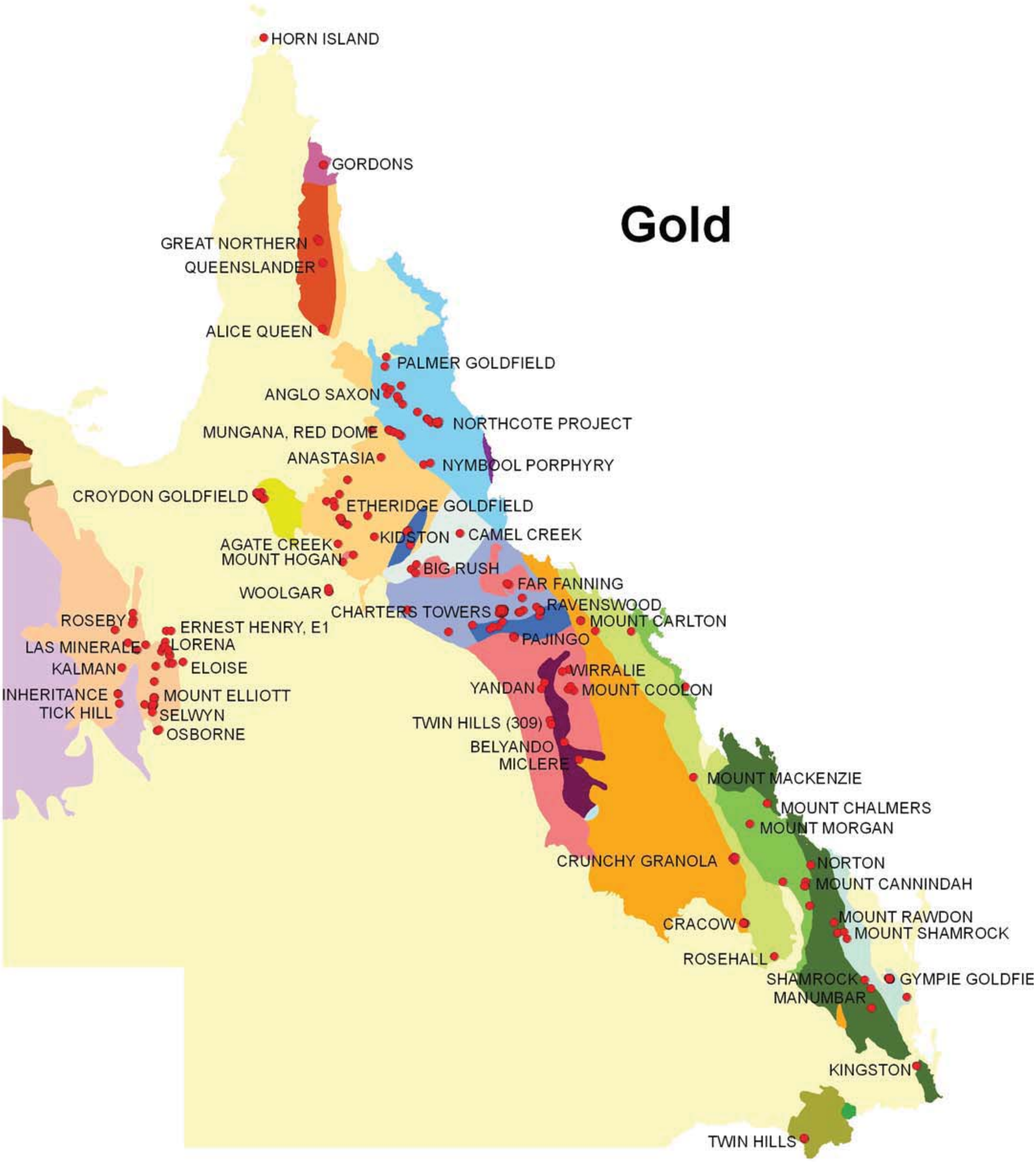

HORN ISLAND
GORDONS
GREAT NORTHERN
QUEENSLANDER
ALICE QUEEN
PALMER GOLDFIELD
ANGLO SAXON
NORTHCOTE PROJECT
MUNGANA, RED DOME
ANASTASIA
NYMBOOL PORPHYRY
CROYDON GOLDFIELD
ETHERIDGE GOLDFIELD
KIDSTON
CAMEL CREEK
AGATE CREEK
MOUNT HOGAN
BIG RUSH
WOOLGAR
FAR FANNING
RAVENSWOOD
CHARTERS TOWERS
MOUNT CARLTON
ROSEBY
ERNEST HENRY, E1
PAJINGO
LAS MINERALE
LORENA
KALMAN
ELOISE
WIRRALIE
YANDAN
MOUNT COOLON
INHERITANCE
MOUNT ELLIOTT
TICK HILL
SELWYN
OSBORNE
TWIN HILLS (309)
BELYANDO
MICLERE
MOUNT MACKENZIE
MOUNT CHALMERS
MOUNT MORGAN
CRUNCHY GRANOLA
NORTON
MOUNT CANNINDAH
MOUNT RAWDON
MOUNT SHAMROCK
CRACOW
ROSEHALL
SHAMROCK
GYMPIE GOLDFIE
MANUMBAR
KINGSTON
TWIN HILLS

Table 8. Major (medium-large-giant) gold deposits in Queensland

Name	Size	Total historical production	Total contained metal in remaining resource	Principal mineralisation style	Host/ore-body province (basin)
Twin Hills (309, Lone Sister)	M	266.9 kg Au 808.6 kg Ag	16 663 kg Au 4 938 kg Ag	Epithermal	Drummond/ Drummond
Agate Creek Epithermal Project	M		16 028 kg Au	Epithermal	Kennedy/ Kennedy
*Charters Towers Goldfield (includes the current CitiGold Corporation Ltd operations - Warrior)	G	29 488 kg Au bullion 105 544.9 kg Au 1925.45 kg Ag	334 408 kg Au 199 539 kg Ag	Mesothermal Magmatic Related Au	Macrossan & Pama/ Pama
Cracow Goldfield (includes Golden Plateau and Klondyke)	L	6151.2 kg Au bullion 44 329.9 kg Au 40 747.1 kg Ag	25 544 kg Au	Epithermal	Connors/ Connors
*Croydon Goldfield	L	› 59 640 kg Au bullion	Unknown	Mesothermal Magmatic Related Au	Croydon/ Croydon (?Kennedy)
E1 (Mount Margaret)	M		2542 kg Au 87 320 t Cu 3120 t U_3O_8	Structurally Controlled, Breccia Hosted Proterozoic Fe-Oxide Related Cu-Au	Eastern Fold Belt/ Eastern Fold Belt
Ernest Henry	L	51 586.9 kg Au bullion 1 348 006 t Cu	58 938 kg Au 1 122 520 t Cu 28 380 000 t magnetite	Structurally Controlled, Breccia Hosted Proterozoic Fe-Oxide Related Cu-Au	Eastern Fold Belt/ Eastern Fold Belt
*Etheridge Goldfield	M	›19 525 kg Au bullion 3 432 kg Au 5 538 kg Ag	Unknown	Mesothermal Magmatic Related Au & associated alluvials	Etheridge/ Pama
Georgetown – Forsayth Project (Electric Light, Red Dam, Jubilee Plunger Group)		107.54 kg Au bullion	5603.6 kg Au 10 509.3 kg Ag	endo- and exo-stockwork/breccia	Etheridge/ Pama
Gympie Goldfield	L	111 755.9 kg Au bullion 1315.8 kg Au 363.4 kg Ag 168.7 kg jewellery Au	3313 kg Au	Mesothermal Magmatic Related Au; alluvial	Gympie/ South-East Queensland Volcanic and Plutonic
*Hodgkinson and Palmer Goldfields		› 57 000 kg Au bullion	Unknown	Mesothermal Metamorphic Related Au (Slate Belt) & associated alluvials	Hodgkinson/ Hodgkinson
Horn Island	S	207 kg Au bullion 745 kg Au 867 kg Ag	4573 kg Au	Mesothermal Magmatic Related Au	Kennedy/ Kennedy
Kalman	M		8326 kg Au 41 910 t Mo 164 610 t Cu 110 000 kg rhenium	Structurally- controlled Proterozoic Cu–Au	Eastern Fold Belt/ Eastern Fold Belt
Kidston	L	1309 kg Au bullion 112 495 kg Au 60 887 kg Ag	Mined out	Porphyry Related Breccia	Kennedy/ Kennedy
Las Minerale	M		6 330 kg Au 313 800 t Cu 16 239 t Co 8 364 000 t magnetite	Structurally Controlled, Breccia Hosted Proterozoic Fe-Oxide Related Cu-Au	Eastern Fold Belt/ Eastern Fold Belt

Table 8 (continued)

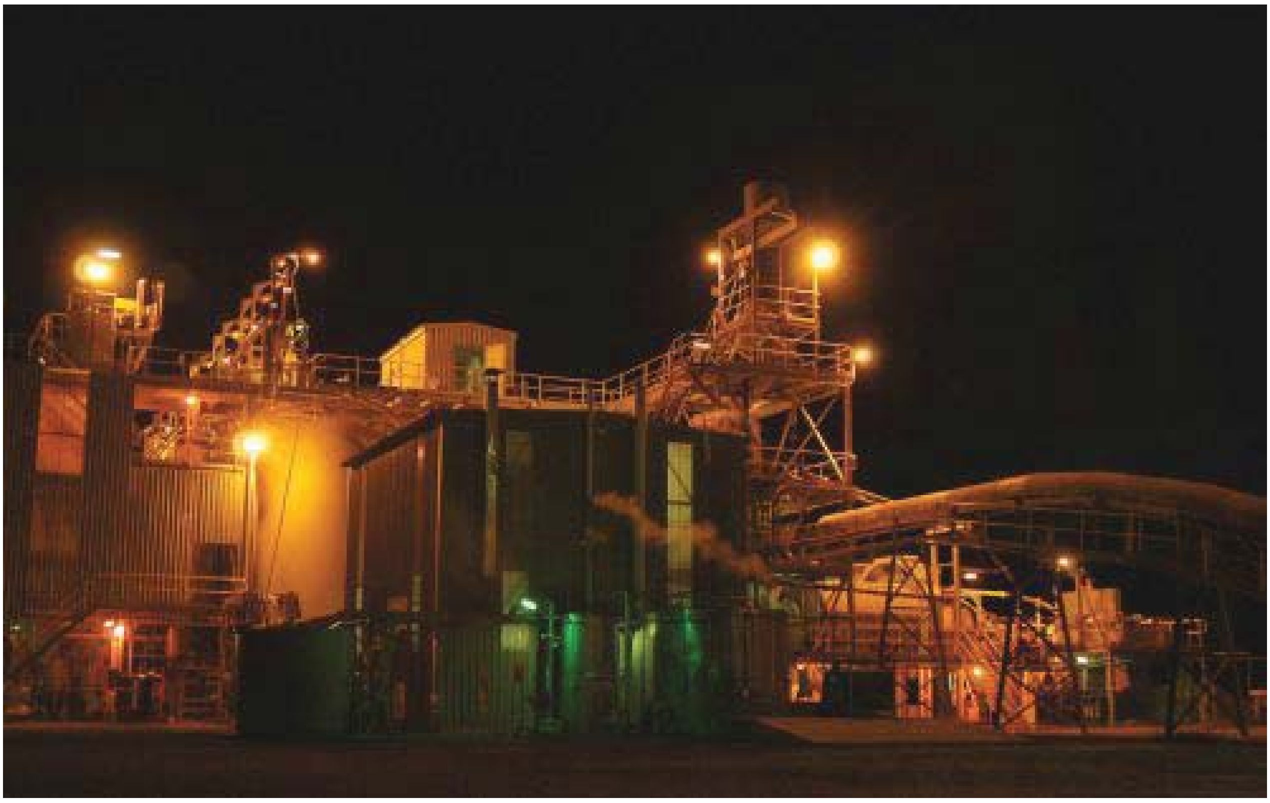
Name	Size	Total historical production	Total contained metal in remaining resource	Principal mineralisation style	Host/ore-body province (basin)
Lorena	S	245.36 kg Au bullion	1757 kg Au	Shear Zone hosted Skarn	Eastern Fold Belt/ Eastern Fold Belt
Miclere Diggings	M	›2500 kg Au (possibly nearer 3t Au)	8 470 kg Au	Deep Lead Placer? Qtz-Pebble Conglomerate Au?	Miclere/ Miclere
Mount Carlton Project (Silver Hill and Mount Carlton) including Herbert Creek East	M		29 584 kg Au 417 724 kg Ag 36 290 t Cu	Epithermal	Bowen Basin/Bowen Basin
Mount Coolon (including Police Creek)	M	7061 kg Au bullion 756 kg Ag	7513 kg Au	Epithermal	Drummond/ Drummond
Mount Elliott	M	6690 kg Au bullion 144 893 t Cu	146 400 kg Au 2 532 000 t Cu	Structurally Controlled Proterozoic Cu-Au (Fe-Oxide Related)	Eastern Fold Belt/ Eastern Fold Belt
Mount Leyshon	L	107 670 kg Au 68 900 kg Ag	Mined out	Porphyry Related Breccia	Kennedy/ Kennedy
Mount Morgan	G	294 056 kg Au 360 616 t Cu 36 842 kg Ag 568 000 t pyrite	16 875 kg Au 20 400 t Cu	Volcanic-Hosted Massive Sulphide?	Yarrol/Yarrol
Mount Rawdon	L	38 943.9 kg Au 66 840.2 kg Ag 8.01 kg Au bullion	39 920 kg Au	Intrusive Related Au	South-East Queensland Volcanic and Plutonic/ South-East Queensland Volcanic and Plutonic
Mount Wright	M	1 545 kg Au bullion 10 225.9 kg Au 3 349.3 kg Ag 1.1t Cu	13 493 kg Au	Porphyry Related Breccia	Macrossan/ Kennedy
Mungana	M		34 376 kg Au 651 606 kg Ag 4620 t Zn 44 t Pb 94 346 t Cu	Porphyry Cu-Au	Hodgkinson/ Kennedy
Northcote Project (East Leadingham, Emily, Emily South, Ethel, Belfast Hill, Black Bess, Pinnacle Creek, Tunnel Hill)	M	411.21 kg Au 79.1 t Sb	8728 kg Au 9462 t Sb	Mesothermal Metamorphic Related Au (Slate Belt)	Hodgkinson/ Hodgkinson
Osborne and Kuthor	L	6540.7 kg Au 13055.8 kg Au bullion 578 481 t Cu	16 820 kg Au 251 500 t Cu 5 442 500 t magnetite	Structurally Controlled Proterozoic Cu-Au (Fe-Oxide Related)	Eastern Fold Belt/ Eastern Fold Belt
Pajingo (Vera-Nancy, Cindy, Scott Lode)	L	83 732.5 kg Au 98 822.5 kg Ag	29 740 kg Au	Epithermal	Drummond/ Drummond
Red Dome	M	22 716 kg Au 105 855 kg Ag 36 059 t Cu	164 060 t Cu 43 687 kg Au 356 770 kg Ag	Skarn	Hodgkinson/ Kennedy
Ravenswood (Area 2, Black Jack, Buck Reef West, General Grant, Slaughteryard, OCA Mines, Sarsfield, Nolan's, Sunset (excluding Mount Wright)	L	70 659.6 kg Au 27 299.3 kg Au bullion 19 487.1 kg Ag	52 158 kg Au	Mesothermal Magmatic Related	Pama/ Kennedy

Table 8 (continued)

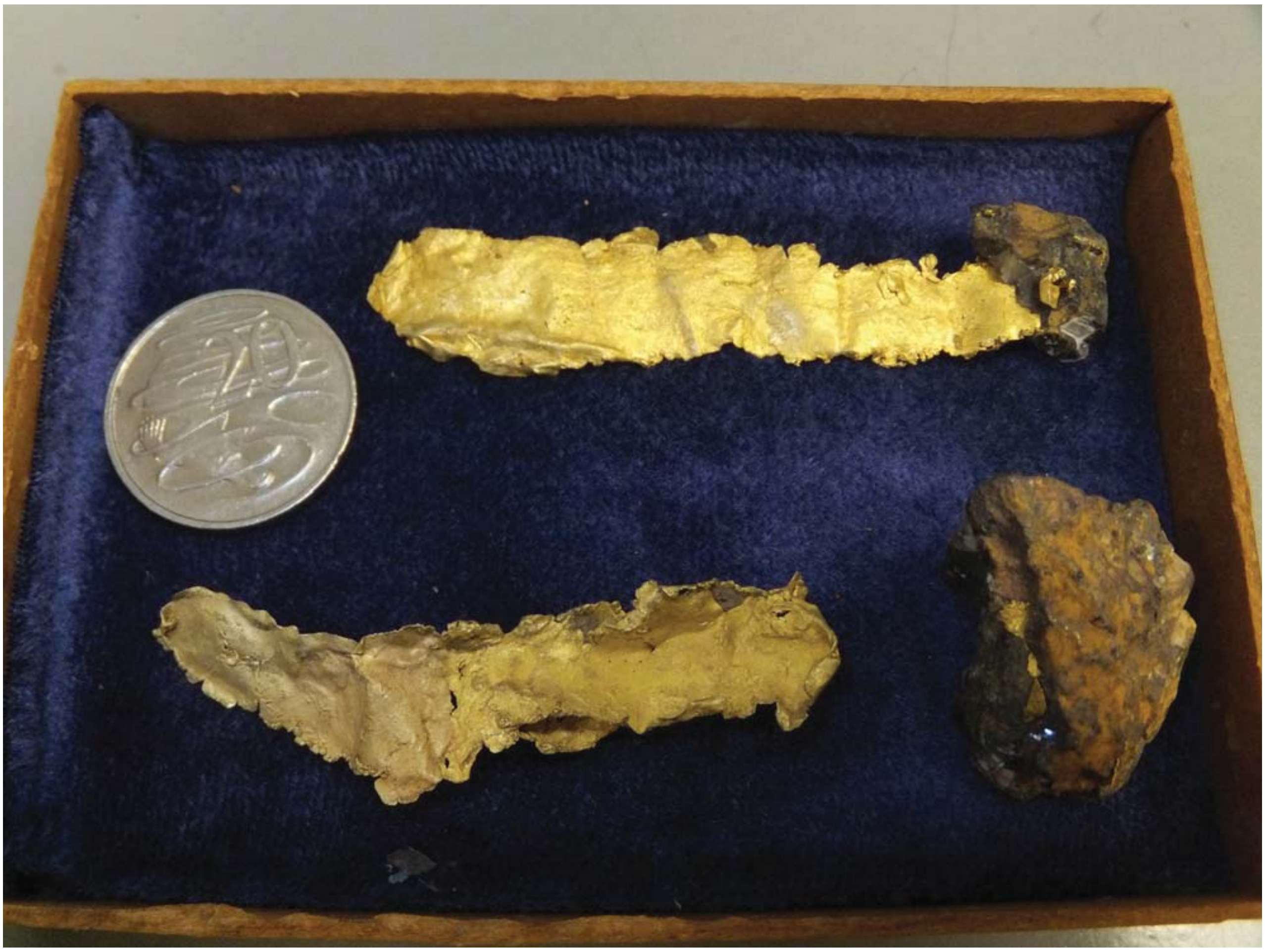
Name	Size	Total historical production	Total contained metal in remaining resource	Principal mineralisation style	Host/ore-body province (basin)
Roseby Copper Project (Bedford North, Bedford South, Blackard, Caroline, Charlie Brown, Great Southern, Ivy Ann, Ken Brown, Lady Clayre, Legend, Little Eva, Longamundi, Scanlan)	L	82.9 t Cu 0.2 kg Au 1.5 kg Ag	38 669 kg Au 3 717 196 t Cu	Structurally Controlled Proterozoic Iron Oxide-Cu-Au	Eastern Fold Belt/ Eastern Fold Belt
Selwyn (includes Areas 222, 224, 251, 257, 276)	L	32 143.1 kg Au bullion 168 500.4 t Cu	19 652 kg Au 124 840 t Cu	Structurally Controlled Proterozoic Cu-Au (Fe-Oxide Related)	Eastern Fold Belt/ Eastern Fold Belt
Tick Hill	M	15 900 kg Au bullion	Mined Out	Shear Zone Hosted Hydrothermal	Eastern Fold Belt/ Eastern Fold Belt
Wirralie	M	17 269.4 kg Au bullion 15.2 kg Au 5 kg Ag	17 060 kg Au	Epithermal	Drummond/ Drummond
Woolgar Gold Project (Explorer, Explorer South, Grand Central, Lost World, Soapspar)	M	141.2 kg Au bullion 6.4 kg Au 0.2 kg Ag	16 669 kg Au	Epithermal	Etheridge/ Kennedy
Yandan project (including Glen Eva)	M	7337.6 kg Au bullion 5101.8 kg Au 1377.5 kg Ag	10 996 kg Au	Epithermal	Drummond/ Drummond

Photograph 100: The preserved boiler at the historic Anglo Saxon mine (image courtesy Vladimir Lisitsin, GSQ).

Photograph 101: Intrusive auriferous chalcopyrite-pyrite quartz vein mineralisation from Charters Towers (sample from GSQ's historical collection, image courtesy Paul Blake, GSQ).



Photograph 102: The Warrior plant at night (image courtesy Simon Crouch, Regional Geologist, 2005).



Photograph 103: Leaf gold from the Mary Lou mine in the Charters Towers Gold Field (sample from GSQ's historical collection, courtesy Paul Blake, GSQ)

length of 5 km and cut by north-northwest-trending cross reefs. The most productive gold-bearing reefs are the Day Dawn, Brilliant and Queen which dip to the north beneath the city of Charters Towers. Ore production was halted in August 2013 allowing the company to focus on re-opening the main Central workings, which are under the central business district of Charters Towers. Access is by the 1.6 km Central Decline which is being refurbished in the western part of the town and which is reported as 75% complete in September 2014. This development will access several major reefs where nearly 4 km of reef strike will be developed. The Citigold Corporation Limited processing plant is about 10 km southwest of Charters Towers. The plant has a current capacity of 340 000 tpa and is designed to allow doubling of the throughput at minimum cost or disturbance to current processing when production warrants the upgrade. Metallurgical recoveries have averaged 97% to 98%. A mine life of over 20 years is suggested at current plant capacity.

In the Etheridge Goldfield, structurally-controlled quartz lodes are hosted by rocks of the Proterozoic Etheridge Province and are possibly genetically related to Silurian–Devonian I-type granitoids of the Pama Province. Similar vein mineralisation in the Croydon Goldfield is hosted by Proterozoic granite and volcanic rocks but may be related to late Paleozoic igneous activity.

The Woolgar gold project is 120 km north of Richmond and consists of two distinct gold-bearing systems, the epithermal vein deposits of Sandy Creek (including Lost World — these deposits are described further under the 'Epithermal deposits' header below)and the orogenic (mesothermal) vein deposits of the Soapspar district 8 km north of Sandy Creek. The orogenic deposits are associated with the Mowbray structure and the Woolgar Fault Zone along three main areas divided into the Lower Camp, Middle Camp and Upper Camp. At Lower Camp the main deposits are Big Vein (Photograph 104) and Big Vein South, at Middle Camp the main deposit is Soapspar and at Upper Camp the deposits are Union and Perserverence. These deposits are held by Strategic Minerals Corporation NL. A large drilling program was carried out since 2013 to increase the 'mesothermal' resource base which is located approximately 8 km to the west of the existing resources in the Sandy Creek epithermal vein system. In June 2013 the combined (measured, indicated and inferred) resource for Soapspar is estimated at 3.314 Mt at 0.89 g/t Au. At Big Vein an inferred resource of 64 000t at 4.85 g/t Au was reported. Another combined (indicated and inferred) resource was reported for Big Vein South of 354 000 t at 1.59 g/t Au (cut-off grades of 0.5 g/t Au for both deposits). This programme has been extremely successful with the drilling cutting multiple intersections that were on average both wider and higher grade than the previous known shallow mineralisation and appearing to indicate that the mineralisation improves with depth. New resource estimates are awaited for the mesothermal vein deposits and a preliminary metallurgical study has commenced. The company's strategy is to establish sufficient

Photograph 104: Historical workings in the vicinity of the Big Vein resource at Woolgar.

gold resources near surface to satisfy initial economic development and provide an on- going cash flow to further explore and develop additional resources within the mesothermal zone.

2) Intrusion-related gold systems

Porphyry-related breccia style mineralisation is mainly associated with Carboniferous to Permian rhyolitic porphyries of the Kennedy Province in north Queensland. The Mount Leyshon, Kidston and Mount Wright deposits are examples of porphyry-related mineralisation, which is commonly associated with subvolcanic intrusion, breccia development and multiphase hydrothermal activity.

Mount Leyshon, south of Charters Towers, was the largest intrusion-related deposit in Queensland when it was worked in 1990. The mineralisation occurred within the Mount Leyshon diatreme, a volcanic intrusive breccia complex, and was generally coincident with a zone of later breccia development where cavities were infilled with sulphide minerals to form a massive porphyry style disseminated orebody (Photograph 105). Higher grade veinlet style gold mineralisation also extended into adjacent rocks. Both the Mount Leyshon and Kidston mines have closed due to depletion of resources.

The Mount Wright deposit is 13 km from Ravenswood and 65 km east of Charters Towers. The deposit is operated by Resolute Mining Limited and its subsidiary Carpentaria Gold Pty Ltd. The Ravenswood gold mine commenced operations in 2007 and sourced their ore from the Mount Wright underground mine and low-grade stockpiles. The mineralisation consists of gold-bearing disseminated sulphides and minor quartz-siderite-sulphide veins in altered and brecciated Millaroo Granite (Photograph 106). The Mount Wright decline is now at its designed depth and has extended its mine life by 14 months to at least the September quarter of 2016. As at 31 December 2014, Mount Wright had a proven ore reserve of 2.655 Mt at 2.7 g/t Au and a probable ore reserve of 0.626 Mt at 1.8 g/t Au with stockpiles encounting for a further 9000 Mt at 2.5 g/t Au. The measured resources were 0.281Mt at 2.9 g/t Au, and 0.042 Mt at 2.1 g/t Au in the stockpiles, the indicated resources 0.29 Mt at 2.8 g/t Au and the inferred resources 0.967 Mt at 3.1 g/t Au. The reserves are reported using a cut-off grade of 2.3 g/t Au and the resources above a 1.8 g/t cut-off grade. Mineral resources are exclusive of reserves. The Ravenswood plant was reconfigured for a reduced throughput of 1.5 Mtpa following depletion of the low-grade stockpiles from Sarsfield and Nolans.

At the Sarsfield deposit near Ravenswood, which is held by Resolute Mining Limited, multiphase gold mineralisation is associated with veining and brecciation of the Silurian to Devonian Jessop Creek Tonalite of the Ravenswood Batholith (Pama Province). Mineralising fluids are interpreted to be derived from an early Carboniferous intrusive of the Kennedy Province that was emplaced into a mesothermal to deep epithermal environment. At30 June 2014, the Sarsfield deposit (Photograph 107) had a proven ore

Photograph 105: Intrusion-related breccia, with infilled sulphides into granite, from Mount Leyshon.

Photograph 106: Breccia with mineralisation within the Millaroo Granite from Mount Wright underground mine.

Photograph 107: Panorama view of the Sarsfield open cut in 2011, showing the plant in the background and waste refill in the back section of the pit.

reserve of 28.45 Mt at 0.8 g/t Au and a probable ore reserve of 18.64 Mt at 0.7 g/t Au using a 0.4 g/t cut-off grade. Construction started early 2013 with the ore treated at a rate of 5 Mtpa in conjunction with the Mount Wright ore. Mineral resources exclusive of the ore reserves at Sarsfield comprise a measured resource of 16.185 Mt at 0.8 g/t Au, an indicated resource of 20.38 Mt at 0.7 g/t Au and the inferred resource is 22.19 Mt at 0. 7 g/t Au.

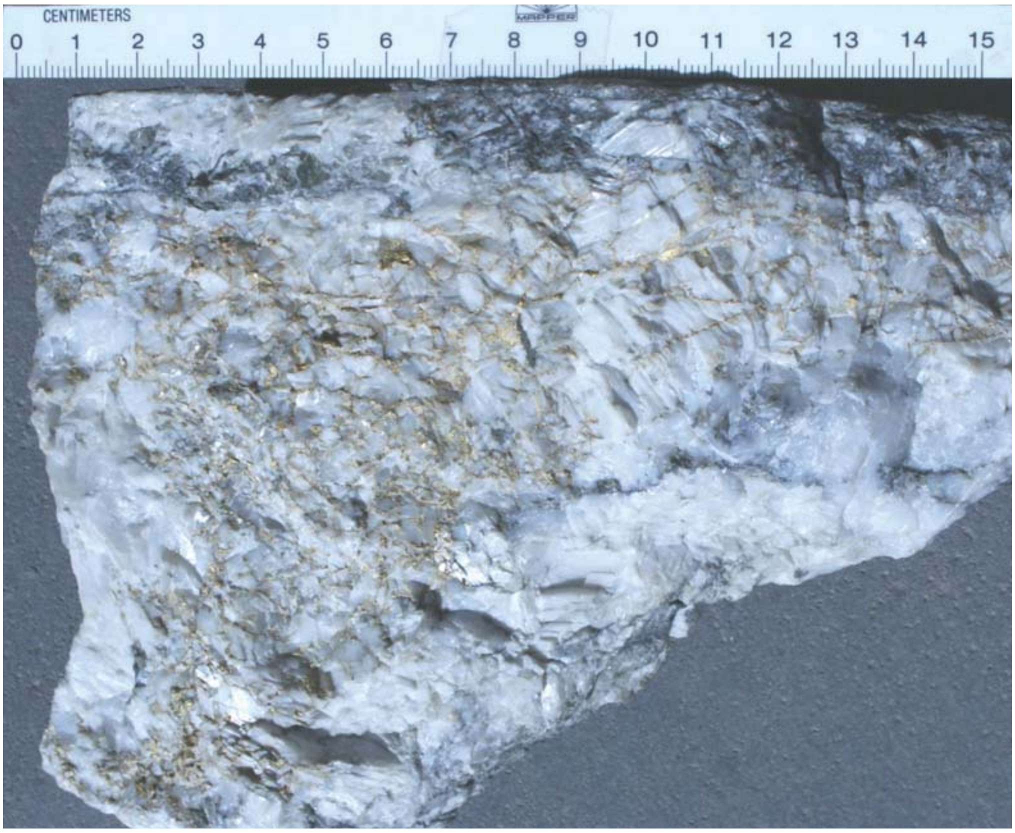
In June 2014, Resolute Mining Limited announced an additional resource at Buck Reef West adjacent to the Sarsfield deposit and processing facility. Historically, underground mining at Buck Reef West exploited narrow high grade lodes that averaged over 15g/t Au. However recent drilling showed an opportunity for a larger scale open pit that can exploit both the narrow veins and the surrounding broader zones of alteration and veining and the company has commenced a scoping study of the Buck Reef West deposit which should take 12 months to complete. Using an 0.5 g/t cut off, the measured resource is 17.857 Mt at 1.1g/t Au, the indicated resource 11.582 Mt at 0.9g/t Au and the inferred resource 12.360 Mt at 0.9 g/t Au. At the Welcome Breccia 40 km northwest of Ravenswood Resolute Mining Limited has calculated an inferred resource of 2.036 Mt at 3.2 g/t gold.

Four main styles of quartz-gold lodes are recognised in the Gympie Goldfield: Gympie veins; break style; Inglewood Lode style and stockworks. In a modern exploration context, stockwork and Inglewood lode styles are the most significant exploration targets. The Inglewood quartz lodes are associated with structural control along the northwest-trending Inglewood Structure, which may have been a significant fluid pathway (Photograph 108). The north-trending, steeply west dipping 'Gympie veins' are linked to the Inglewood Structure and occur along joints. These veins form stockworks where they intersect carbonaceous shale 'breaks'. A genetic link between the gold mineralisation and a heat source (the Woondum Granite of the South-East Queensland Volcanic and Plutonic Province to the southeast of Gympie) forms the basis of a current mineralisation model for the goldfield. The Mount Mother Granite, which is a member of the Woondum Igneous Complex, is a felsic, near minimum-melt intrusion that shows evidence for internal fractionation and exsolution of a volatile phase late in its crystallisation history. These volatiles could transport Mo at high temperatures and Au, As, Sb, Te, Pb-Zn at moderate to lower temperatures. The resulting alteration systems may have been derived from hydrothermal processes associated with crystallisation of the Mount Mothar Granite stock and may be realted to the Gympie mineralisation. Operations at Monkland and the Lewis Decline ceased at the end of 2009 (Photograph 109).

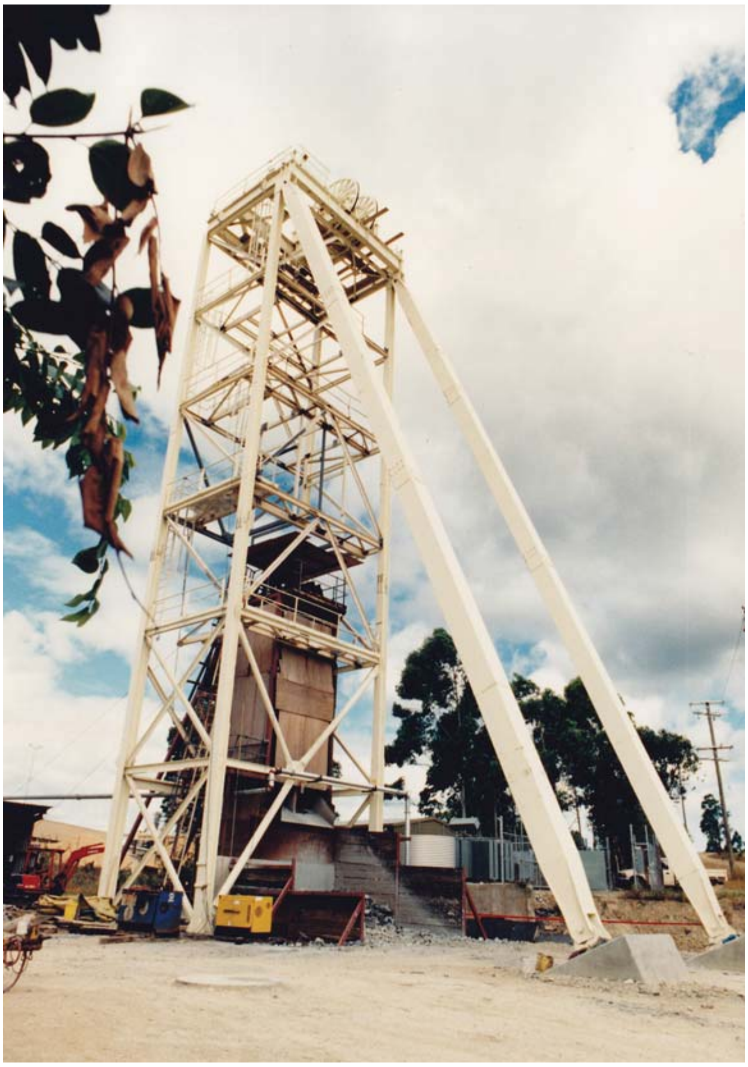
The Norton gold mine, about 100 km southwest of Gladstone, is on care-and-maintenance. The Norton deposit is considered an intrusive-related polymetallic Ag–Pb–Zn vein system, but only gold and silver production was recorded. Gold and silver are contained in sub vertical, high-grade shears that occur from surface. The mining lease contains the existing mine site within which 8 main shears make up the currently defined deposit. Three of the best shears have previously been mined or pre-stripped and remain open and ready for near immediate mining, pending some additional minor earthworks and preparation. Norton Gold Fields Limited mined the deposit in two stages: They produced 64.22 kg of gold bullion in 1996–1997 (trucked to and processed at Eidsvold Joint Venture heap-leach operation), and then 36.63 kg of gold bullion in 2005 and 2006 and toll treated that ore at the Gympie Eldorado Gold Mine plant (Photograph 110). Mining operations were suspended on 31 October 2006 after concerns arose that the base metal content in the tailings dam at the Gympie plant could potentially exceed licence conditions. The total measured, indicated and inferred resource is 453 000 t of ore grading 7.4 g/t Au. Mantle Mining Corporation acquired the deposit in March 2013 and is designing an infill exploration program to target at least an indicated resource under the 2012 JORC Code to allow for effective mine production scheduling.

The Mount Rawdon gold deposit is 22 km southeast of Mount Perry, in southeast Queensland. Equigold NL purchased the project in August 1998 and commenced operations in 2001 (Photograph 111). The operation has subsequently produced consistently as an open cut mine (Photograph 112) and had a number of ownership changes, with the latest being Evolution Mining Limited since 2011. Mount Rawdon is an intrusion-related low-grade gold silver depost hosted by interbedded subaerial pyroclastic flow, surge and ash-fall deposits of the Aranbanga Volcanic Group that are intruded by coeval dacite. The bulk of the host rock sequence consists of massive rhyodacitic pyroclastic rocks (Photograph 113) and dacite (Photograph 114). Gold occurs as microscopic grains in pyrite and sphalerite veins and disseminations in the pyroclastic rocks and dacite. The processing capacity is about 3.5 Mtpa with a recovery of about 92% Au as gold–silver dore. At 30 December 2013, the stockpile reserves were proved 76 000 t at 0.5 g/t Au and open cut probable reserves were 29.8 Mt at 0.9 g/t Au using a cut-off grade of 0.3 g/t Au. The indicated resource was 42.4 Mt at 0.8 g/t Au and the inferred resource 7.94 Mt at 0.6 g/t Au at a cut-off grade of 0.23 g/t Au, these figures being inclusive of the ore reserves. The current life of mine planning continues the operation up to 2022.

A small mesothermal intrusive-related gold and base metal deposit on Horn Island in Torres Strait was discovered in 1894. Early historical production up to 1901 yielded 31 kg of alluvial Au and 190 kg of Au from 16 626 t of ore. Undocumented mining occurred in the 1930s and 1950s. An open cut covering the Welcome, Triumph and Gympie Reefs was mined for a short interval in 1988-1989 by AuGold N.L. and Giant Resources Ltd (Photograph 115). The gold and base metal mineralisation (Photograph 116) was emplaced along tensional structures within a regional shear couple during late stages of the emplacement of the fine grained Badu Granite within the Horn Island Granite (Levy & Storey, 1990; von Gnielinski, 1996). A secondary fluorite-(tin-tungsten) mineralisation expressed as infill veins and the Welcome Siliceous Breccia, which overprint the gold mineralisation, are likely sourced at depth (Photograph 117). In 1989 Giant Resources stated a combined measured, indicated and inferred resource of 2.35 Mt at 2.37 g/t Au for the stage 1 open cut area to a depth of 40m. Subsequently 640 495 t of ore were mined to a depth of 18 m, yielding 1435 kg of Au bullion (52% gold). Exploration drilling at the southeastern end of the Welcome Lode (mined in the stage 1 open cuts) indicated an additional measured and indicated resource of 134 000 t at 3.9 g/t Au. Due to the companies going into receivership the mine was closed in December 1989. The Queensland Government placed a Restricted Area (RA295) over the Horn Island mine area and undertook rehabilitation of the site since 1991. In 2013 Kauraru Gold, a private joint venture company (partners: Alice Queen Holding and Kaurareg Aboriginal Land Trust (KALT) on behalf of the Kaurareg Aboriginal People) have successfully applied to have the RA295 lifted and have designed a drilling program to test below identified high-grade structures and mineralisation extensions.



Photograph 108: Gold mineralisation in the structurally controlled Inglewood Lode quartz, Gympie mine (sample from GSQ's historical collection).

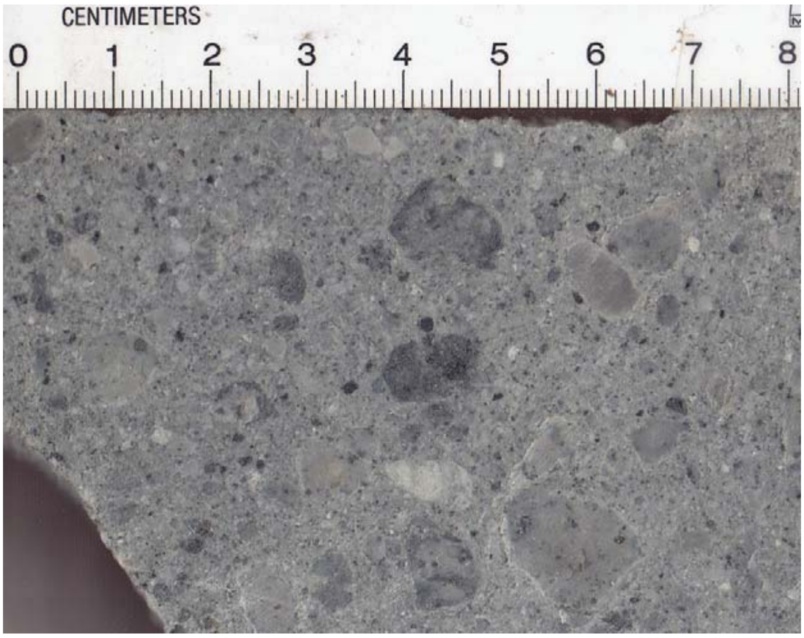


Photograph 109: Headframe of the Gympie Scottish Nr.2, around 1996.

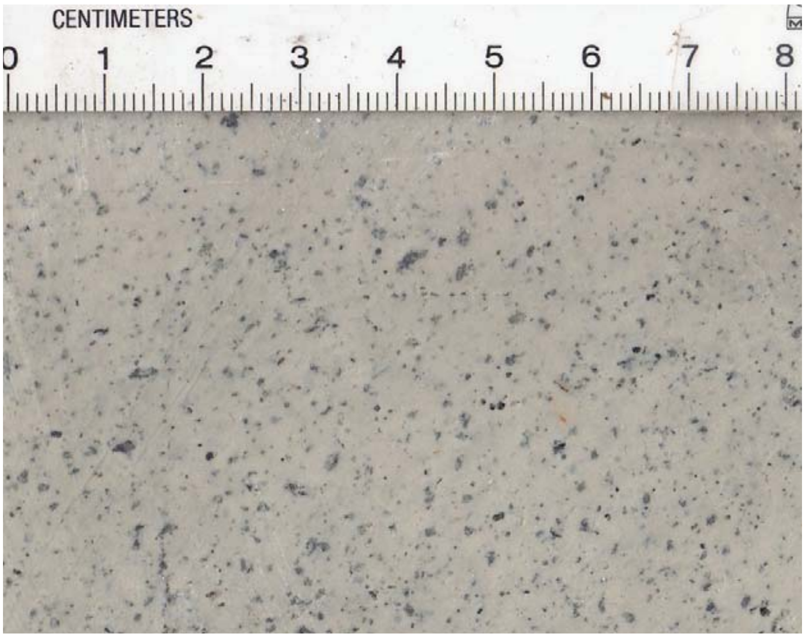
Photograph 110: The Gympie Eldorado treatment plant in 1996.

Photograph 111: Treatment plant at Mount Rawdon (image courtesy David Carmichael, DNRM).

Photograph 112: Mount Rawdon open cut viewed from the lookout point.



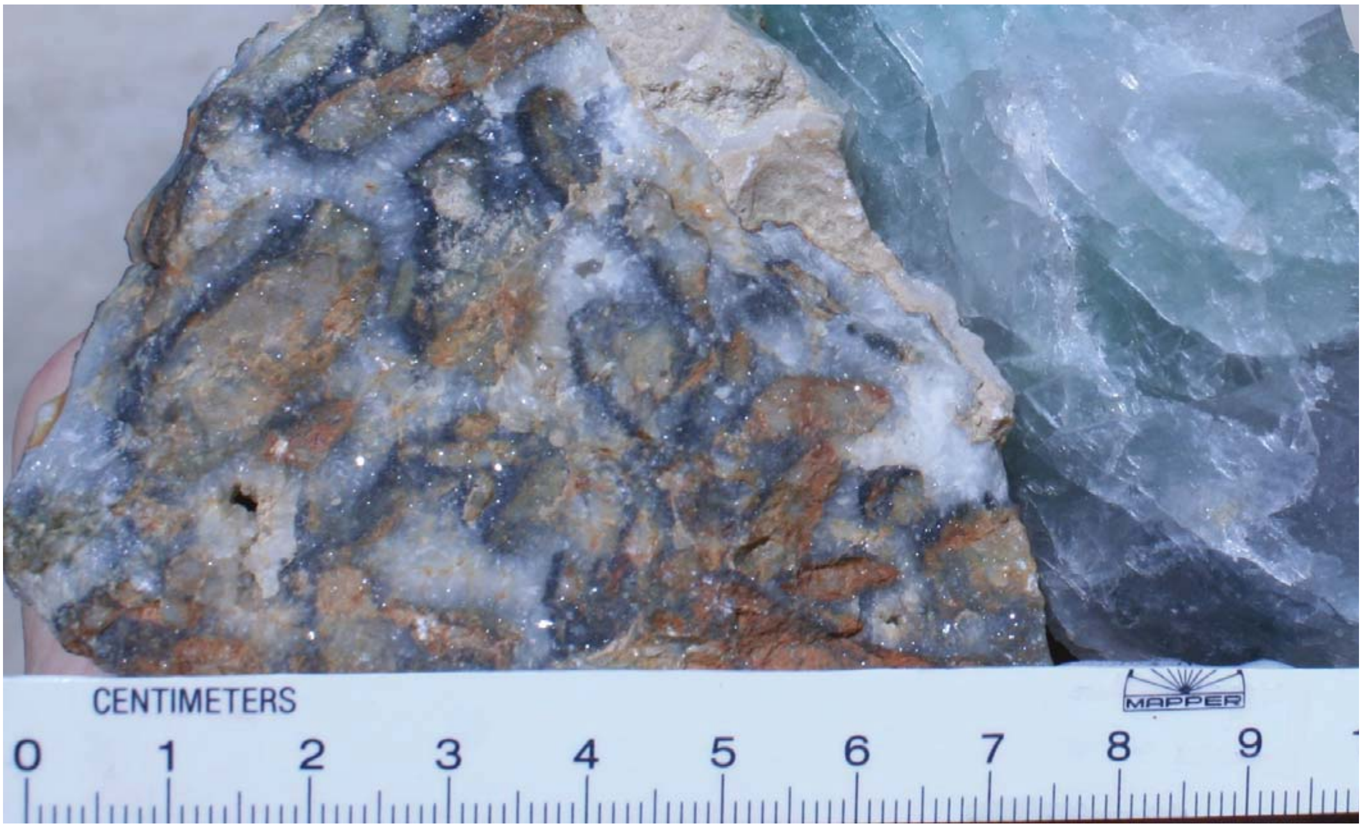
Photograph 113: Pyroclastic rock within the Aranbanga Volcanic Group hosted very fine disseminated auriferous pyrite, from Mount Rawdon.



Photograph 114: Mineralised (non-visible disseminated auriferous pyrite) dacite within the Aranbanga Volcanic Group, from Mount Rawdon.

Photograph 115: Horn Island Gold Mine plant in 1990.

Photograph 116: (left) Gold and base metal (mostly lead and zinc) in a silicified porphyry breccia from Horn Island; (right) massive sphalerite, chalcopyrite and galena bands as vein-infill from Horn Island.



Photograph 117: Welcome Siliceous Breccia with tin-quartz-fluorite mineralisation from Horn Island.

Photograph 118: Outcrop of mineralisation in sheared granite at Big Reef East, Georgetown region.

14 diamond holes at +200m depth at a total meterage of 3090m are scheduled for May-June 2015. A JORC acceptable resource estimation is planned.

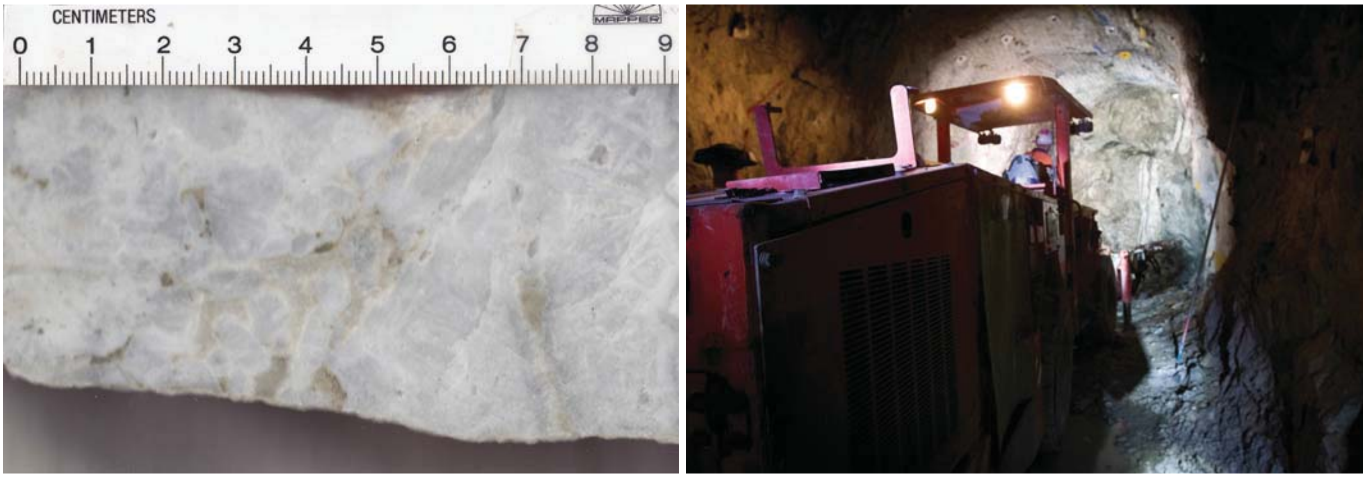
Australia United Mining Limited (formerly Altius Mining Limited) is aiming to develop a mining project based on a number of historical workings in the Forsayth area. Included in the assessment are the Ropewalk and Flying Cow deposits 15 km southeast of Forsayth which have already been developed as a small open cut mine and small underground mine respectively. They are interpreted as gold vein-related deposits but their resources are restricted to low tonnage, medium to high-grade, shear-controlled quartz vein systems. A small mill capable of recovering gravity gold is also available. A 2011 indicated resource of 10 000 t at 10 g/t Au was estimated for Ropewalk and 16 300 t at 31 g/t Au for Flying Cow.

Various smaller intrusive-related gold deposits were mined between 2010 and 2011 by Deutsche Rohstoff AG in the Georgetown and Forsayth region. The Electric Light and Red Dam gold deposits are 15 km and 42 km northeast of Georgetown and the Jubilee Plunger deposit is 30 km southeast from Forsayth. The Electric Light deposit is interpreted as an endo- and exo-stockwork/breccia associated with Permo-Carboniferous rhyolite porphyry, localised by a deviation in the Delaney Fault. Deutsche Rohstoff AG commenced mining the oxide ore at Red Dam in October 2010, at the Electric Light in December 2010 and at the Jubilee Plunger in early August 2011, with the ore transported to Georgetown for processing. A total of 367.31 kg of gold bullion was produced from this operation, but only reported against the Jubilee Plunger deposit. Mining ceased in December 2011 and Deutsche Rohstoff AG sold the operation to JKO Mining in September 2012. JKO Mining has extended exploration to a number of smaller historically worked deposits like the Try No More Reef and the Big Reef East (Photograph 118) and West in the vicinity of the renamed Central Gold Mines Plant. JKO Mining had recommenced production in 2013. In total 71 460 t of ore were processed and 367.310 kg of gold bullion were produced. Under Agreement with Laneway Resources Limited JKO mined and treated a 5472 t bulk sample of high-grade surface ore (from Agate Creek). The recovered grade was 9.8 g/t Au from a feed grade of 11.2 g/t Au (recovery of 87%) between December 2013 and January 2014. Administrators were appointed to JKO Mining in June 2014.

3) Epithermal deposits

Early Carboniferous epithermal gold (-silver) mineralisation of the low sulphidation (quartz-adularia) style occurs within Cycle 1 volcanics of the northern Drummond Basin in north Queensland. The Pajingo (Vera-Nancy and Scott Lode), Mount Carlton, Wirralie, Twin Hills (309 and Lone Sister), Yandan and Mount Coolon deposits are significant examples.

Pajingo is the largest epithermal gold deposit in Queensland, about 72 km south of Charters Towers. The deposit consists of several ore shoots along the southeast-trending Vera-Nancy trend. Initially the Pajingo goldfield was discovered in 1983 by Battle Mountain



Photograph 119: (left) Epithermal quartz veins from Pajingo; (right) mineralised sheared fault in Vera Nancy (Pajingo) open cut (image courtesy Vladimir Lisitsin, GSQ).

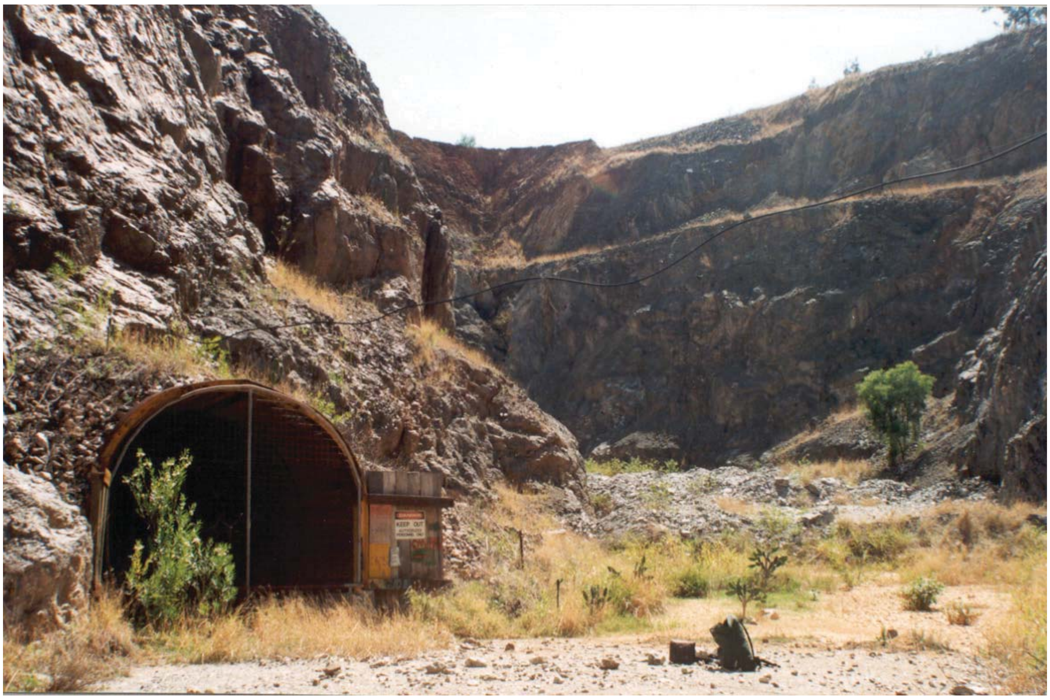
Gold Company and first gold production was achieved in 1986. The Pajingo epithermal field, which covers an area of ~150 km^2, contains an array of southeast-trending gold-silver veins that are disrupted by east-trending faults. The veins dip steeply, range in thickness from centimetres to 20 m and are usually enclosed by zones of silicic alteration up to 50 m thick (Photograph 119, left). The Vera-Nancy structure is considered to be a predominantly strike-slip fault, with mineralisation occurring on dilational jogs or flexures. Mineralisation is hosted by porphyritic andesitic lithic tuff previously assigned to the Star of Hope Formation, but now considered to be part of the Cycle 1 volcanics of the Drummond Basin. Drilling over a strike length of ~3 km has intersected high-grade gold mineralisation to depths of >400 m along the structure. Mining has been carried out at the Nancy North, Nancy, Vera North, Vera, Vera South, Venue and Jandan orebodies. Pajingo has subsequently produced consistently by either open cut or underground methods (Photograph 119, right) from a number of orebodies and had a number of ownership changes (Newmont Mining Corporation, North Queensland Metals Ltd, Conquest Mining Ltd) with the latest being Evolution Mining Limited. At 30 December 2013 the underground reserves (including stockpiles) were proved 178 000 t at 7.1 g/t Au and probable 595 000 t at 6.0 g/t Au using a cut-off grade of 3.3 g/t Au. Using a cut off of 2.5 g/t Au the measured, indicated and inferred underground resources which are inclusive of the ore reserves are 4.51 Mt at 6.3 g/t Au. An inferred open cut resource remains of 320 000 t at 1.2 g/t Au at a cut-off grade of 0.5 g/t Au. Evolution Mining was successful in increasing its resource and reserve base over its rate of mining depletion during 2012 and 2013. The processing plant has a design capacity of 650 000 tpa. Metallurgy is simple with current and estimated future gold recoveries of 95% gold and gold–silver dore being produced. Given the historic conversion of mineral resources to ore reserves, the forecast mine life is about five years. In 2013 a new high grade gold shoot within 1200m from the Pajingo current workings has been discovered. The Moonlight and Io mineralisation on the Moonlight corridor run parallel to the Vera Nancy trend and may represent a new and largely untested structure. In 2013 5 diamond drill holes (2700m) have intersected the mineralisation at Io over a 200m strike length and approximately 400m below surface. The mineralisation occurs within crustiform banded quartz-adularia vein breccias, typical of mineralised systems at Pajingo.

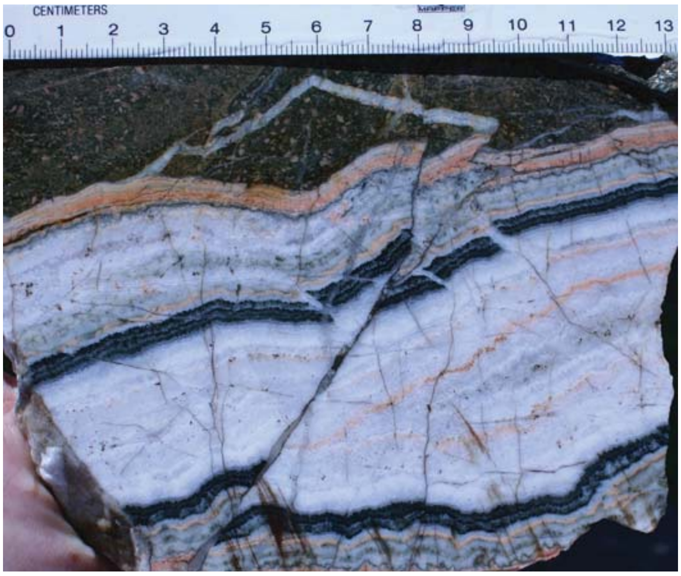
The Twin Hills gold project (Photograph 120, left) comprises the 309 and Lone Sister deposits, respectively 107 km north-northwest and 155 km north-northwest of Clermont. BMA Gold Ltd commenced underground mining operations at 309 in 2005 (Photograph 120, right), but a downgrading of resource figures led to a decision to close the mine in February 2007. Evolution Mining Limited acquired Twin Hills under the same arrangement as the Pajingo mine acquisition. The ore has the potential to be trucked north 190 km along the sealed road to Pajingo. The 309 deposit has an existing decline in place for quick access and potential for both an open cut and underground operation. During 2014 Evolution Mining Limited reclassified the resources to the inferred category, as the resource relies on historical data and no work has been undertaken since 2009. The inferred open cut resource is 3.06 Mt at 2.1 g/t Au (cut-off grade is 0.5 g/t Au). A further 540 000 t at 4.3 g/t Au of inferred underground resources have been identified (cut-off grade is 2.0 g/t Au). The Lone Sister deposit has a underground inferred resource of 1.02 Mt at 3.7 g/t Au (cut-off grade is 2.0 g/t Au).

A low-sulphidation epithermal mineralisation also occurs near Cracow, 50 km southeast of Theodore in central Queensland. The outcropping Golden Plateau Lode was discovered in 1932 and production commenced soon after (Photograph 121). The Golden Plateau and satellite deposits such as the Klondyke, Klondyke North and Crown Shoot are associated with quartz veining and zones of silicification (Photograph 122). Andesitic lavas, tuffs and coarse breccias of the Camboon Andesite (Connors–Auburn Province) host these deposits. The veins hosting the mineralisation are commonly steeply dipping. Newcrest has developed an underground mine on the Klondyke group of veins. The current underground mine development began in September 2003 (Photograph 123) and the first gold pour was in November 2004. Ever since the mining development in the underground mine has been continuous. High-grade gold mineralisation defined in the project resources occurs within five deposits (Royal Shoot, Crown Shoot, Sovereign Shoot, Klondyke North and Kilkenny Shoot), each developed at the intersection of major structures. Exploration continues to define additional mineralisation in this region. Recent near mine exploration has progressed the Coronation, Griffin and Denmead epithermal veins to maiden inferred status while a new lode was identified between Empire and Coronation and named the Imperial. The 70% Newcrest interest in the Cracow mining operations (Photograph 124) were purchased by Catalpa Resources



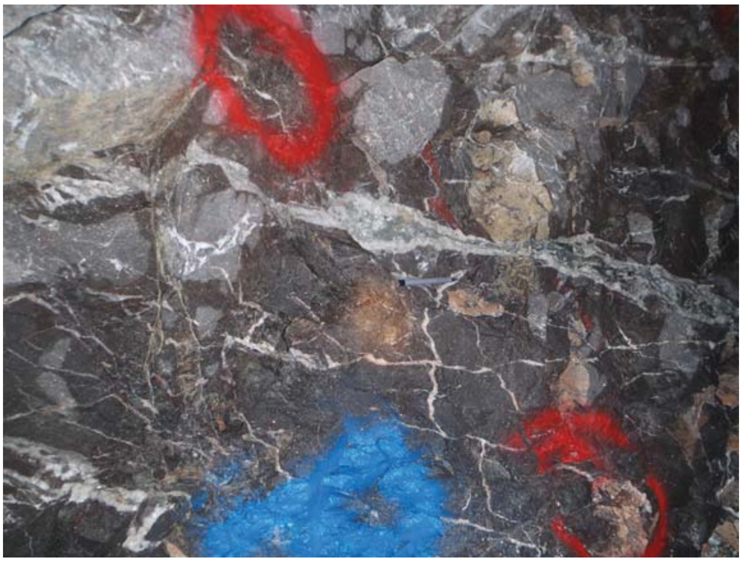
Photograph 120: (left) Twin Hills processing plant in 2005; (right) Twin Hills underground portal opened in 2005 (images courtesy David Wallis, DNRM).


Photograph 121: Golden Plateau open cut with underground portal in 1997, Cracow Gold mine.

Photograph 122: (above) Auriferous colliform quartz veining and brecciation, Cracow Gold mine; (right) auriferous quartz veining with adularia alteration, GoldenPlateau open cut, Cracow Gold mine.

Photograph 123: Mineralised vein breccia and silicified volcanic rock at Roses Pride underground mine, Cracow.

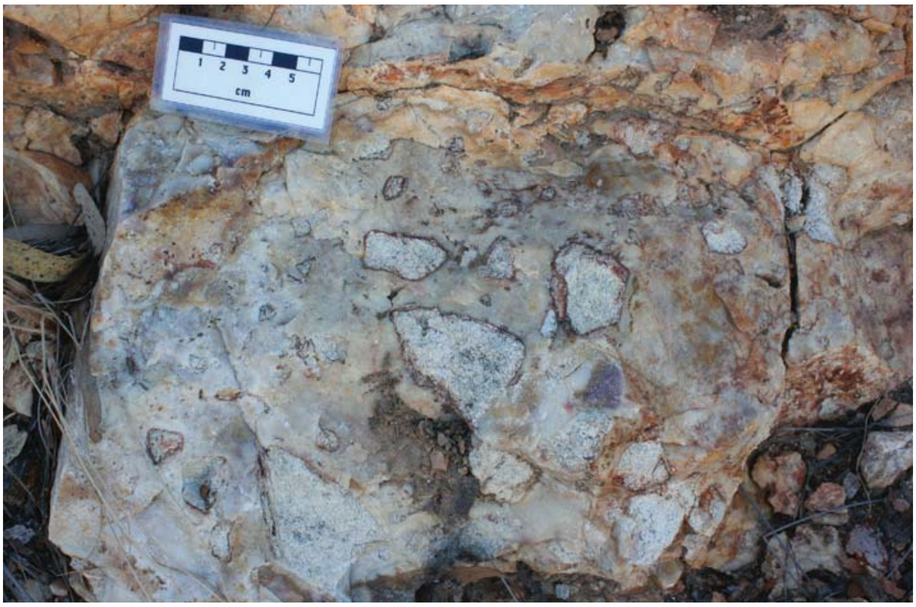


Photograph 124: Cracow Gold Mine plant in 'care and maintenance' in 1997, as operated by the Cracow Mining Venture.

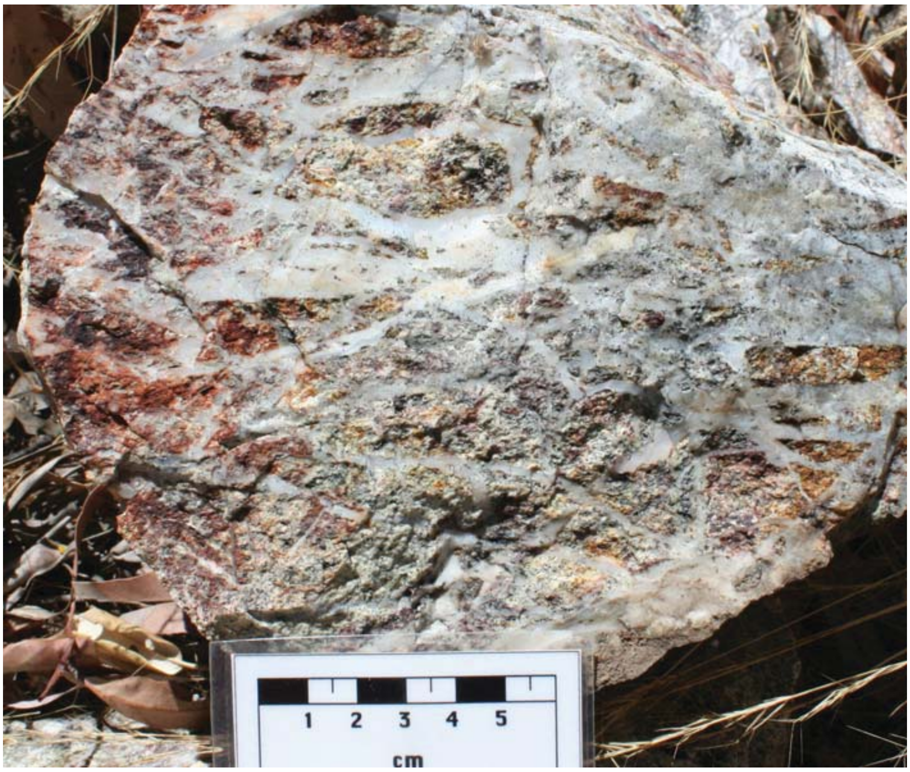
and Conquest Mining in June 2011. The two companies merged to form Evolution Mining Limited in 2012. At 30 December 2013, the proved ore reserves were 353 000 t at 7.3g/t Au and the probable reserves were 1.00 Mt at 5.5 g/t Au using a cut-off grade of 3.5 g/t Au. The total resource which is inclusive of the ore reserves and use an indicative cut off grade of 2.8 g/t Au are were 3.43 Mt at 6.6 g/t Au. An additional resource estimate is underway at the Coronation shoot which is a new discovery approximately 550 m below surface and 250 m north of active mining operations. Forecast mine life is five years. The ore is free milling and is treated on site to produce gold-silver dore. The processing plant was upgraded from 450 ktpa to 550 ktpa in 2011. Forecast mine life remains at five years.

In the Sandy Creek area of the Woolgar Inlier, Mesoproterozoic rocks of the Etheridge Province host several smaller epithermal deposits of probable Carboniferous to Permian age. The Woolgar gold project is 120 km north of Richmond and consists of two distinct gold-bearing systems, the epithermal vein deposits of Sandy Creek (including Lost World, Grand Central, Explorer and China Wall, Shanghai) and the orogenic (mesothermal) vein deposits of the Soapspar district 8 km north of Sandy Creek (as described earlier). Exploration for near-surface epithermal gold mineralisation is essentially complete and at June 2013. As reported in June 2013 the Sandy Creek Epithermal resource (including Lost World and Explorer) has a combined (measured, indicated and inferred) resource of 7.117 Mt at 1.63 g/t Au. (at a cut-off grade between 0.8 and 1.0 g/t Au). Strategic Minerals Corporation NL is actively exploring the area to define sufficient resources for mining operations. Newer work is ongoing around deposits belonging to the older parts of the Woolgar goldfield between the Union, Brien Shear, Big Vein and Big Vein South prospects. A smaller resource at the Big Vein South prospect was estimated to a combined inferred and indicated resource of 354 000 t at 1.59 g/t Au. Defined gold resources at Woolgar in 2012 exceed 15.4 t of Au in seven vein systems. Strategic Minerals is investigating the feasibility of a stand-alone, small-scale, pilot mine development at the Soapspar prospect.

Renison Consolidated Mines NL (now known as Laneway Resources Limited) has delineated significant epithermal gold resources at its Agate Creek Project in north Queensland. Mineralisation occurs along reactivated faults between the Silurian Robin Hood Granodiorite (Pama Province) and rhyolitic intrusives of the Carboniferous to Permian Agate Creek Volcanic Complex (Kennedy



Photograph 125: Siliceous epithermal breccia in Robin Hood Granodiorite near Sherwood, Agate Creek Project.



Photograph 126: Stockworked veining in highly altered Robin Hood Granodiorite near Sherwood, Agate Creek Project.

Province). Swarms of chalcedonic veins grade into breccias (Photograph 125) and zones of stock working (Photograph 126). The indicated and inferred resource is 17 Mt at 0.94 g/t Au at a 0.3 g/t cut-off and 9.47 Mt at 1.36 g/t Au at a 0.5 g/t cut-off. Following a pre-feasibility study into an open cut mine and carbon-in-pulp development to produce approximately 1.7 t per year (60 000 oz per year) of gold, the company is conducting further exploration with a view to expanding the resource base for a mine life of at least eight years. As part of this work, a broad 31 m zone of stock-work veining was intersected grading 5.96 g/t gold from 124 m. This high grade zone is within the currently modelled pits and is expected to add to the current resource which is expected to be updated in the first half of 2015. In January 2014 Laneway Resources poured their first gold from a removal of 5472 t metallurgical test sample from Agate Creek with an average head grade of 9.8 g/t Au (the feed grade was 11.2 g/t Au). Mining and processing was done by JKO Mining Pty Limited (now in liquidation).

Conquest Mining Ltd has discovered significant high sulphidation epithermal silver mineralisation at the Silver Hill and low sulphidation epithermal gold-silver mineralisation at Mount Carlton prospects (older names), 45 km northwest of Collinsville in northern central Queensland in 2006. The mineralisation comprises gold, silver and copper primarily as copper arsenic sulphides and silver arsenic sulphides and some native gold (within pyrite) that occurs exclusively in rhyodacitic volcanics. The Mount Carlton project is now operated by Evolution Mining Limited. The Mount Carlton operation comprises two discrete zones: the large gold dominant V2 deposit and the smaller, silver-rich A39 deposit (Photograph 127). The V2 deposit is flat lying with mineralisation

Photograph 127: Discovery outcrop at A39; outcrop expression of high grade silver mineralisation, Mount Carlton Project.

Photograph 128: Mineralised quartz veins from Glen Eva.

occurring as matrix infill to a north dipping breccia or fracture zone that is situated 20 m to 180 m below surface and is 70 m thick with a 500 m by 500 m areal extent. A39 is a fault controlled silver dominant breccia mineralisation (including baryte). The two deposits are 200 m apart. The vein systems are hosted by the Early Permian Lizzie Creek Volcanics (Bowen Basin). At December 2013 probable open cut reserves at A39 using a cut-off grade of 53 g/t Ag were 410 000 t at 295 g/t Ag and 0.31% Cu and indicated resources were 55 000 t at 260 g/t Ag and 60 000 t at 0.26% Cu with 260 000 t at 72 g/t Ag in the stockpiles. Probable open cut reserves at V2 using a cut-off grade of 0.35 g/t gold were 7.11 Mt at 3.0 g/t Au, 22 g/t Ag and 0.28% Cu and proved resources in the stockpiles, 190 000 t at 1.6 g/t Au, 19 g/t Ag, 0.16% Cu. In addition to the stockpiles, the indicated open cut resources at V2 which include the reserves are 10.4 Mt at 2.4 g/t Au, 23 g/t Ag and 0.27% Cu and the inferred underground resource at V2 770 000 t at 4.7 g/t Au, 15 ppm Ag and 0.33% Cu, using an 2.5 g/t Au cut-off grade. The first concentrate from the A39 deposit was produced from the 800 000 tpa plant in March 2013 and commercial mining commenced in July 2013. The A39 open cut is nearing completion and some deposit extensions may be developed via underground access. At full production the annual gold production is expected to be around 55,000 ounces and the initial mine life for Mount Carlton is 12 years. Gold-silver-copper concentrate from V2 and silver-copper concentrate from A39 is exported to smelter customers in China via Townsville. Metallurgical recoveries are dependant on ore-type material properties and grade. The current and estimated future recoveries at V2 are 89% for gold 91% for silver and 91% for copper and at A39, 88% for silver and 92% for copper.

The Mount Coolon project, which is held by Drummond Gold Limited, is about 200 km west of Mackay. The project largely consists of the wholly owned Eugenia, Koala, Police Creek and Glen Eva (Photograph 128) deposits within 10 km of Mount Coolon. The total measured, inferred and indicated resources of the Mount Coolon deposits are 5.174 Mt at 1.7 g/t Au of which an inferred resource of 4.416 Mt at 1.3 g/t gold occur at the Eugenia prospect.

The Yandan project 45 km west of Mount Coolon, with an inferred resource of 8.56 Mt at 1.5 g/t Au, is for sale by the holder Straits Resources Limited.

4) Iron oxide–Cu–Au (IOCG)

Gold is produced as a by-product of processing copper ores from structurally-controlled Proterozoic copper–gold deposits of the Eastern Fold Belt Province in the Mount Isa Province. Deposits tend to be associated with magnetite-rich iron oxide bodies (*e.g.* Ernest Henry, Osborne, Selwyn, Mount Elliott, E1, Las Minerale) within spatially extensive sodic-calcic alteration zones and local K-silicate alteration. Gold is generally concentrated in the chalcopyrite lattice within the ore.

Ernest Henry differs from other deposits because it is developed within variably brecciated and altered felsic to intermediate volcanic rocks, with primary mineralisation forming within a magnetite-carbonate gangue. Magnetite makes up 20–25% of the primary ore.

Minor gold may be produced from the Rocklands project (Las Minerale) held by CuDeco as a by-product. Gold was reported in the magnetite resource quoted in the 'Ironstone and magnetite' section.

Refer to the 'Copper' section for more detail on these IOCG deposits.

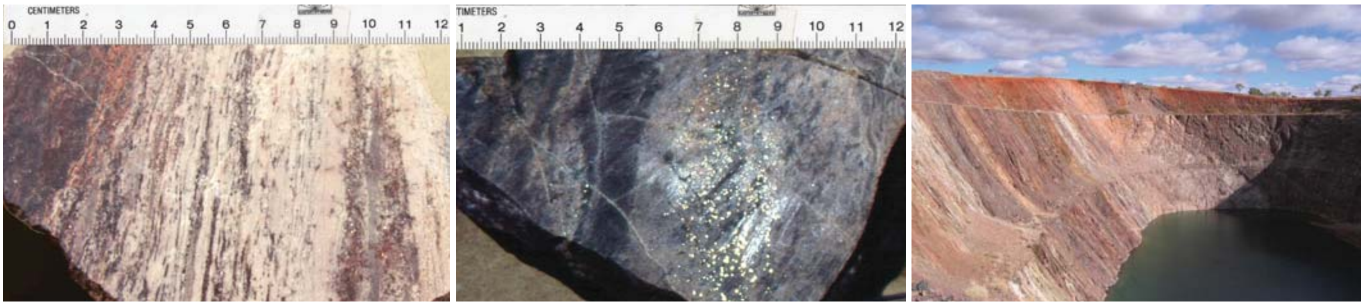
5) Volcanic-hosted massive sulphide

Mount Morgan is one of the more significant historical mines in Australia in terms of total gold and copper production. The Mount Morgan mine, 38 km southwest of Rockhampton, operated from 1883 to 1981 and for a time was the largest gold mine in the world (Photograph 129) and produced 8.4 Moz gold, 4000,000 t of copper and 1.2 Moz silver from the mining of about 50 Mt of ore at a grade of 5.9 g/t gold. Of the tailings, between 1981 and 1991, 28 Mt were re-treated via a 3 Mtpa carbon-in-pulp plant before operations were suspended due to low gold prices and excessive cyanide consumption caused by soluble copper. Total production from 1884 to 1990 recorded ›294 t of gold, ›360 600 t of copper and ›36.8 t of silver. The Mount Morgan deposit is hosted by a belt of Middle Devonian volcanic and sedimentary rocks of the Yarrol Province that forms a roof pendant in a Late Devonian tonalite intrusion. The genesis of the Mount Morgan mineralisation has long been controversial, but the deposit is now widely regarded as being a volcanic-hosted massive sulphide type. The Mount Morgan project was acquired by Norton Gold Fields Limited in 2007. The project was sold to Carbine Resources in April 2014. As part of the right to mine agreement with Norton, Carbine acquired all existing plant and equipment associated with the Kundana CIP plant that Norton decommissioned, refurbished and packed for transport to Mount Morgan from the Paddington mine in Western Australia where it is still located. A scoping study originally commissioned by Norton Gold Fields has outlined a minimum 8 year mine life based on the current JORC resource at the nominal capacity of 1 Mtpa of tailings at Mount Morgan. The proposed operation would produce an estimated 36,000 ounces of gold dore bullion, 850 t of copper cathode and 230,000 t of pyrite concentrate. The 8 year project life is based on an indicated resource (at 30 June 2012) of 2.487 Mt at 1.59 g/t Au and 0.16% Cu and an inferred resource of 5.861 Mt at 1.07 g/t Au and 0.14% Cu. An additional mineral inventory of more than 4 Mt is expected to be sourced from former mine waste material. Tailings testwork by Carbine Resources has successfully resulted in a 81 per cent reduction in cyanide consumption using the selective removal of copper prior to gold recovery, a significant increase in gold extraction to 78%, 56% of the copper and 91% recovery of pyrite to a saleable high-grade concentrate. Flowsheet optimisation work and resource drilling are to be carried out prior to a preliminary feasibility study in 2015.

Photograph 129: Mount Morgan mine site showing the main chimney and former mine buildings (image courtesy DNRM).

6) Shear zone hosted hydrothermal

The Tick Hill deposit, 110 km south-southeast of Mount Isa in the Mount Isa Province, forms a unique but potentially important style of mineralisation. Mineralisation consists of high-grade gold, dominantly in quartz-feldspar laminite bands (Photograph 130a&b) within a broader strongly strained zone comprising quartz-feldspar granofels (colloquially termed 'galahstone') and quartz-scapolite-amphibolite ('lodestone-unit') in the Corella Formation of Cover Sequence 2 in the Eastern Fold Belt Province. Quartzite units flank the ore horizon on the footwall and hanging wall associated with interbedded biotite schists and biotite-magnetite calc-silicates (Photograph 130c). The deposit was mined by Carpentaria Gold Pty Limited between 1992 and 1995 producing 15.9 t of gold at an average gold grade of 22.5 g/t. Superior Resources Limited acquired the rights to Tick Hill in November 2014. The company intends to define a high-grade gold resource similar to that previously mined by Carpentaria Gold. Superior Resources have identified a fault near the bottom of the previously mined gold ore body, which may give opportunity to a similar ore body in an offset position.



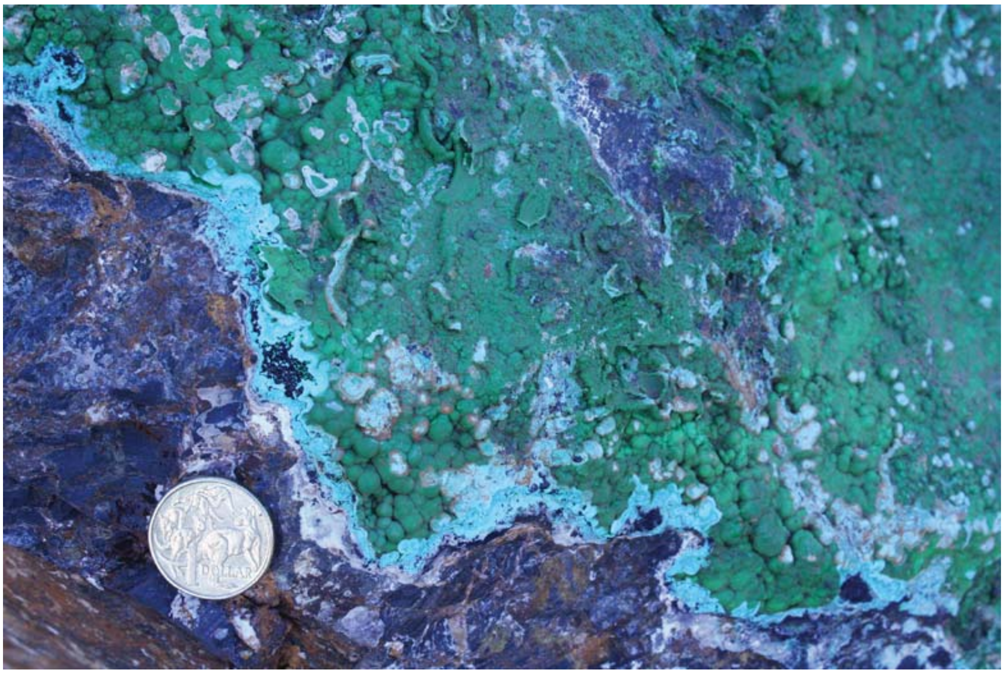
Photograph 130: (a, left) Fine quartz-feldspar laminite bands in Corella Formation, host to the gold mineralisation at Tick Hill; (b, centre) High-grade gold mineralisation in quartz-feldspar laminate bands granofels "galahstone' in Corella Formation at Tick Hill; (c, right) The Tick Hill open cut looking south. The steeply dipping light coloured band of laminated granofels, which holds the gold mineralisation, is distinct at the 'back' of the pit flanked by the quartzites and biotite schists (purple-red colours).

The Lorena gold project 14 km east of Cloncurry is interpreted to be a Proterozoic structurally-controlled hydrothermal stockwork system within the Corella Formation (Photograph 131). This project was acquired by Malachite Resources in February 2011. In November 2012, Malachite Resources executed a joint venture agreement with BCD Resources NL to jointly develop the deposit. BCD is hopeful of having gold concentrate (with a gold grade of around 60 g/t Au) produced for transport to and treatment (benefication to gold dore by bacterial leaching) at its Beaconsfield plant in Tasmania in late 2013. Project construction began in the March 2014 quarter and commissioning is forecast to commence before year end. The Lorena gold project is forecast to mine a head grade of 11 g/t Au to produce around 30,000 ounces of gold from an open cut in its first year of operation. In 2014 Malachite Resources has estimated a measured resource of 105 800 t at 5.3 g/t Au and an indicated resource of 228 200 t at 5.2 g/t Au at the 'A' Lode, and an indicated resource of 8 400 t at 3.6 g/t Au and an inferred resource of 45 000 t at 4.1 g/t Au at the 'B' Lode (all data at cut-off grade 0.5 g/t Au). While the grade is attractive for a small open cut mine of about 100 000 tpa, high-grade gold results have been discovered at depth and other promising gold prospects have been found in the surrounding area. Past production from the open cut mining of the oxidised part (Photograph 132) of the deposit yielded 245.36 kg of gold bullion until 2000.

7) Skarns

Gold-copper skarn mineralisation in the Red Dome – Mungana corridor, north of Chillagoe, also contributes to gold resources and reserves in Queensland. The Mungana and Red Dome gold projects are 15 and 12 km northwest of Chillagoe respectively. The Mungana ore body is regarded as a intrusion-related gold deposit, consisting of high-grade, zinc-rich, polymetallic, skarn-related mineralisation, which appears to be overprinted by low-grade gold ore related to veining in a porphyry system. Red Dome comprises a skarn breccia system related to a porphyry intrusion. Mining of the Red Dome deposit occurred from 1986–1998, producing 22 716 kg of Au, 105 855 kg of Ag and 36 059 t of Cu from 12.2 Mt of ore (Photograph 133). Mining of the ore body had ceased in 1996, but stockpiles continued to be processed until 1998. Mungana Goldmines Limited and Kagara Mining have since delineated new resources. Prior to the company abandoning work, stage one of the Mungana Gold Project feasibility study was completed. The favoured mining option is a 4 Mtpa operation over a 10 year mine life, which has the Red Dome pit extension, the mineable resource of which is 22.8 Mt, as its 'base'. In addition the Mungana open cut mine would contribute 3.4 Mt of ore, the Mungana underground mine a further 7.9 Mt and the Red Dome underground mine 2.4 Mt of ore. About 5.5 Mt of low-grade stockpiles on site also have the potential to be processed. An updated estimate, utilising data from additional drilling and combining the two deposits, uses a 0.35 g/t Au equivalent cut off grade. The total resource is 131.1 Mt at 0.64 g/t Au, 8.07 g/t Ag and 0.21% Cu. It comprises a measured resource of 41.1 Mt at 0.79 g/t Au, 0.29% Cu and 11.63 g/t Ag, an indicated resource of 49.8 Mt at 0.58 g/t Au, 0.18% Cu and 6.7 g/t Ag, and an inferred resource of 40.2 Mt at 0.58 g/t Au, 0.15% Cu and 6.2 g/t Ag. On the 4th of August 2014 Mungana Goldmines Limited completed the acquisition of Kagara's Chillagoe gold assets in North Queensland including the Mungana underground gold body.

Photograph 131: Sulphide mineralisation (arsenopyrite with gold) from an ore lens in the Lorena Gold mine open cut.



Photograph 132: Copper (arsenic) phosphate mineralisation from oxidised zone at Lorena Gold mine.

Photograph 133: Red Dome open pit.

8) Alluvial deposits

Significant alluvial gold production has accompanied hard rock gold mining, particularly in north Queensland goldfields. In many regions, it was the alluvial gold potential that led to the large 'gold rushes' that established the goldfields. The main alluvial gold mining area in Queensland is the Palmer River drainage system (Palmer River Goldfield). The Palmer River drains areas of orogenic gold mineralisation from the Hodgkinson Province, and has produced >33 t of alluvial gold. The Etheridge Goldfield, incorporating the Gilbert River, Percy River and drainage systems around the Kidston deposit, has also been a significant producer, with >5.5 t of alluvial gold. In 2010–11 (2011–12) gold production from various small-owner operated alluvial workings yielded 39.7 kg of Au and 4.3 kg of Ag (55.7 kg of Au bullion — no Ag reported separately) (Photographs 134 and 135).

Photograph 134: Processing of alluvial gravel at the Prophet Gold Mine, Kilkivan.

Photograph 135: Sluice box with carbon matt for collecting fine alluvial gold from gravel at the Prophet Gold Mine, Kilkivan.

At the Miclere Diggings, near Clermont in central Queensland, gold mineralisation is concentrated within basal conglomerates of the Permian Miclere Basin, which lies unconformably on rocks of the Anakie Province. The genesis of this mineralisation remains controversial, with the source of the gold most likely originating from epithermal deposits. Alluvial, deep lead and unconformity-related gold has been historically mined in the area. The Miclere Diggings mining leases are currently held by Plenty Gold Miclere Pty Limited.

Indium

No official production figures for indium are recorded in Queensland, however a 'European Commission Polinares working paper n.39, Fact Sheet: Indium' (2012) reports indium as an estimated by-product of zinc production from Australia. Indium is recovered to about 95% as a by-product of zinc smelting. This working paper cites Roskill Information Services (2010) estimating 470 t of indium being co-produced through world-wide zinc mining in 2009. The average indium content in the world's zinc ore concentrate (sphalerite) is taken as being between 15 and 50 ppm, although this assumption is believed to be conservative. Australia then produced 12.3% of the world's zinc-concentrate production yielding an estimated 29 t of indium. From this total production Queensland roughly produced 63% or 18.3 t of indium for 2009.

Trace metal amounts of indium occur in base metal sulphides, dominantly sphalerite but also chalcopyrite and stannite, by ionic substitution. Indium is most commonly recovered from the zinc-sulphide ore mineral sphalerite. The average indium content of zinc deposits ranges from 1 ppm to 100 ppm. Even though indium can also occur with other base metals — copper, lead and tin — to a lesser extent also with bismuth, cadmium and silver, most deposits of these metals are sub-economic for indium.

Indium can accumulate in a multitude of different deposits. Because of its relatively low average level of occurrence indium is classified as a trace element and can only be extracted as a by-product under appropriate conditions. The most important deposits are base metal sulphide deposits, which are characterised by their metal abundance and a large tonnage. These include volcanic-hosted massive sulphide, sediment-hosted Ag–Pb–Zn, polymetallic vein-type, epithermal Ag-Au and zinc skarns. Reporting on indium production is not available since most zinc-sulphides are sold as zinc concentrates to overseas refineries. The only countries that have the appropriate indium preparation line included in their refinery process are China, South Korea, Japan, Canada, Belgium and Peru. Major zinc-concentrate producers have been discussed in the 'base metals' section, but no direct source for indium has been reported from these deposits.

In the past resource figures were reported for polymetallic sulphide-tin deposits of the Hodgkinson Province, since these are the only deposits that have indium reported as contained commodity. Baal Gammon, which is 65 km southwest of Cairns, is owned by Consolidated Tin Mining Limited, who commenced mining in March 2014, with the ore treated at the company's Mount Garnet plant. At that time, a stockpile of 6368 t of broken ore grading 2.86% Cu and 67.87 g/t Ag was on the ROM pad at the Baal Gammon mine site awaiting trucking to Mount Garnet. Production was subsequently suspended in April 2014 following heavy rainfall associated with Cyclone Ita and the mine placed on care and maintenance. Consolidated Tin Mines Limited signed an asset sale agreement with Snow Peak Mining in October 2014 to purchase the Mount Garnet plant and all tenements associated with Snow Peak's holdings including the Baal Gammon mine. Before Monto Minerals sold Baal Gammon to Snow Peak they had reported indium values in their combined resources. Monto Minerals reported a combined (indicated and inferred) resource of 2.8 Mt of ore at 0.996% Cu, 0.199% Sn, 18 g/t Ag and 39 g/t In (metal content: Cu 28 000 t, Sn 5572 t, Ag 50 400 kg, In 109 200 kg). All of these metals are expected to report in the concentrate.

Isabel is an abandoned mine about 60 km southwest of Cairns which is also classed as a polymetallic sulphide-tin deposit of the Hodgkinson Province. Small pods of almost pure Ag-Pb-Zn occur along a general zone of fracturing. Sphalerite and galena are infill minerals in large vug systems. Indium is reported to be associated with sphalerite. This deposit has a pre-JORC combined resource of 48 000 t at 140 g/t Indium with a metal content of 6720 kg. Other deposits in the Irvinebank–Herberton and Mount Garnet areas are Arbouin, Black Sparkle, Orient Camp, Weinert and Khartoum.

Roskill Information Services Ltd., 2010: Indium: Global industry markets and outlook (9th ed.). London, United Kingdom, Roskill Information Services Ltd., p. 142.

European Commission, European Research Area: POLINARES Consortium 2012: Polinares working paper n.39, March 2012, Fact Sheet: Indium, Version 1.10.

Ironstone and magnetite

Up to 2008 no iron ore was produced within Queensland since the Mount Biggenden mine ceased to produce magnetite in 1999. Mount Moss commenced magnetite production in 2008 (Photograph 136). A first shipment of magnetite from Ernest Henry was bound for Asia's steel industry in June 2011. Queensland's production figures for 2011–12 (2012–13) totalled 811 327 t (634 508 t) of magnetite and iron oxide ore.

The Ernest Henry deposit represents a structurally-controlled Proterozoic iron oxide–Cu–Au (Iron oxide Cu–Au) mineralisation style, which occurs mainly in the Eastern Fold Belt Province of the Mount Isa Province. Primary iron-rich mineral associations comprise oxidised magnetite, hosted in variably altered, brecciated felsic volcanic rocks with primary mineralisation forming a magnetite-carbonate gangue. Magnetite makes up 20–25% of the primary ore. At Ernest Henry magnetite was liberated during the copper-gold concentrating process and was traditionally discarded as tailings. Following the reconfiguration of the existing concentrator to align with the underground mine production rate, a separate extraction circuit was built to recover the magnetite from the concentrator tailings stream. The plant also provided the opportunity for the reprocessing of existing mine tailings in the future to extract magnetite, potentially enabling a reduction in the amount of tailings stored and a further extension of mine life. The latest total (probable, proven) open cut resource was 17 Mt at 22.59% magnetite and the total underground (measured, inferred and indicated) resource is 88 Mt at 27.89% magnetite. Design, construction and initial testing, including initial production of 1.2 Mt per annum magnetite facility base plant at Ernest Henry mine, have been completed and the plant was commissioned in the second quarter of 2011. The planned mine life was to at least 2024. In June 2013 the magnetite production was suspended to the increasing

Photograph 136: Primary (unoxidised) iron ore concentrate at -70µm (>63% Fe) produced at Mount Moss, (this product is used in the coal washing industry or as sinter cake in the steel refining industry).

Ironstone and magnetite

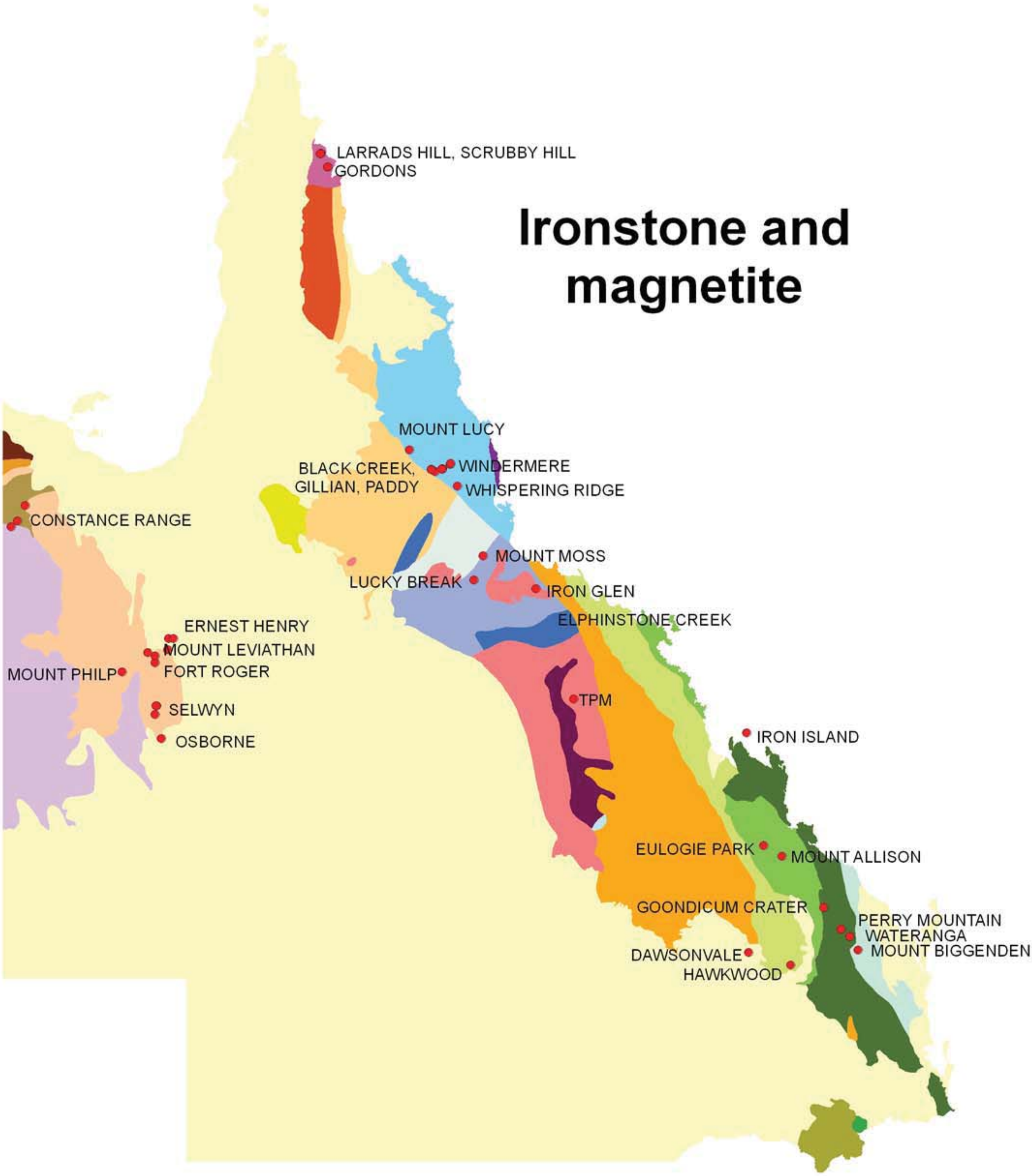


Table 9. Major ironstone and magnetite deposits in Queensland

Deposit Name	Location	Total resources	Production
Constance Range — Deposit A	250km NNW of Mount Isa	236.4 Mt at 53.2% Fe	
Constance Range — Deposit I	270km NNW of Mount Isa	21 Mt at 42.2% Fe	
Constance Range — Deposit P	255km NNW of Mount Isa	44 Mt at 46.3% Fe	
Dawsonvale	26km E of Taroom	199 Mt at 37.5% Fe	
Ernest Henry (underground)	38km NE of Cloncurry	88 Mt at 27.89% magnetite	778°801°t magnetite
Fort Roger	14.8km S of Cloncurry	1 Mt hematite, 0.23 Mt magnetite	
Hawkwood	29km NE of Auburn	103.7 Mt at 13.8% Fe, 0.05% V and 1.83% Ti	
Goondicum Crater Ilmenite	100km SW of Gladstone	2.26 Mt titano-magnetite	4900t titano-magnetite
Iron Island	135km SE of Mackay	2 Mt magnetite	
Larrads Hill	27km NW of Portland Roads	2.69 Mt at 46.1% Fe and 2.5% Mn	
Las Minerale (Rocklands)	15km W of Cloncurry	8.4 Mt at ~26% Fe	
Mount Biggenden	38.4km ENE of Gayndah	Essentially mined out	
Mount Leviathan	3.6km WSW of Cloncurry	2 Mt at 57% Fe	
Mount Moss	100km W of Townsville	20 Mt at 41% Fe	952°111°t magnetite (reg) 41°734°t magnetite (Coking grade)
Mount Philp	54.4km ESE of Mount Isa	19.1 Mt at 41.4% Fe (indicated) 11.4 Mt at 33.8% Fe (inferred)	
Osborne	195km SE of Mount Isa	15.5 Mt tailings at 35% magnetite	
Perry Mountain Ironstone	6.3km ESE of Mount Perry	101 600 t at 34% Fe	
Scrubby Hill	30km NW of Portland Roads	100 000 t at 33.4% Fe and 14.3% Mn	
TPM	5.4km SSW of Mount Coolon	60 960 t magnetite	
Whispering Ridge Magnetite Prospect	37km S of Ravenshoe	Confidential	

production and transport costs and the eroded margins to global iron ore prices. Total production of magnetite ore from Ernest Henry totalled 763 385 t of magnetite up to 2012.

The Osborne deposit, like Ernest Henry, is a structurally-controlled Proterozoic iron–oxide–Cu–Au deposit in the Mount Isa Province with an oxidised magnetite mineralisation. The Chinova Resources Limited owned Osborne has reported inferred resources of 15.5 Mt at 35% magnetite.

Mount Moss is a skarn-related magnetite deposit, 105 km northwest of Townsville, which was acquired by Curtain Brothers Queensland Pty Limited in 2005. The company outlined an inferred resource in February 2009 of 20 Mt at 41% iron, 0.35% Cu and 0.35% Zn. A geological review of the operation is currently underway which will update this figure and indicate the potential for associated by-products including limestone, copper and zinc. Open cut mining commenced on the Willett’s Knob deposit in 2007 (Photograph 137). Mount Moss Mining processes stockpiled magnetite ore through two separate beneficiation circuits to produce a range of saleable product streams. These include magnetite lump suitable for feed stock in the steel-making industry and magnetite fines suitable for use as sinter cake feed in the steel-making industry or heavy medium in the pipe weight-coating industry. In addition, coal-washing magnetite powder is produced and sold mainly to coal-preparation plants in central Queensland although the product can also be used for the production of pellets used in the steel-making industry. Total production of magnetite between 2008 and 2012 was 476 807 t of general magnetite and an additional 39 081 t of ‘coal washing’ quality magnetite (Photograph 138) between 2010 and 2012. A total of 5165.5 t of crushed limestone was produced as by-product. The March 2013 resource was reported as 11 Mt at 44.51% iron in total comprising 1.59 Mt at 42.12% iron oxide and 9.42 Mt at 44.92% iron fresh.

Photograph 137: Open pit of Mount Moss magnetite mine.

Photograph 138: Magnetite screening plant at Mount Moss.

The Hawkwood and Eulogie deposits located about 50 km southwest of Eidsvold and about 200 km southwest of Gladstone are held by Eastern Iron Limited in joint venture with Rugby Mining Pty Limited. The ore bodies are associated with a magnetite-bearing ferrigabbro within a layered basic igneous complex within the Rawbelle Batholith (Photograph 139). In May 2012 Eastern Iron Limited released a maiden inferred resource for Hawkwood of 103.7 Mt at 13.8% Fe, 1.82% TiO_2 and 0.05% V_2O_5. A high quality magnetite concentrate grade of 64.6% Fe, 0.6% V_2O_5 and 1.6% TiO_2 was achieved in a Davis Tube Recovery (DTR) analysis. The Eulogie magnetite-titanium-vanadium deposit 50 km west of Gladstone that was wholly owned by Eastern Iron Limited has been relinquished.

Additional moderate resources have been delineated (Table 9). The main area of ironstone mineralisation in Queensland is in the Constance Range area, in northwest Queensland. BHP explored the Constance Ranges from 1956 to 1963 and delineated 15 iron deposits over a strike length of 100 km but ceased work when the Pilbara iron ore province in Western Australia was discovered. Up to ten lenticular beds of iron formation, with interbedded shale, siltstone and sandstone, form the Train Range Ironstone Member of the South Nicholson Group in the South Nicholson Basin. Outcropping ironstones consist of a variable mixture of ochrous red hematite, finely crystalline blue-black hematite, limonite, quartz grains and cement, clay and relict siderite, and vary in appearance from oolitic forms to quartz sandstone with hematite matrix. Below the zone of oxidation, the ironstones comprise oolites of hematite, siderite and/or chamosite and silica grains in a matrix of siderite, hematite, quartz and carbon. Exploration by the Broken Hill Proprietary Company Ltd in the early 1960s outlined three main resources: Deposit A, Deposit I and Deposit P. In 2007,using a cut-off grade of 49% iron, CBH Resources Limited established an inferred resource at the largest deposit known as Deposit A. Outside of the National Park, but within a 1 km buffer zone from the boundary, it delineated 132 Mt at 53.1% iron, 10.5% SiO_2, 0.02% phosphorous, 2.1% Al_2O_3 and 11.1% loss on ignition. Outside this buffer zone, 104 Mt at 53.4% iron, 10.1% SiO_2, 0.02% phosphorous, 1.0% Al_2O_3 and 11.2% loss on ignition were delineated. This deposit is currently held by the Viento Group subsidiary

Photograph 139: Magnetite bearing ferrigabbro within layered basic igneous complex within Rawbelle Batholith in Delubra Quarry, Hawkwood deposit.

Qld Iron Pty Ltd (70%) and KBL Mining Limited (30%). KBL estimates a potential exploration target for about 8 Mt of 56.5% iron may be available for a direct shipping project using truck haulage to Burketown. In May 2011 the Constance Range Iron Ore Alliance was launched through a memorandum of understanding of strategic cooperation between four of the holders of other tenures, the Viento Group, Icon Resources Limited, Resolve Geo Pty Ltd and Australian Minerals and Mining Group Ltd (now renamed Altec Chemicals Limited) with a view to advancing their interests in the region though a coordinated approach. In 2012, Australian Minerals and Mining Group Limited calculated an inferred resource of 6.1 Mt at 39.9% iron at BHP historical Deposit D and has entered into an agreement to acquire BHP historical Deposits I and J from Icon Resources Ltd. Deposit D is the closest deposit to the infrastructure at the Century zinc mine, about 40 km to the southeast.

Oolitic ironstone occurs in the Jurassic Evergreen Formation at Dawsonvale in the Mundubbera region. In the Dawsonvale area, prominent plateaus and scarps with residual mesas extend from Gebe Mountain in the northwest to Mount Misery in the southeast. The mesas are flat-topped ironstone formation ranging from 5–30 m in height, and have a reddish soil cover. The ironstone formation occurs in flat-lying sandstone of the Evergreen Formation and consists of two distinct subunits. The basal subunit consists of thick-bedded oolitic ironstone and large spheroidal concretionary hematitic structures. The upper subunit is interlayered hematitic oolitic ironstone and limonitic sandstone. A scarp marks the basal contact of the ironstone unit. The oolitic ironstone at Dawsonvale is a type of sandy, clayey and oolitic sediment deposited in a shallow inland sea. The deposits are generally a few metres thick and chert-poor, but are rich in phosphorous and aluminium.

Magnetite is used by the Queensland coal industry as a heavy media in the coal washing process. Until 1999, most of the magnetite used in southeast Queensland was supplied from the Mount Biggenden deposit, a magnetite skarn deposit in the Gympie Province that is associated with intrusives of the South-East Queensland Volcanic and Plutonic Province (Photograph 140). Mount Biggenden is now mined out and magnetite for coal washing has been imported. Mount Moss has recently commenced production of this commodity as discussed earlier. Mount Biggenden produced 740 462 t of magnetite from 1942 to 1999.

Magnetite skarns occur throughout the Tasman Orogenic Zone, as do magnetite-bearing layered gabbro complexes (*e.g.* Goondicum, Hawkwood). Significant magnetite resources are also associated with many of the iron oxide-copper-gold deposits and hematite-magnetite ironstone lenses and bodies in the Eastern Fold Belt Province of the Mount Isa Province. Barrick Gold Corporation is investigating the possibility of producing magnetite from tailings and from future mining operations at its Osborne mine.

The Rocklands project (Las Minerale) held by CuDeco stands to produce magnetite concentrate as they have evaluated a separate inferred resource for magnetite in addition to their copper resources. CuDeco reported the magnetite only inferred resource for the Rocklands project in November 2013 at 10% magnetite cut-off of 328 Mt at 0.02%Cu, 70 ppm Co, 0.01 g/t Au and 26.6% magnetite yielding approximately 47 Mt of contained magnetite.

Photograph 140: Biggenden open cut and underground portal in 2009.

The hematite schists within the Sefton Metamorphics ('banded iron formations' — mislabelled in early company reports) of the Iron Range Province in far north Queensland also contain magnetite. However, most magnetite occurrences do not have ore that meets the specifications for dense medium coal washing purposes. Titano-magnetite from the Goondicum mine was being trialled as a dense medium for coal washing by Monto Minerals before the mine was placed under voluntary administration. Now Belridge Enterprise has re-opened the mine (as discussed under 'Rutile, ilmenite and zircon'). Cerro Resources also holds the Mount Philp haematitic iron deposit 6 km northwest of Kalman and has outlined an indicated resource of 19.1 Mt at 41.4% Iron and 37.9% SiO_2, and an inferred resource of 11.4 Mt at 33.8% Iron and 47.7% SiO_2.

Lithium, tantalum and niobium

No resources of lithium, tantalum or niobium have yet been recognised in Queensland. Lithium, tantalum and niobium have been recorded in mineralisation assemblages at Grants Gully and Buchanan's Creek. These deposits are in alluvial sediments sourced from Proterozoic rocks which host swarms of pegmatite dykes containing Ta, Li and Nb. A sample of concentrate contained 34.4% Ta, 21.68% Nb and 0.825% Sn.

Lithium also occurs in association with rare earth elements in a duricrust in the Camel Creek Province, believed to be leached from glassy volcanic rocks to form a manganese oxide cemented sandstone. Lithium-bearing minerals have been reported associated with tin mineralisation in the Stanthorpe region. Lithium and tantalum are regarded as strategic minerals in Queensland.

Mercury

The majority of Queensland's historic production and known resources of mercury are in the Kilkivan area in southeast Queensland, where mercury occurs in epithermal systems confined to north-northwest-trending fracture zones, predominantly within the Neara Volcanics. The mineralisation comprises cinnabar veinlets and disseminations in multiphase carbonate quartz veins. The carbonates are mainly ferroan ankerite and calcite, with lesser late-stage coarse calcite and minor dolomite and siderite. Narrow alteration envelopes characterised by pervasive carbonatisation, with lesser silicification, sericitisation, argillisation and chloritisation, enclose the veins. The largest producers were Cirsons (4.17 t Hg) and Commotion (5.62 t Hg).

The Commotion Alluvial and Eluvial Cinnabar deposit, west of Kilkivan, is the most significant mercury resource identified in Queensland. It is estimated to contain 611 644 m^3 at a grade of 454g/m^3 mercury and comprises alluvial and eluvial material derived from cinnabar-bearing veins in diorite of the South-East Queensland Volcanic and Plutonic Province. This resource is poorly defined from historical literature.

A small hard rock mercury resource (probable reserve of 7000 t at 907 g/t Hg) has been defined at the ML108 deposit, northwest of Kilkivan.

Molybdenum and rhenium

In Queensland, within the traditionally known molybdenum deposits, the metal occurs as an accessory phase associated with porphyry-style mineralisation, intrusive-related tin and tungsten deposits and uranium deposits. Up to 2009 molybdenum was

Molybdenum - Rhenium

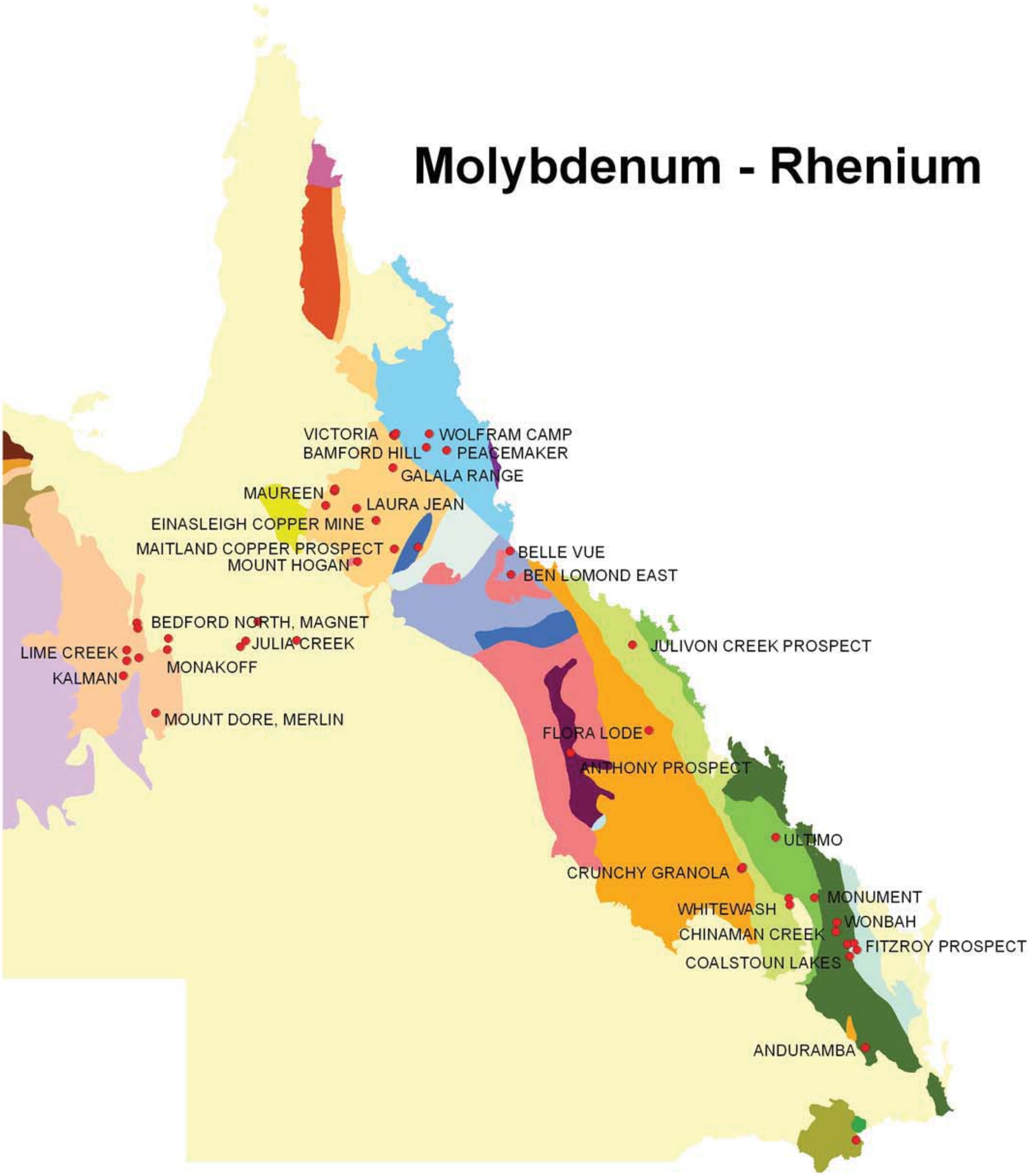


Table 10. Molybdenum and rhenium deposits of Queensland

Name	Total recorded production	Contained metal in remaining resource	Principal mineralisation style	Formation/ Province
Anduramba Prospect		17 083 t Mo 149 395 kg Ag 4338 t Cu	Porphyry	Eskdale Granodiorite/ South East Queensland Volcanic and Plutonic Province
Anthony		121 940 t Mo	Porphyry	Anakie metamorphics/ Anakie Orogen
Bamford Hill	170 t molybdenite 2000 t wolframite 20 t bismuthinite		Greisen	Bamford Granite/ Kennedy Province
Far West 5		163 t Mo	Stratabound U-Cu	Gilberton Formation/ Gilberton Basin
Far West 7		108 t Mo	Stratabound U-Cu	Gilberton Formation/ Gilberton Basin
Julia Creek Vanadium-Molybdenum Prospect (Alisona-Richmond and St Elmo- Burwood)		2 053 374 t molybdenite	Oxidised oil shale	Toolebuc Formation/ Eromanga Basin
Julivon Creek Prospect		3850 t Mo 54 600 t Cu	Porphyry	Hecate Granite/ Urannah Batholith
Kalman		41 910 t Mo 164 610 t Cu 8326 kg Au 110 000 kg rhenium	Shear zone-hosted veins	Corella Formation/ Eastern Fold Belt Province
Linfield		Not available	Oxidised oil shale	Toolebuc Formation/ Eromanga Basin
Maitland Copper Prospect	293 t Cu 18 kg Ag	294 t Mo 22 041 t Cu	Shear-hosted	Einasleigh Metamorphics/ Etheridge Province
Maureen		2028 t Mo 2980 t U_3O_8	Stratabound U-Cu	Gilberton Formation/ Gilberton Basin
Merlin (including Little Wizard)		97 773 t Mo 171 258 kg rhenium	Shear zone hosted breccia	Kuridala Formation/ Quamby–Malbon Subprovince
Monument		1243 t Mo 32 088 t Cu	Skarn	Rockhampton Group/ Yarrol Province
Mount Dore		14 440 t Mo 14 440 kg rhenium	Shear zone hosted breccia	Kuridala Formation/ Quamby–Malbon Subprovince
United Allies	2 t Cu	388 t Mo 9870 t Cu	Porphyry Cu–Mo–Au	Rockhampton Group/ Rockhampton Subprovince
Victoria	29 t Pb 25.5 kg Ag 34 t Cu	51 t Mo 76 490 kg Ag 175 020 t Zn 38 160 t Cu 489 kg Au	Skarn	Chillagoe Formation/ Hodgkinson Province
Whitewash/ Gordons		69 479 t Mo 453 590 kg Ag 468 853 t Cu	Porphyry Cu–Mo–(Ag)	Wingfield Granite/ Rawbelle Batholith
Wolfram Camp Tungsten	217.42 t molybdenite 7971.69 t wolframite 1535 t bismuthinite	1718 t Mo 8528 t tungstic oxide	Greisen	Fames Creek Granite/ Kennedy Province
Wonbah Molybdenite	100 t molybdenite	51 t molybdenite	Molybdenite- quartz pipe	Wonbah Granodiorite/ South East Queensland Volcanic and Plutonic Province

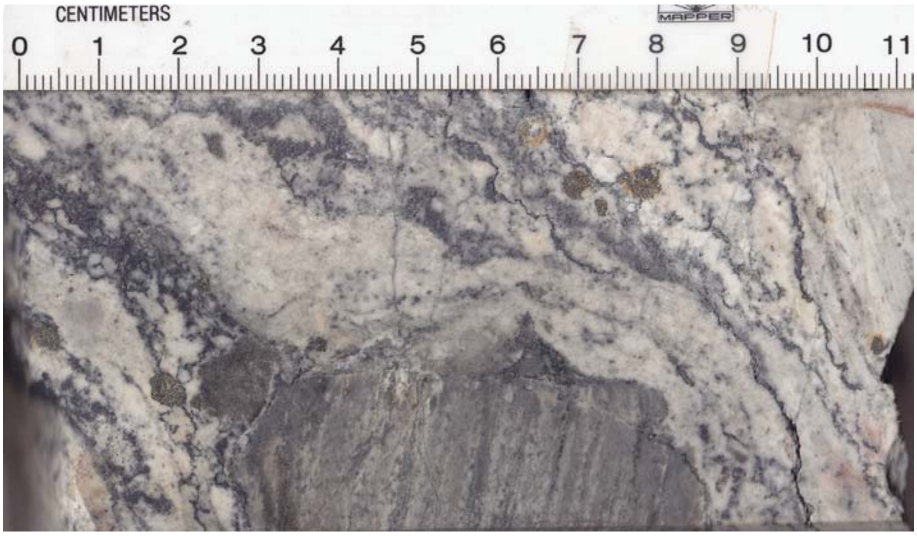
not mined as a primary commodity in Queensland. By-product metal was produced from Bamford Hill, Wolfram Camp and Wonbah totalling 430 t of Mo. The major significant resources of molybdenum related to the porphyry and intrusive-style mineralisation are at Anduramba, Wolfram Camp, Ben Lomond, Ben Lomond East, Maureen and Monument (Table 10).

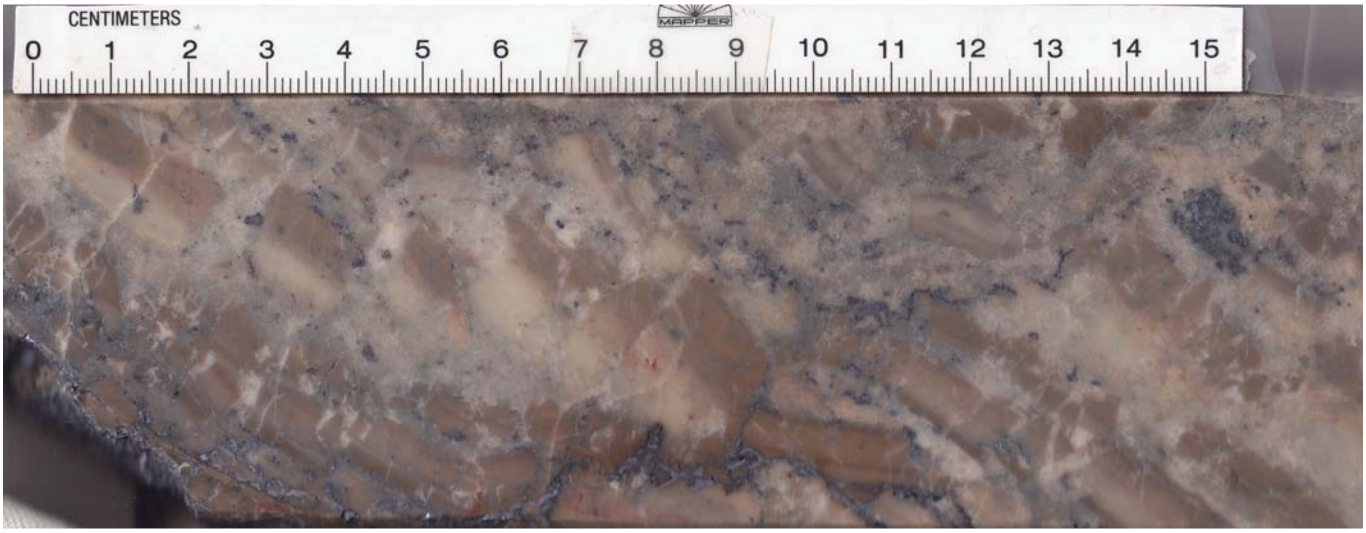
With the discovery of several new high grade molybdenum and rhenium deposits a significant boost to Queensland and world resources in molybdenum and rhenium have been unlocked. These significant new discoveries include the world-class Merlin molybdenum rhenium deposit, the Kalman copper molybdenum project and the Anthony molybdenum prospect. In 2008–09 new total production in Queensland of 25 t of molybdenum concentrate was reported. No new figures were reported for 2009–2012. In 2014 Wolfram Camp reported 28.4 t of Mo produced as by-product. Rhenium has been identified as a strategic metal in Queensland.

The deposit style for the molybdenum and rhenium at Merlin (including the Little Wizard zone) and Kalman is considered to be new for Queensland and the world. Rhenium occurs together with molybdenum as breccia infill in carbonaceous metasediments with associated disseminations and styolites hosted by a late fault system (Photographs 141 and 142). Inova Resources (formerly Ivanhoe Australia Limited) had chosen not to go into production at Merlin in 2012–13 but after the acquisition by Chinova Resources in 2014, they in turn are starting preparations for production in 2015.

Merlin, which is classed as the world's highest grade molybdenum and rhenium deposit, is south of Cloncurry, underneath the Mount Dore copper deposit. Merlin was a totally unexpected blind discovery made while Ivanhoe Australia Ltd was conducting resource drilling of the Mount Dore project. An east-dipping tabular body of molybdenite formed as breccia infill, disseminations and styolites within carbonaceous metapelites and metasiltstones of the Kuridala Formation. The ore body is hosted by a late fault within the Mount Dore Fault Zone. Inova Resources was conducting a scoping study covering an underground mine, molybdenum concentrator and roaster at Merlin in 2013. The indicated and inferred resource at Merlin is 6.7 Mt at 1.33% Mo and 23.2 g/t rhenium. This resource contains approximately 89 700 t of Mo and 155 t of rhenium. Additionally, a zone of bonanza grade molybdenite was discovered about 90 m below surface and 55 m west of a proposed decline into the Merlin deposit. This zone

Photograph 141: Fault breccia infill in highly altered metasediments with molybdenite and rhenium mineralisation from the Merlin deposit.





Photograph 142: Porphyry breccia with earlier chalcopyrite veinlets and later-stage molybdenite and rhenium mineralisation veinlets from Merlin deposit.

has been called the Little Wizard and has an inferred resource estimate of 15 000 t at 6.5% Mo and 84 g/t rhenium. The Little Wizard zone could potentially host a direct shipping operation before a concentrator is built in Merlin. Plans for commencement of production were set for 2013, but may now succeed in 2015. The Merlin development plan included the option of a roaster being built in Townsville or Asia to process the molybdenum concentrate. Approximately one third of the estimated capital cost for Merlin (about $345 m in total) is associated with building the roaster to process the molybdenum concentrate and enable rhenium capture. Inova Resources sold all tenements and operations in the Cloncurry area to Chinova Resources in 2014.

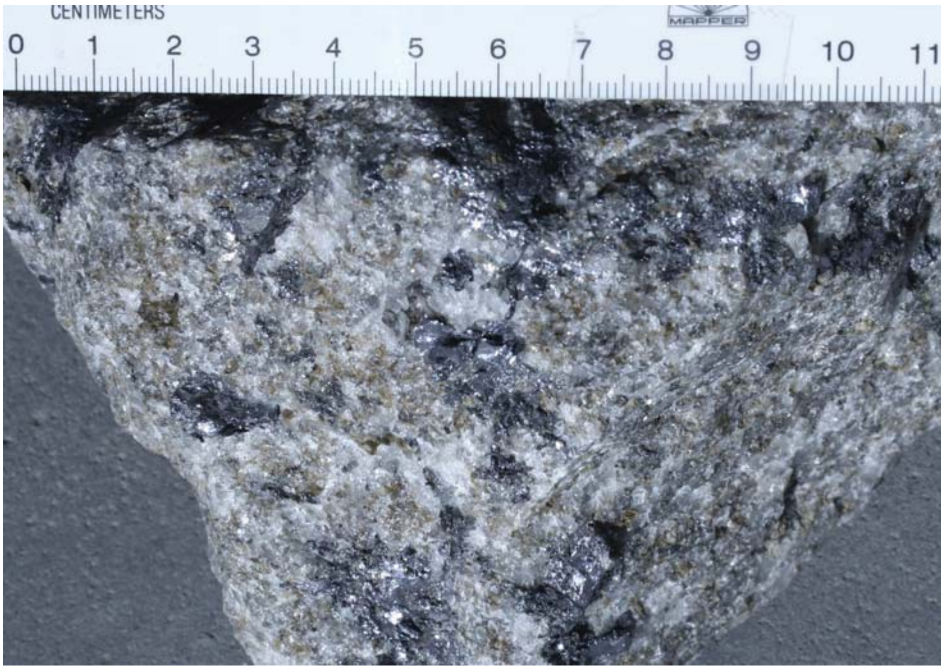
Since purchase of the Inova tenements in 2014, no additional exploration by Chinova Resources in the area has been reported. Exploration results released in 2009 by Inova Resources included a drill intercept at Lanham's Shaft, approximately 50 km north of Merlin contained 36 m at 1.08% Mo and 1.69 g/t rhenium from 116 m, including 18 m at 2.15% Mo and 3.37 g/t rhenium.

The Kalman copper molybdenum prospect, 60 km southeast of Mount Isa, was discovered in 2006 by Kings Minerals NL and is now held by Hammer Metals Limited. Wide zones of copper, molybdenum, gold and rhenium were identified in a major shear zone along the Pilgrim Fault. An inferred resource of 30 Mt at 0.54% Cu, 0.08% Mo, 2.2 g/t rhenium, 0.28 g/t Au and 1.3 ppm Ag has been identified. Of this total, the open cut resource is 22 Mt at 0.42% Cu, 0.07% Mo, 1.9 g/t rhenium, 0.22 g/t Au and 1.1 ppm Ag and the underground resource is 8.3 Mt at 0.87% Cu, 0.11% Mo, 2.9 g/t rhenium, 0.42 g/t Au and 2.0 ppm Ag. Early stage mining studies at Kalman are evaluating the potential for the development of an open pit mine followed by an underground development on the deeper higher grade sections of the deposit. This deposit is still at an early feasibility stage.

Zamia Metals Ltd has completed a scoping study on the Anthony molybdenum project 67 km north-northwest of Clermont. Mineralisation at Anthony is related to a porphyry molybdenum copper system. Zamia has reported an inferred sulphide resource of 250 Mt at 0.039% Mo in sulphide ore body (0.02% Mo cut-off grade). The primary deposit (oxide – transition zone) is below a zone 60 to 80 m from the surface that consists of molybdenum oxide and mixed sulphide-oxide. The inferred mixed sulphide-oxide resource is 13 Mt tonnes at 0.04% Mo. The inferred oxide resource is 53 Mt at 0.037% Mo. The resource consists of higher-grade zones of sulphide and oxide material within larger lower-grade zones, with the near-surface higher-grade zones likely to be mined first. Zamia Metals Ltd has stated that preliminary metallurgical test work indicates that a simple pre-concentration process is likely to be used to upgrade mined ore with an average grade of 450 ppm molybdenum to about 1000 ppm.

The Anduramba Prospect, west-northwest of Brisbane, is a porphyry molybdenum system with inferred and indicated resources of 31.6 Mt at 0.05% Mo, 0.014% Cu and 4.7 g/t Ag. D'Aguilar Gold Ltd is carrying out a feasibility study at this prospect.

Wolfram Camp, 16 km north of Dimbulah, west of Cairns, has a measured-indicated-inferred resource of 1.42 Mt at 0.12% molybdenum and 0.60% tungstic oxide. Molybdenum, tungsten and bismuth mineralisation occurs as numerous, irregular, branching pipes in greisen zones in the roof zone of the highly fractionated, late Carboniferous James Creek Granite (Kennedy Province). Molybdenite is concentrated along pipe margins (Photograph 143). In 2009 Planet Metals Ltd took over ownership of this project with a view to returning it to production. In September 2011 Deutsche Rohstoff AG completed acquisition of Wolfram Camp and in December 2011 the company commenced production of tungsten and molybdenum concentrates from an open cut. They were mining an open cut reserve of 730 000 t at 0.77% WO_3 and 0.056% MoS_2 (2011 numbers). This followed a re-evaluation of plant and mining procedures and the introduction of an X-ray sorter. The operator Wolfram Camp Mining had concentrated on the tungsten production only in 2012 and 2013. The Canadian company Almonty Industries Inc has acquired Wolfram Camp in 2014 and recommenced producing molybdenite, including material which was stockpiled by the previous owners. As part of its acquisition process Almonty carried out a detailed analysis of historical exploration data and confirmatory due diligence sufficient



Photograph 143: Crystalline platy molybdenite from pipe margins of intrusive quartz lodes into greisenised granite from the Wolfram Camp mine.

Photograph 144: Remains of the headframe and the mullock heap of the Wonbah Molybdenite mine, near Mount Perry.

to convert the historical data into a NI 43-101 technical report dated March 31, 2014. As a result, Almonty have calculated an indicated resource of 423 000 t at 0.20 % WO_3 and 0.04 MoS_2 and an inferred resource of 1 048 000 t at 0.21% WO_3 and 0.06 MoS_2. The probable reserves are 234 000 t at 0.19 WO_3 and 0.038 MoS_2. The resources has a cut off of 0.10% WO_3 and the reserve a cut-off of 0.09% WO_3. The indicated resource and the reserve are open cut constrained and the resources are inclusive of the reserves.

Small molybdenum resources are associated with stratabound uranium–fluorite mineralisation at Maureen, Far West 5 and Far West 7, north of Georgetown. Mineralisation is confined to relatively coarse, fluviatile arkosic sediments of the Gilberton Formation (Gilberton Basin).

The Monument prospect, west of Bundaberg, is a copper skarn that contains an inferred resource of 8.022 Mt at 0.4% Cu and 0.02% Mo. It is hosted by sandstone and siltstone of the Rockhampton Group (Yarrol Province). Mineralisation is related to a Permo-Triassic granodiorite intrusion. Mount Cannindah Mining Pty Ltd holds a mining lease over the prospect. The United Allies porphyry Cu–Mo deposit, near Monto, is also hosted by the Rockhampton Group and is held by Mount Cannindah Mining. It has an inferred resource of 1.97 Mt at 0.5% Cu and 0.02% Mo.

Bamford Hill, near Chillagoe, was an important historical molybdenite producer. Molybdenite, wolframite and bismuthinite occur in sheeted quartz veins and pipes associated with a greisen zone on the contact of the Bamford Granite (Kennedy Province). Queensland Ores Ltd is currently exploring this prospect for additional resources.

The Wonbah Molybdenite mine, near Mount Perry in southern Queensland, was another important historical molybdenite producer (Photograph 144). Historical production yielded 100 t molybdenite together with 248 t of lump silica. Molybdenite occurs in a roughly cylindrical, steeply dipping quartz pipe in Late Triassic Wonbah Granodiorite (South-East Queensland Volcanic and Plutonic Province).

Potentially significant molybdenum resources occur within the Julia Creek oil shale deposits in the Cretaceous Toolebuc Formation of the Eromanga Basin in northwest Queensland. Intermin Resources Ltd has estimated that the oil shales contain 1 917 032 t of molybdenite.

Kings Minerals NL has delineated significant molybdenum resources at its Kalman Cu-Au-Mo prospect, southeast of Mount Isa. Total inferred resources of 60.8 Mt at 0.05% Mo were reported in 2011.

Nickel, cobalt and scandium

Until 2012, Queensland's nickel–cobalt production came from either imported ores or as a by-product of treating base metal ores. Queensland Nickel Group, purchased by Clive Palmer in 2009 from Queensland Nickel Pty Ltd, is Queensland's sole producer of nickel and treats imported ores at its Palmer Nickel and Cobalt Refinery (formerly Yabulu Nickel Refinery) near Townsville (Photograph 145). In November 2012 the Queensland Nickel Group started production of nickel laterite from the Brolga nickel mine, approximately 55 km north of Rockhampton. In 2014 new production of 41 t of nickel from Queensland was reported. The company will use the ore to supplement overseas sourced nickel ore as feedstock for the Palmer Nickel and Cobalt refinery outside Townsville. Queensland Nickel Pty Ltd reported that 75 Mt ore supply trade milestone between Queensland Nickel and the Port of Townville was reached in May 2013. The Sun Metals zinc smelter, also at Townsville, produces minor by-product cobalt and nickel.

Nickel and cobalt occur in two basic forms in nature:

- as sulphides in primary deposits
- as oxides and silicates in laterite.

Most of Queensland's nickel–cobalt resources (Table 11) are contained in lateritic deposits formed by weathering of nickeliferous serpentinites and other ultrabasic rocks. Current Queensland laterite resources and reserves contain >1.3 Mt of nickel and >140 000 t of cobalt. At Metallica Metal's SCONI project at Greenvale and Lucknow scandium resources were identified containing >1 390 000 t. Recognized as one of the most valuable of the 17 rare earth elements (REE), scandium (Photograph 146) now plays an important role in the Ni-Co & Sc projects sourced from laterite deposits in northern Queensland. Scandium has been recognised as a strategic metal in Queensland. Lateritisation involves the movement of groundwater through the nickeliferous rock and the dissolution of small quantities of metal from the mineral assemblage. These mobile metals migrate and redeposit lower down in the weathering profile. Typically, laterite comprises an upper zone in which nickel is combined with iron oxides (limonite zone), and a lower zone where nickel occurs in complex magnesium-rich silicates (saprolite zone). The only mining of nickeliferous laterite in Queensland has occurred at Greenvale, Lucknow and Brolga in northern and central Queensland. Mining at Brolga recommenced in 2012 and Metallica Minerals' Greenvale and Lucknow deposits are in development stage constituting the SCONI project.

The largest unexploited nickel and cobalt laterite resources in Queensland are located in the Marlborough district, 90 km northwest of Rockhampton. The Marlborough deposits form about 13 discrete nickel laterites, about 20 km south of Marlborough. These deposits are post–mid-Cretaceous lateritic enrichments of serpentinised peridotite of the Marlborough Block (Wandilla Province).

Photograph 145: Yabulu nickel refinery; stockpile of imported nickel laterite (courtesy DNRM/ QNI Pty Ltd (Queensland Minerals and Petroleum Review, 2003–2004).

Nickel - cobalt

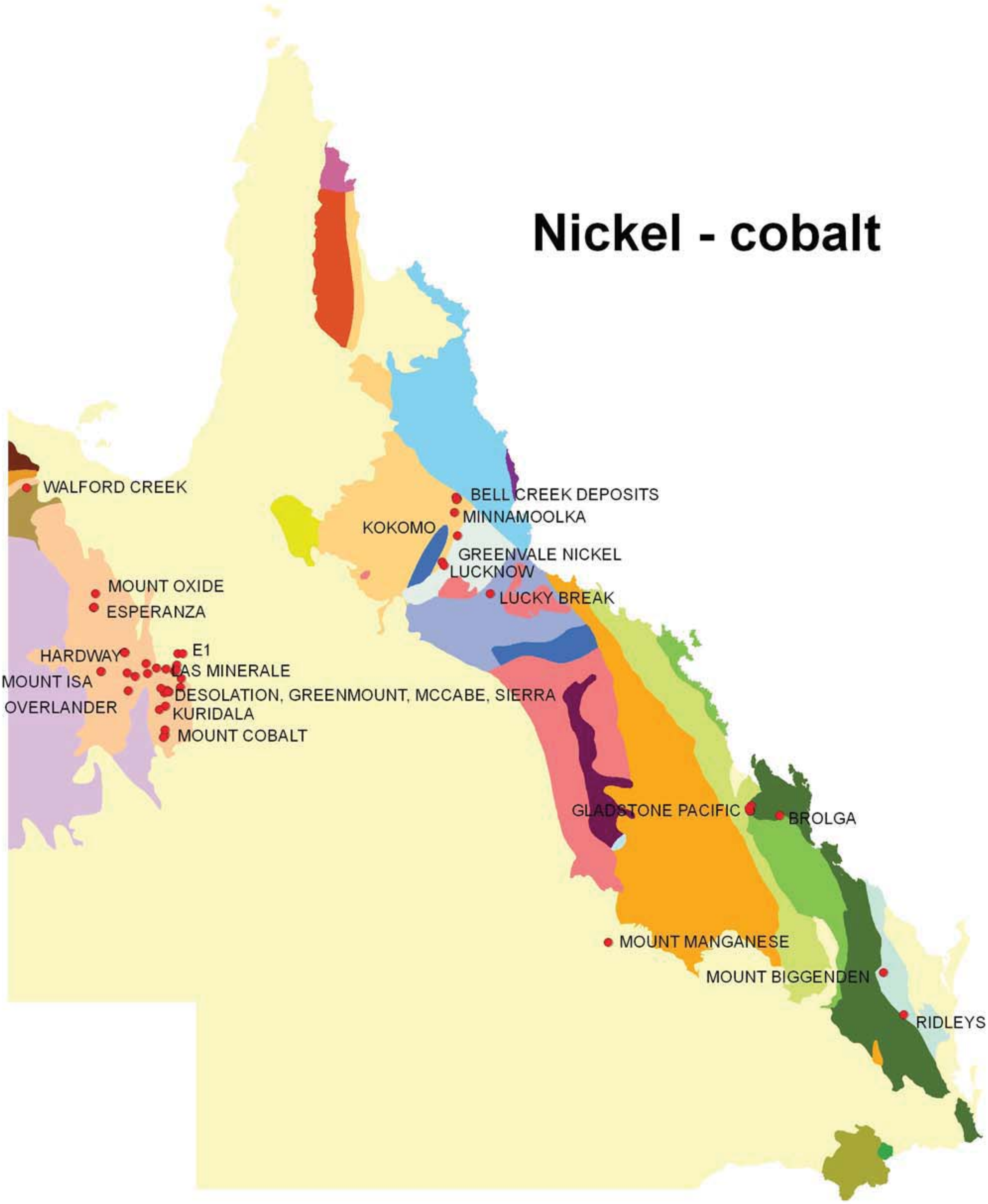


Table 11. Major nickel and cobalt deposits of Queensland

Deposit name	Historical nickel and cobalt production	Total contained nickel and cobalt metal in remaining resource	Current holder
Bell Creek North Lease		17 200 t Ni 690t Co	Metallica Minerals NL
Bell Creek North West		20 250 t Ni 1250 t Co	Metallica Minerals NL
Bell Creek South Lease		82 746 t Ni 6365 t Co	Metallica Minerals NL
Brolga	15312 t Ni 613 t Co		Queensland Nickel Pty Ltd
Cobra Central (Main Deposit)		5568 t Ni 1577 t Co	Candala Pty Ltd
Cobra's Camp ML 5780		204 905 t Ni 218 t Co	Candala Pty Ltd
Gladstone Pacific Nickel Project (Slopeaway, Slopeaway North, Gumigil East, Coorumburra East, Coorumburra Central, Coorumburra West, Whereat)		650 760 t Ni 42 720 t Co	Gladstone Pacific Nickel Ltd
Greenvale Nickel	436 430 t Ni 36 456 t Co	118 380 t Ni 8580 t Co 607 t scandium	Metallica Minerals NL
Las Minerale		16 239 t Co	Cudeco Ltd
Lucknow		54 750 t Ni 11 730 t Co 2790 t scandium	Metallica Minerals NL
Minnamoolka		47 588 t Ni 2710t Co	Metallica Minerals NL
Mount Isa Copper and Silver–Lead–Zinc Orebodies	12 886 t Co	Co content not documented in resources	Xstrata Plc
Walford Creek		4550 t Co	Copper Strike Ltd

The Marlborough laterite resources extend for 850 km^2 and potentially contain 210 Mt at 1.02% Ni and 0.06% Co. Efforts to move this resource into production failed due to limitations of the pressure acid leach technology chosen for treating the laterite ores. Five of the thirteen deposits have a confirmed (JORC and NI43101) resource of 70.9 Mt averaging 0.91% nickel and 0.06% cobalt, at a cut-off grade of 0.7% nickel. There were renewed efforts in 2005 to bring this resource into production when the Queensland Government granted 'Significant Project' status to Gladstone Pacific Nickel Ltd's Marlborough Nickel–Cobalt Project. This announcement allowed the Environment Impact Statement for Stage 1 of the project to proceed. Stage 1 of the project comprises a two-autoclave HPAL plant and refinery with a design capacity to produce approximately 63 000 tpa nickel, 6000 tpa cobalt and 175 000 tpa ammonium sulphate by-product to be constructed at the Gladstone State Development area at Yarwun. Stage 2 will result in an expansion to a four-autoclave HPAL plant and refinery with a design capacity to produce 126 000 tpa nickel, 12 000 tpa cobalt and 360 000 tpa ammonium sulphate. The nickel–cobalt ore feed would be transported via a 175 km slurry pipeline from the Marlborough Ni–Co laterite mine. A feasibility study was released in early 2008. An extensive drilling program has been completed at the Marlborough deposits to provide infill information on known resources and to identify additional resources. The deposits currently contain proved and probable reserves of 48.65 Mt at 0.94% Ni and 0.06% Co within a total resource of 70.9 Mt, at 0.91% Ni and 0.06% Co. The Federal Government, in May 2009, approved the EIS for Stages 1 and 2 of the Gladstone Nickel Project.

In October 2009, Gladstone Pacific Nickel signed a memorandum of understanding with the China Tianchen Engineering Corporation for the development of a heap leach project at Marlborough. This heap leach project has the potential to produce up to 24 600 t Ni and 1700 t Co in an intermediate product. The company believes there is sufficient ore at Marlborough to supply the feed for a stand-alone heap leach operation in addition to providing partial feed for the proposed HPAL plant at Gladstone. On 11 May 2012 Fairway Coal announced an unconditional takeover offer for all ordinary shares in Gladstone Pacific Nickel Limited and successfully acquired 92% of total shares in October 2012. The EIS stages 1 and 2 in relation to the project and the Marlborough leases and resources remain current after the takeover. Trial mining has been carried out at the Whereat deposit at Marlborough and the ore has been processed at Yabulu (Palmer nickel and cobalt) refinery.

Photograph 146: Aluminium-scandium master alloy, Metallica Metals 2012.

Metallica Minerals Limited holds the SCONI (Sc–Co–Ni) project which incorporates the next largest lateritic nickel–cobalt resource in Queensland (Photograph 147). These resources occur in the Sandalwood Serpentinite of the Greenvale Province (formerly Cape River Province) at Bell Creek, Bell Creek North-west, Bell Creek South, Minnamoolka and the old Greenvale nickel mine. The Lucknow resource occurs in the Gray Creek Complex of the Greenvale Province. Lateritised serpentinite of the Argentine Metamorphics (Charters Towers Province, formerly Cape River Province) forms a small nickel–cobalt resource at Lucky Break (previously Verde Tinto). All of these deposits are held by Metallica Minerals Limited and originally were collectively referred to as the Nornico Ni-Co & Sc project. In 2011 Metallica changed its development strategy from heated Atmospheric Acid Leach (AAL) processing to High Pressure Acid Leach (HPAL) processing with an acid-power plant, which will enable treatment of all iron-rich ores, particularly the high scandium high iron Lucknow and Kokomo ores.

To reflect the company's new focus on its scandium resources, Metallica renamed the Nornico Ni-Co and Sc 'tri-metal' project to the SCONI (Sc–Co–Ni) project in 2012. Metallica completed a scoping study based on a 750 000 tpa operation, mining and processing their total resources from Greenvale, Lucknow and Kokomo deposits (the southern portion of the SCONI project) over a 20 year mine life. Sconi Phase 1 was a plan that first envisaged processing the high-grade scandium resources using a high-pressure acid-leach process from the Lucknow deposit at a rate of approximately 200 000 tpa to produce an average of 51 tpa of scandium oxide for delivery to a third party. Total capital cost is $247 million with a 20% contingency and mine life would be over 20 years. This option was deferred until a time that it could be completely funded. Metallica was also continuing its market development work for scandium, including ongoing discussions with end users in the Solid Oxide Fuel Cell (SOFC) and aluminium alloy market sectors. Sconi Phase 2 was a potential expansion that envisaged processing 750 000 tpa from the Greenvale, Kokomo and Lucknow laterite deposits to produce 5000 tpa nickel, 700 tpa cobalt and 70 tpa scandium oxide. The project would use a high-pressure acid-leach process and include a sulphur-burning acid plant and associated power station. The decision to proceed with Phase 2 was likely to occur after the commissioning of Sconi Phase 1. However, while it was believed that this should be more compatible with the pace of developments expected from the scandium needs of end users in the early years of operation and more capital cost effective, the company has so far been unable to fund the project and in the short term is now favouring any development being as a nickel project with by-product scandium and cobalt.

In July 2012, Metallica re-organised the Kokomo, Greenvale and Lucknow resources into a 'SCONI Project — Southern Deposits' group, since these deposits were the focus of the scoping study and possible development as SCONI Phase 1 & 2. The Bell Creek South, Bell Creek North, Bell Creek North-west, the Neck and Minnamoolka resources form the 'SCONI Project Resources — Northern Deposits' group. The main Bell Creek and Minnamoolka deposits are 30 and 55 km south of Mount Garnet respectively.

Metallica reported the Southern Deposits resources to contain a combined (measured, indicated and inferred) resource of 59.5 Mt at 0.51% Ni, 0.07% Co and 64 g/t Sc. The Northern Deposits resource, that comprise Bell Creek, Minnamoolka and the Neck,

Photograph 147: Lateritic nickel ore from the Greenvale Nickel mine open cut.

contains a combined (measured, indicated and inferred) resource of 18.4 Mt at 0.88% Ni and 0.05% Co. Both these estimates are reported at a cut-off grade of NiEq 0.7% (Ni + 1.5Co + 0.01Sc).

Mineralisation at Greenvale consists of terraced remnants of Tertiary laterite profiles developed from strongly serpentinised harzburgites that intrude Proterozoic schists of the Greenvale Province. The Greenvale nickel deposit produced 428 762 t of nickel and 35 776 t of cobalt between 1974 and 1992. Greenvale closed in July 1995 after producing an additional 7668 t of nickel and 680 t of cobalt. Using a cut-off of 0.7% Ni equivalent, Greenvale has a measured, indicated and inferred resource of 16.3 Mt at 0.73% Ni, 0.05% Co and 38 g/t Sc.

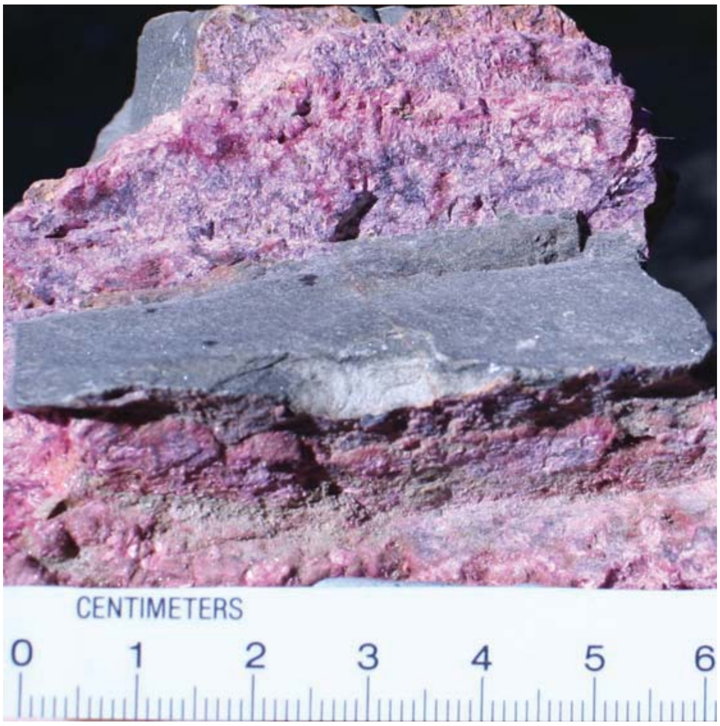
The Lucknow Ni–Co–Sc deposit consists of lateritised serpentinites of the Gray Creek Complex of the Greenvale Province. Lucknow was mined in conjunction with the Greenvale operations and production figures are included with the Greenvale deposit. Within the Lucknow deposit there is a well-defined high-grade measured and indicated scandium resource of 4.03 Mt at 204 g/t Sc, 0.16% Ni and 0.02% Co using a 130 g/t Sc cut-off grade which could support the Sconi Phase 2 operation for about 20 years. The overall measured, indicated and inferred scandium resource at Lucknow is 7.3 Mt at 176 g/t Sc, 0.23% Ni and 0.06% Co using a 100 g/t Sc cut-off.

The Kokomo deposit, 60 km north-northeast of Greenvale, comprises a laterite plateau with a nickel–cobalt zone. High grade scandium mineralisation is predominantly confined to the eastern margin of the central Kokomo plateau. The scandium mineralisation generally occurs above the nickel–cobalt zone. Four zones of scandium mineralisation have been identified for a separate scandium resource estimate. Kokomo has a measured, indicated and inferred resource of 29.5 Mt at 0.49% nickel, 0.08% cobalt and 55 g/t scandium.

Metallica Minerals Limited had entered a joint venture agreement with Metals Finance to progress the separate Lucky Break nickel–cobalt project towards implementation. Metals Finance was responsible for funding, developing and managing the project. All environmental and operating permits were obtained and the project is ready to commence development. The Lucky Break project comprises two distinct nickel and cobalt-bearing laterite ore bodies, Dingo Dam and Circular Laterite located 80 km southeast of Greenvale. A revised feasibility study has been completed on a small heap-leach nickel–cobalt project treating 60 000 tpa of high-grade ore at 1.35% nickel for six years, to be followed by 100 000 tpa of ore at about 0.8% nickel for a further three years. Metallica Minerals Limited indicates a resource estimate of 1.133 Mt for a total of 8538 t of contained nickel and nickel recoveries of about 85%. Metallica had previously arranged the sale of its entire product to the Yabulu nickel refinery (now the Palmer nickel and cobalt refinery). The company announced a nickel ores sales and royalty agreement in January 2015 with a “privately owned company” who is seeking to mine and extract nickel ore from Lucky Break.

The Brolga laterite deposit 55 km north of Rockhampton was mined between 1993 and 1996 to supplement imported ore, following the closure of the Greenvale mine. Total production (including historic production) was 15271 t Ni and 613 t Co. Mining at Brolga by Queensland Nickel Group re-commenced in 2012. Brolga ore grades are 1.2–1.8% nickel and mine life is estimated at about 12 years at 400 000 tpa, for which the company has secured approval to mine at this stage. The main purpose was to supplement overseas-sourced nickel ore imported for treatment at the Palmer nickel and cobalt refinery in Townsville (previously known as the Yabulu refinery) and to carry out test work. The mine was placed on care-and-maintenance in May 2013 due to the low nickel price. Following the process trials of Brolga ore at the Palmer Nickel and Cobalt Refinery, QNI Resources Pty Ltd re-commenced mining in August 2014 with a planned progressive ramp up in ore extraction to 80 000 wet million tonnes per month with production

Photograph 148: Erythrite (secondary cobalt mineralisation) veins in metasediments from Mount Cobalt.



expected to continue at this rate for three years. The ore is screened to minus 100mm before being transported to the Yabulu refinery. Crushing of the +100mm ore fraction to recover additional product has increased reserves.

In southeast Queensland, D'Aguilar Gold Ltd is currently investigating lateritic Ni–Co deposits hosted by the Mount Mia Serpentinite (Wandilla Province) at Mount Cobalt and Black Snake. Resources have not been calculated for these deposits yet. In 1996, Electrometals Mining Ltd reprocessed the Mount Cobalt tailings for a recorded production of 21.5 t of cobalt.

Cobalt is also associated with copper in brecciated sediment-hosted base metal deposits in northwest Queensland. An example is the structurally-controlled Esperanza copper–cobalt orebody, which is hosted by carbonaceous shale and chert breccia near the convergence of the Mammoth and Mammoth Extended Faults. Mineralisation consists of a primary zone of pyrite-chalcopyrite-cobaltite as veins, disseminations and minor massive sulphides. Open cut mining commenced in 1998 but cobalt is not recovered and remains in the tailings.

The Mount Isa orebodies also contain approximately 0.14% cobalt in both the copper and silver–lead–zinc ores. Refining recovers ‹1000 tpa of cobalt, but ~10 000 tpa of cobalt associated with pyrite is discarded in tailings. Various processes have been investigated for economic recovery of the metal, but none have proved viable. Cobalt credits also occur in other zinc and copper–gold ores of the Mount Isa Province, for example, Greenmount and Walford Creek.

Small quantities of cobalt have been produced from the Cloncurry area in the Mount Isa Province. Mount Cobalt, 30 km south of Selwyn, produced 270 t of cobalt from 1919 to 1943 at an average grade of 18% cobalt (Photograph 148). Resource expansion drilling in 2012 has revealed some cobalt vein mineralisation at Mount Kelly within the brecciated sediment-hosted Paradise Creek Formation. In general the deposit yields copper sulphides in carbonate veins, but in some areas cobalt contents increases to the detriment of copper values.

Scandium has also been associated with the Wateranga Gabbro, west of Bundaberg. Scandium was identified in eluvial sands draining the gabbro complex.

Drilling in the oxidised zone at the Mount Moss magnetite skarn deposit, 100 km west of Townsville, identified scandium with copper and zinc mineralisation. One drill hole returned 78m @ 20.7 g/t Sc, 0.24% Cu and 2.03% Zn.

Tin

Queensland contains several major tin resources at various stages of development; the improving world tin market conditions may stimulate development of these resources (Table 12). Queensland's known resources comprise 51 861 t of tin and 125 984 t of cassiterite. The Collingwood tin mine, south of Cooktown, commenced operations in 2005 and produced 2848 t of cassiterite concentrates in 2007–08. Queensland's production figures for 2011–12 (2012–13) totalled 3.68 t (36 t) of cassiterite concentrates producing 2 t (24 t) of tin.

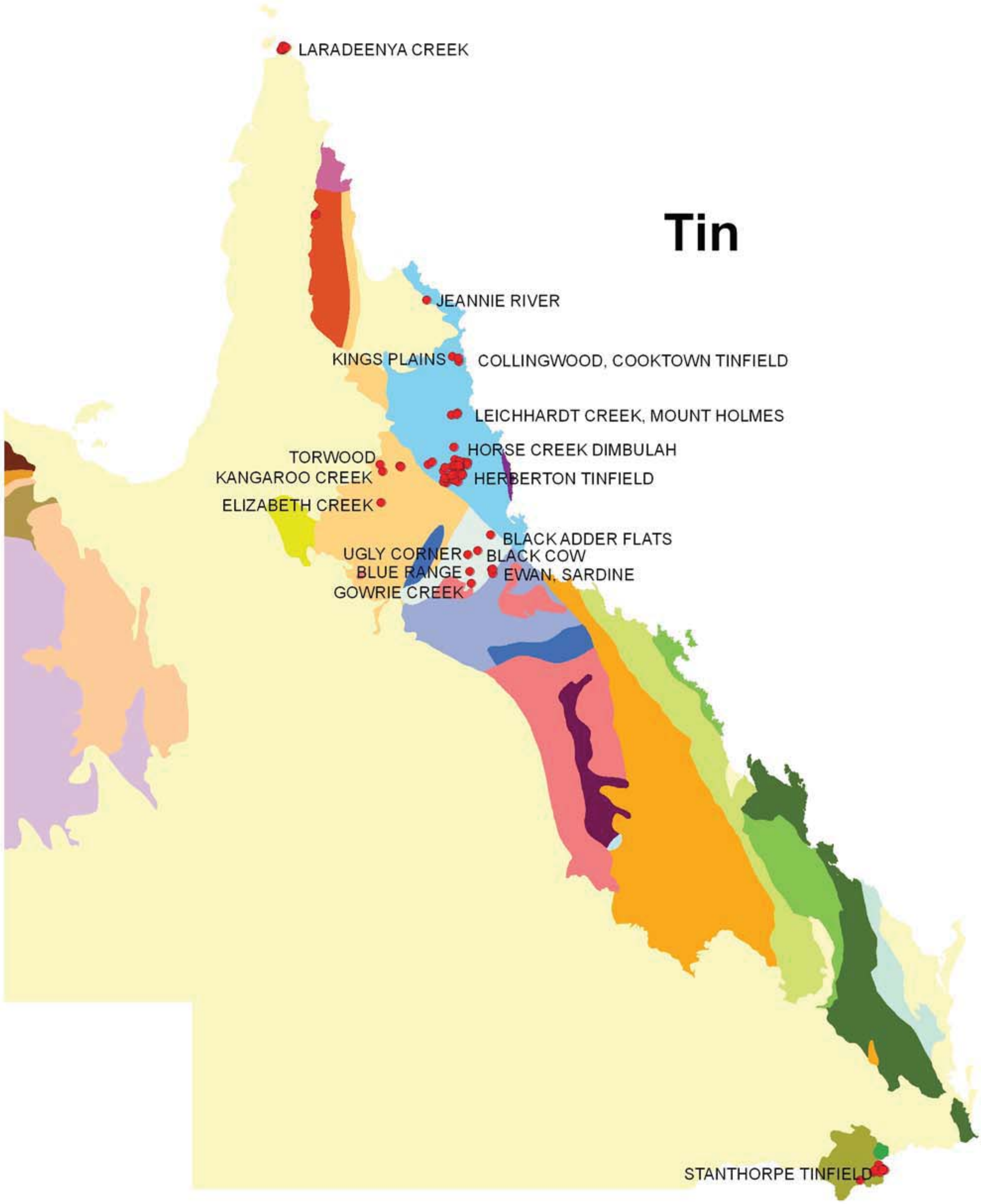
Tin mining districts, particularly in northern Queensland, have a long mining history. Queensland tin mineralisation can be classified as tin veins (Cornish style), tin greisens, tin skarns and alluvial/eluvial deposits. Tin vein deposits (Photograph 149) contain quartz + cassiterite wolframite base metal sulphides forming fissure fillings associated with reduced, crystal-fractionated

Table 12. Tin deposits of Queensland

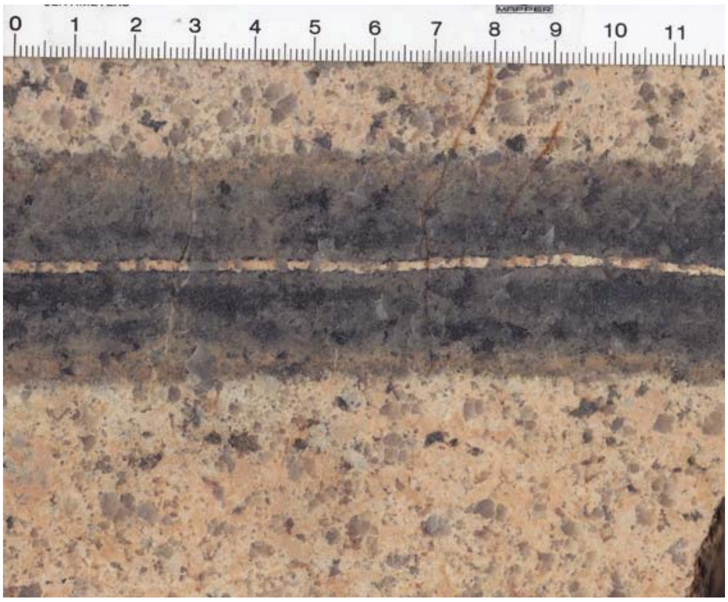
Deposit name	Total resources and reserves	Total production
Adventure		2100 t cassiterite
Archer River Tin	4400 t cassiterite	341.5 t cassiterite
Baal Gammon	30 t Sn	88.35 t cassiterite
Battle Creek	2256.4 t cassiterite	
Black Adder Flats	237.9 t cassiterite	
Black Cow	133.4 t cassiterite	
Blue Range	4620 t cassiterite	1300 t cassiterite
Booty Flats Extended	154.1 t cassiterite	
Boulder West	3120 t cassiterite	13.2 t cassiterite
Collingwood	7660 t cassiterite	6518.5 t cassiterite
Comeno	86.6 t cassiterite	
Dalcouth	348 t Sn	5.899 t cassiterite
Dalcouth Creek	351 t cassiterite	
Deadman Creek Prospect	166 t cassiterite	
Deadmans Gully	1509 t Sn	
Elizabeth Creek Prospect		136 t cassiterite
Emuford Tin	1100 t cassiterite	
Ewan Tin Prospect	600 t cassiterite	
Federation	1875 t cassiterite	74.3 t cassiterite
Gibson Flats	201t cassiterite	
Gift	1030t cassiterite	93.2t cassiterite
Gillian Prospect	19 858 t Sn	
Governor Norman	263 t cassiterite	1800 t cassiterite
Gowrie Creek	356.8 t cassiterite	104.5 t cassiterite
Granite Creek	4400 t cassiterite	333.5 t cassiterite
Great Southern Tin	260 t cassiterite	1382 t cassiterite
Herberton Deep Lead		4000 t cassiterite
Horse Creek Dimbulah	262.5 t cassiterite	
Hunter Tin	1164 t cassiterite	
Jeannie River	13 440 t cassiterite	
Jumna	525 t cassiterite	468 t cassiterite
Kangaroo Creek	700 t cassiterite	421.97 t cassiterite
Kings Plains Tin Prospect	6336.5 t cassiterite	
Koorboora Creek	105 t cassiterite	55 t cassiterite
Lady Luck	127.4 t cassiterite	
Lancelot		1369 t cassiterite 25.5 kg Ag 6.1 t Pb
Laradeenya Creek	1372 t cassiterite	

Table 12 (continued)

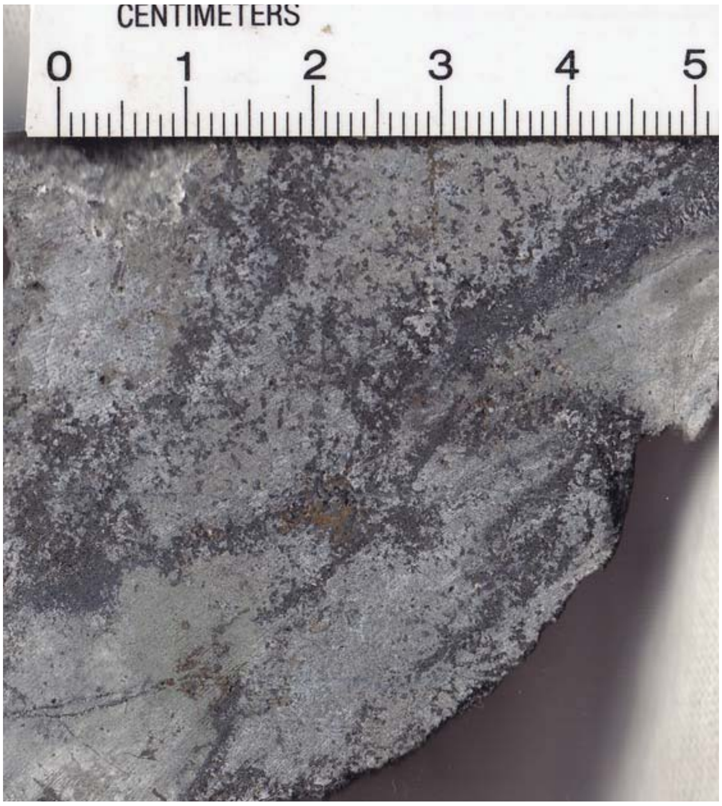
Deposit name	Total resources and reserves	Total production
Laradeenya Flats	1102.9 t cassiterite	
Laradeenya South	328.9 t cassiterite	
Laradeenya North	97.5 t cassiterite	
Leichhardt Creek Tin Mine	510.9 t Sn	94 t cassiterite
Lion Extended	496.4 t cassiterite	3.7 t cassiterite
M & R	162 t cassiterite	15.3 t cassiterite
Mayday Line	300 t cassiterite	
Moody Flats	225.6 t cassiterite	
Mount Holmes	7000 t cassiterite 1000 t wolframite	180 t cassiterite
Mount Ormonde	132.9 t cassiterite	27.8 t cassiterite
Mungumby Creek Flat	173.9 t cassiterite	
Nettle Creek	2617 t cassiterite	
Nettle Creek North Tin	2750 t cassiterite	
Never Can Tell	30 000 t cassiterite	7.4 t cassiterite
Nymbool Tin	119 t cassiterite	
Peacemaker	280 t cassiterite	449 t cassiterite
Roma Flats	204 t cassiterite	
Sailor Tin Prospect	10 000 t cassiterite	
Sardine		1466 t cassiterite 466 t stannite
Shannon	707 t cassiterite	
Smiths Creek	3360 t Sn	2709.7 t cassiterite 2 t wolframite
Smith's Creek Alluvial Tin	320 t cassiterite	
Soda Springs Tin	1250 t cassiterite	
Station Creek	8280 t cassiterite	
Sugarloaf Creek	301 t cassiterite	1157.3 t cassiterite
Summer Hill Tin	545 t cassiterite	
Tate River	492.8 t cassiterite (alluvium) 5729.1 t cassiterite (dumps and tailings)	1595 t cassiterite
Torwood Sand Ridge	4725 t cassiterite	
Two Jacks	180 t cassiterite	451 t cassiterite
Ugly Corner	390 t cassiterite	1.1 t cassiterite
Valetta	160 t cassiterite	125.2 t cassiterite
Viking	244 t cassiterite	
Vulcan Tin Mine		13 961 t cassiterite
Windermere Prospect	11 566 t Sn	
World's Fair	321.6 t cassiterite	19.3 t cassiterite
Wyndham	1650 t cassiterite	


Tin
LARADEENYA CREEK
JEANNIE RIVER
KINGS PLAINS
COLLINGWOOD, COOKTOWN TINFIELD
LEICHHARDT CREEK, MOUNT HOLMES
HORSE CREEK DIMBULAH
TORWOOD
KANGAROO CREEK
HERBERTON TINFIELD
ELIZABETH CREEK
BLACK ADDER FLATS
UGLY CORNER
BLACK COW
BLUE RANGE
EWAN, SARDINE
GOWRIE CREEK
STANTHORPE TINFIELD

Photograph 149: Tin vein (Cornish style) mineralisation in granite from New St Patrick mine, near Herberton.



Photograph 150: Tin mineralisation from the Great Adventure mine, near Irvinebank.



S- and I-type granites. Deposits occur as simple veins, sheeted veins, stockworks and breccia-hosted deposits. Jeannie River and the major tin fields of Herberton, Stanthorpe and Cooktown contain numerous examples of tin vein deposits (Photograph 150). The new owners Monto Minerals Ltd reported in 2011 that the Baal Gammon deposit, 7 km west of Herberton, contains an indicated and inferred resource of 5.48 Mt at 0.79% Cu, 0.2% Sn, 28.62 g/t Ag and 29.01 g/t indium. The mine was expected to process approximately 500 000 tpa over 6 to 7 years (mine life) to produce about 20 000 tpa of concentrate from open cut mining, but to date the mine is not developed and in 2014 ownership has changed to Consolidated Tin Mining Limited.

Tin greisen deposits form at high temperatures (300–500°C) in the apical portions of acidic, late-fractionated granite melts. Post-magmatic and metasomatic fluids high in silica and volatile components are responsible for this mineralisation, which occurs close to or within the contact zones of the granites. Greisen lodes are in or near cupolas and ridges developed on the roof or along the margins of granites, but can also be associated with brecciated masses and dykes.

The Collingwood (35 km south of Cooktown) and Sailor Tin (near Mount Garnet) prospects are examples of tin greisen deposits. Metals X Limited (formerly Bluestone Tin Limited) recently acquired the Collingwood deposit (underground mine) and commenced ore extraction in late 2005 and production of concentrates in early 2006. The Collingwood project was expected to produce at a rate of 350 000 t of ore per annum for a yield of ~5000 t of tin concentrates, containing ~3500 t of tin metal, but was put on care and

Photograph 151: General view of the Mount Veteran tin milling plant.

Photograph 152: Exploration work on the Dalcouth tin prospect.

maintenance in May 2008 and was acquired by Global Mineral Resources Limited in 2014. An Estonian group of major shareholders within this company subsequently took full ownership of the project under the name Bluestone Nominees Pty Limited. The identified mineral resource for Collingwood is currently 643 000 t at 1.19% tin.

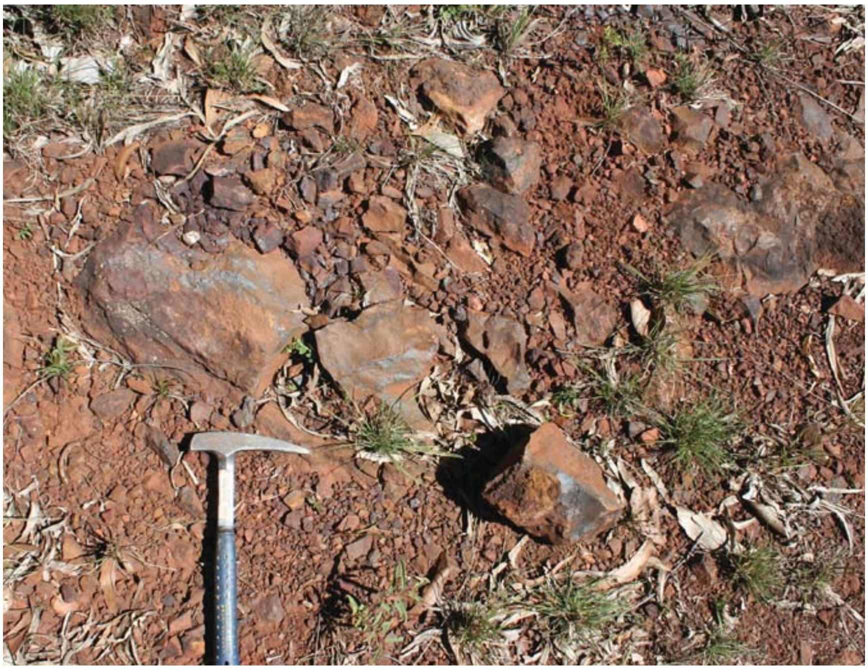
Mount Veteran, 13 km northeast of Mount Garnet, consists of several tin deposits. These deposits are held by MGT Resources Limited. The tin vein mineralisation (Cornish type) is understood to have a magmatic hydrothermal origin. The Mount Veteran mill was constructed in 1980 to treat hard-rock tin ores in the region (Photograph 151). MGT Resources has upgraded the Mount Veteran plant to process hard rock ore at a rate of 70 000 tpa and re-commenced production from stockpiled ore in early 2013.

Close to the Mount Veteran mill, MGT Resources Limited has estimated an indicated resource of 491 000 t at 0.5% tin at Summer Hill and an inferred resource of 102 400 t at 0.34% tin at Dalcouth (Photographs 152 and 153) and at Smiths Creek, 15 km west southwest of the mill, an inferred resource of 200 000 t at 1.68% tin. Smiths Creek is a 6 to 10 m wide quartz-tourmaline pipe which has been mined to 167 m and has the potential to be mined at depth. During 2013 MGT Resources Limited conducted drilling at Dalcouth, 500 m from Mount Veteran mill, which is the company's first priority open-pit mining target and in 2014 in the mining lease further away from the mill. Results have been highly encouraging and are expected to lead to an upgraded resource estimate. MGT Resources Limited plans to upgrade the mill from 70 000 tpa to 250 000 tpa for a modest CAPEX, when sufficient JORC resource targets have been met and environmental authorities are approved.

The Mount Garnet tin project is largely based on the Gillian, Pinnacles and Deadmans Gully/Windermere tin and fluorine-bearing wrigglite magnetite skarns. These deposits are held by Consolidated Tin Mines Limited. The main Gillian deposit is 7 km west southwest of Mount Garnet, and the Pinnacles project and Deadmans Gully/Windermere prospect respectively 7 km and 24 km east-northeast of Mount Garnet. The Gillian Prospect is regarded as the only major tin skarn deposit in Queensland. Mineralisation formed through emplacement of the late Carboniferous Hammonds Creek Granodiorite into reactive calcareous sedimentary rocks of the Chillagoe Formation, creating a complex replacement deposit rich in fluorine and iron. Consolidated Tin Mines Limited acquired

Photograph 153: Cassiterite quartz vein mineralisation at Dalcouth prospect.

Photograph 154: Outcrop expression (tin mineralisation) at Gillians prospect, near Mount Garnet



an interest in this deposit from Metals X Ltd and held an MDL since 2006. The skarn deposits contain fine cassiterite closely associated with iron oxides that has historically presented challenges to recovery methods developed for coarse tin ore. Extensive metallurgical test work using a variety of tin recovery methods to develop and optimize the final tin extraction circuit has been carried out. Various test programs were completed by ALS AMMTEC Ltd, Burnie Research Laboratory (BRL), CSIRO, Walk Institute, Downer EDI, Nagrom and Newcastle Institute for Energy & Resources (NIER). Testwork has included commissioning pilot scale rotary kiln reduction roasting/tin fuming trials and reverse silica flotation to improve float performance and recoveries. Consolidated Tin Mines Limited has signed an asset sale agreement with Snow Peak Mining in October 2014 to purchase the Mount Garnet plant and the pre-feasibility study will use a reconfigured Mount Garnet concentrator as the basis for the process plant design. In 2014 the Gillian deposit (Photograph 154) has a combined (measured indicated and inferred resource) of 2.53 Mt at 0.78% Sn and 32.8% Fe which includes a measured resource of 1.2 Mt at 0.86% Sn. The indicated and inferred resource at Pinnacles (Wafer - Sniksa - Hartog - Llahsram) is 7.04 Mt at 0.30% Sn and 19.55% Fe and 5.80% fluorine. The indicated and inferred resource at Windermere is 2.04 Mt at 0.27% Sn, 24.54% Fe and the nearby Deadmans Gully prospect has an indicated resource of 444 000 t at 0.34% Sn and 26.70% Fe. A pre-feasibility study has confirmed the potential for an open cut mining project on these deposits with a production profile of 1 Mtpa for nine years or greater. The concentrator would produce an estimated 2944 tpa of tin in concentrate at 68% tin and 234970 tpa of iron in concentrate at 65% iron for export, and 53860 tpa fluorite at 86% CaF_2 in concentrate (acidspar quality achieved in metallurgical testing). A definitive feasibility study has now commenced and is near completion. If successful open cut mining would commence with the Gillian deposit in 2015 followed by Pinnacles. Obtaining further viable tin deposits to develop in the immediate area would become an exploration focus to increase mine life and production.

Consolidated Tin Mining Limited has also acquired the Jeannie River prospect, 90 km northwest of Cooktown, which has an inferred resource of 2.24 Mt at 0.6% tin.

A significant amount of Queensland's tin production has come from alluvial, eluvial and deep lead deposits. Alluvial tin deposits were commonly worked by large floating dredges, which operated along the major drainage systems in the Herberton and Stanthorpe tin fields. The most recent major alluvial tin mining operation in Queensland was commissioned in October 1995 by Norminco Ltd at Leichhardt Creek, southeast of Mount Carbine in far north Queensland. This operation encountered production difficulties, resulting in its closure in 1997. Consolidated Tin Mines Limited holds a significant portion of historical tin fields in the Mount Garnet area. A potential future alluvial mining operation would consist of an open cut mine. The alluvial assets are viewed by the company as 'value-add' operations to their hard rock Mount Garnet tin project and may be processed when that operation commences.

Paterson Mining Pty Limited acquired a deep lead tin deposit shedding from the Wolverton Granite on the Wolverton property adjacent to Granite Creek, 7km east of the Archer River Roadhouse in 2013. The company has set up a trial plant near Granite Creek and successfully demonstrated viable production of alluvial cassiterite in 2014. Various alluvial deep leads have been identified and plans for the construction of a standard flotation plant are progressing.

Tungsten

Tungsten occurs in two main deposit styles — tungsten vein/greisen deposits (*e.g.* Mount Carbine) and tungsten skarn deposits (*e.g.* Watershed). Queensland's historical tungsten production has come almost entirely from the Mount Carbine deposit, which closed in 1986. At the time of operation in 1986, Mount Carbine was the largest low-grade tungsten mine in the world (Table 13). Tungsten production has recommenced in Queensland in 2012. Queensland's production figures for 2011–12 (2012–13) totalled 47.8 t (457.8 t) of wolframite concentrate producing 31 t (226 t) of tungstic oxide.

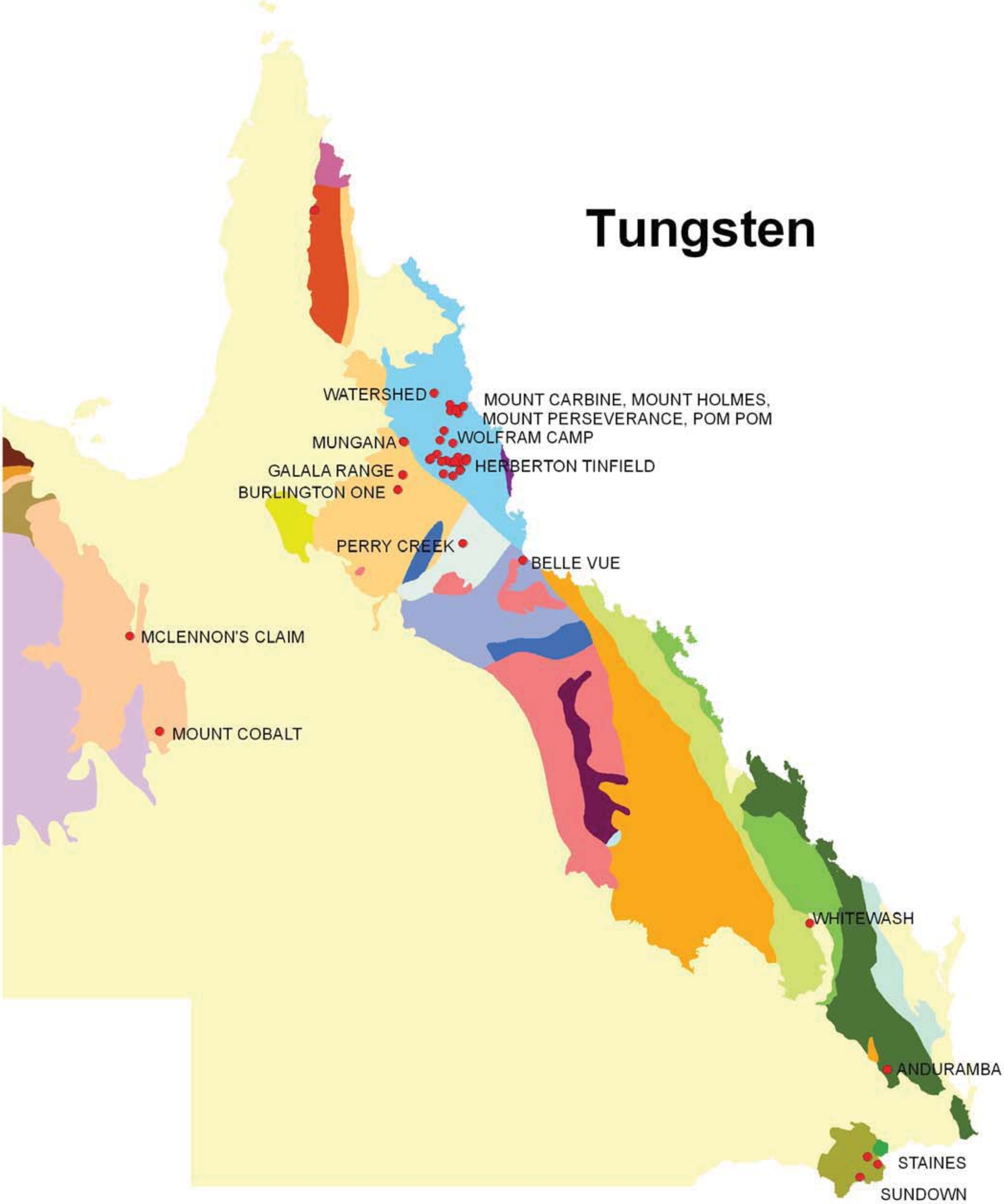
Tungsten vein/greisen deposits contain wolframite, scheelite, molybdenite and base metal sulphides in quartz vein swarms, usually in fracture systems associated with felsic intrusives (Photograph 155). There is no strong affinity with a specific granite type or redox state. In Queensland, there is a strong spatial association of tungsten vein mineralisation with the tin vein deposits, particularly in the Herberton tin field.

Wolfram Camp, 16 km north of Dimbulah, west of Cairns, has a measured-indicated-inferred resource of 1.42 Mt at 0.12% molybdenite and 0.66% tungstic oxide (WO_3). Molybdenum, tungsten and bismuth mineralisation (Photographs 156 and 157) occurs as numerous, irregular, branching pipes in greisen zones in the roof zone of the highly fractionated, late Carboniferous James Creek Granite (Kennedy Province). Molybdenite is concentrated along pipe margins. In 2008 Queensland Ores Ltd produced

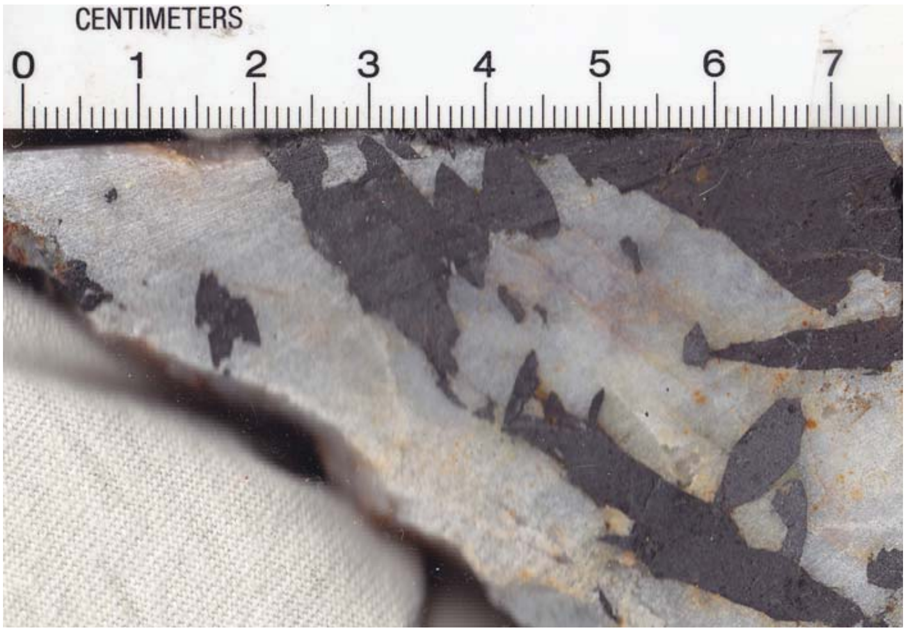
Table 13. Tungsten deposits of Queensland

Deposit name	Total production	Total resources and reserves
Bamford Hill	2000 t wolframite 170 t molybdenite 20 t bismuthinite	
Belle Vue	100 t wolframite	
Burlington One		18 750 t wolframite
Galala Range	52 t wolframite	
McLennon's Claim	6 t tungsten	
Mount Carbine	16 400 t wolframite 7.8 t cassiterite	70 660 t wolframite
Mount Holmes	180 t cassiterite	1000 t wolframite 7000 t cassiterite
Mount Perseverance	130 t wolframite 1.7 t cassiterite	3900 t wolframite
Neville	590 t wolframite	
Perry Creek	8 t scheelite	800 t scheelite
Pom Pom	2 t wolframite	350 t wolframite
Staines wolfram mines	7 t wolframite	
Watershed		50 972t tungstic oxide
Wolfram Camp Tungsten Prospect	6918.3 t wolframite 1535 t bismuthinite 159.6 t molybdenite	8528 t tungstic oxide

Tungsten



WATERSHED
MOUNT CARBINE, MOUNT HOLMES,
MOUNT PERSEVERANCE, POM POM
MUNGANA
WOLFRAM CAMP
GALALA RANGE
HERBERTON TINFIELD
BURLINGTON ONE
PERRY CREEK
BELLE VUE
MCLENNON'S CLAIM
MOUNT COBALT
WHITEWASH
ANDURAMBA
STAINES
SUNDOWN



Photograph 155: Tungsten quartz vein mineralisation from Mount Carbine wolfram mine.

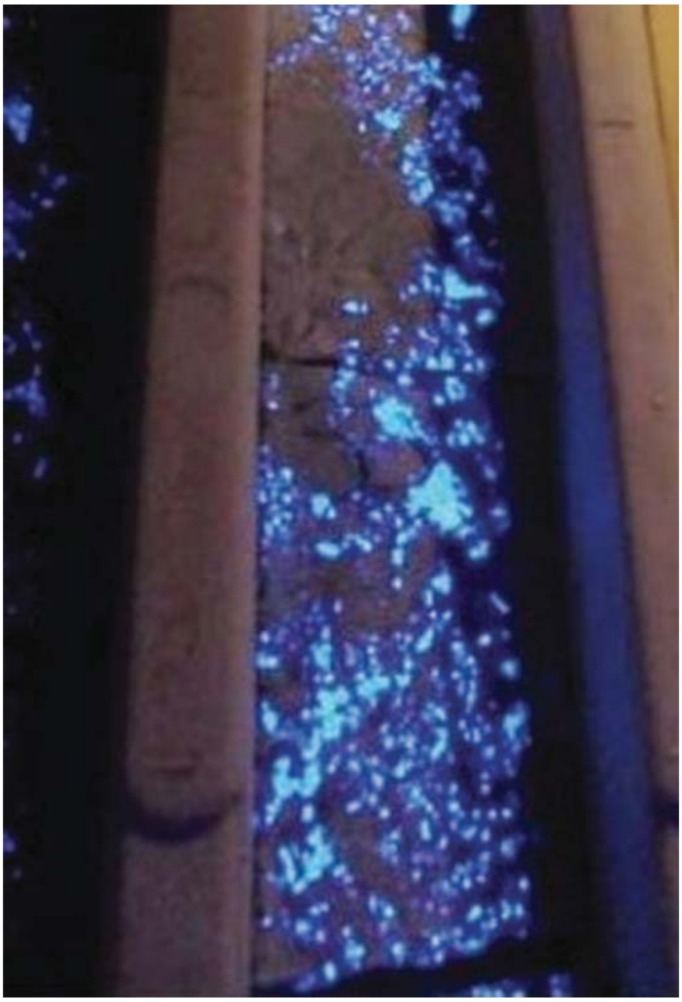
Photograph 156: Wolframite and molybdenite mineralisation in Wolfram Camp open cut.

Photograph 157: Wolframite and molybdenite mineralisation in quartz vein lode within granitic greisen in Wolfram Camp open cut (pictured F. von Gnielinski).

9.36 t of tungstic oxide and 2.88 t of molybdenum before placing mine on care and maintenance in November 2008. Wolfram Camp was operated as a shallow open cut operation (Photograph 158) from July 2008 to November 2011 by Planet Metals Limited. In September 2011 Deutsche Rohstoff AG completed acquisition of Wolfram Camp and in December 2011 the company commenced production of tungsten and molybdenum concentrates from an open cut 'reserve' of 730 000 t at 0.77% WO_3 and 0.056% Mo. This followed a re-evaluation of plant and mining procedures and the introduction of an X-ray sorter. The operator Wolfram Camp Mining had concentrated on the tungsten production only in 2012 and 2013. The plant was still at the commissioning phase and a mine life of some four years was envisaged. Deutsche Rohstoff AG was also evaluating Bamford Hill 25 km to the south for additional ore. The Canadian company Almonty Industries Inc has acquired Wolfram Camp in 2014. As part of its acquisition process Almonty carried out a detailed analysis of historical exploration data and confirmatory due diligence sufficient to convert the historical data into a NI 43-101 technical report dated March 31, 2014. As a result, Almonty have calculated an indicated resource of 423 000 t at 0.20 % WO_3 and 0.04 MoS_2 and an inferred resource of 1 048 000 t at 0.21% WO_3 and 0.06 MoS_2. The probable reserves are 234 000 t at 0.19 WO_3 and 0.038 MoS_2. The resources has a cut off of 0.10% WO_3 and the reserve a cut-off of 0.09% WO_3. The indicated resource and the reserve are open cut constrained and the resources are inclusive of the reserves.

The Watershed tungsten skarn deposit, 140 km northwest of Cairns in north Queensland, comprises fine- to coarse-grained disseminated scheelite in quartz vein swarms (Photographs 159 and 160), in stratabound replacement lenses in calc-silicate

Photograph 158: Panorama view of the open cut, waste dump and plant operations at Wolfram Camp mine.



Photograph 159: Scheelite mineralisation under ultra violet light in drill core from the Watershed tungsten project.

Photograph 160: Quartz veins with disseminated scheelite mineralisation intruding metasediments of the Hodgkinson Formation at the Watershed tungsten project.

rocks of the Hodgkinson Formation, and in dyke-like intrusions of albitised granite. Tungsten skarns are commonly associated with granites that were emplaced at moderate depths in the crust and developed large contact metamorphic aureoles. Vital Metals Ltd reported an updated combined (measured, indicated and inferred) resource of 20.66 Mt at 0.25% tungstic oxide (WO_3) in 2012. The Watershed deposit is owned by Vital Metals Limited (70%). JOGMEC (Japan Oil, Gas and Metals National Corporation, a Japanese government agency) has earned 30% of the project by funding a recently completed definitive feasibility study. The total resource at Watershed is 49.32Mt at 0.14% WO_3 at a cut-off grade of 0.05% WO_3. The proven ore reserve is 6.4Mt at 0.16% WO_3 and the probable ore reserve is 15.0Mt at 0.14 per cent WO_3 using a cut off grade of 0.05% WO_3 and with a strip ratio of 3:1. There is an additional 1.7 Mt of inferred resource at 0.14% $WO_{3.}$ Based on a mining rate of 2.5Mtpa, it is expected that the open cut mine will have a life of 10 years. There are also additional open cut targets and significant exploration potential exists to support the development of an underground mine in the future, with tungsten grades observed to increase with depth. Pending securing a new Japanese partner following a transfer from JOGMEC, Vital Metals Limited aims to progress the project through off-take and financing arrangements and commence construction in 2015 with a view to the first ore production before the end of 2016.

Photograph 161: Mount Carbine open cut (water is about 45m deep).

Photograph 162: (left) Mount Carbine tailings retreatment plant; (right) Mount Carbine tailings dam currently being re-worked. Note the fine layering in the material in the background.

The Mount Carbine mine, 120 km northwest of Cairns, was Australia's leading tungsten producer in the 1980s until closure due to low metal prices. The Mount Carbine tungsten deposit comprises a large sheeted vein-stockwork system with sub-vertical quartz veining hosting wolframite and scheelite. A large open cut mine operated from 1972 to 1986 (Photograph 161), with underground development advancing to access extensive mineralisation beneath the open cut, before the mine closed in November 1986 due to economic pressure. In this time 16 400 t of wolframite was produced. Since 2008 Icon Resources Ltd had re-developed the mine and reported an inferred resource of 113.6 Mt at 0.06% tungstic oxide in the hard rock deposit and another inferred resource of 1.6 Mt at 0.11% wolframite in the tailings dam No.4. No production of tungsten was recorded, but Icon Resources Ltd produced 381 983 t of silica from the mine between 2007–2010. The Mount Carbine mine is now operated by Carbine Tungsten Limited (formerly Icon Resources). Carbine Tungsten Limited commissioned a tailings re-treatment facility in March 2012 and a first shipment of bulk tungsten concentrate was despatched to Brisbane for shipment in June 2012. This project has demonstrated that it is possible to recover about 80% of the tungsten previously locked in the fines (Photograph 162). Production of 260 000 tpa tungsten concentrate is envisaged starting in 2014. Carbine Tungsten has been able to secure funding package options from Mitsubishi Corporation RtM Japan Limited that will allow the Company to progressively develop the Mt Carbine mine. Production of tungsten concentrate continues from the tailings dam with the concentrate shipped to the off-take partner, Mitsubishi Corporation RtM in Japan. Production ceased in December 2013, mostly from the greater than 50 micron fraction. The stockpile includes a basal layer of approximately 400 000 t of slimes with an average grade of 0.35% tungsten and trials to recover the tungsten are continuing. In the low-grade ore stockpiles and reject dumps there is also about 12 Mt at 0.07% tungsten present as wolframite and scheelite. Trials by X-ray sorting on bulk samples has resulted in a significant reduction in the size of the processing plant required. A feasibility study to process the low-grade stockpiles and to re-open the hard rock tungsten mine based on an indicated resource of 18 Mt at 0.14% WO_3 (using a cut-off of 0.05% WO_3) has demonstrated the viability of the project. Environmental approvals have been secured for the low-grade stockpiles part of the project which is based on a throughput of 1.5 Mtpa over a life of eight years. Production of 260 000 tpa of tungsten concentrate is envisaged from early 2016. The inferred resource for the primary mineralisation, using an 0.05% WO_3 cut-off, is an additional 29.3 Mt at 0.12% WO_3. The open-pit indicated hard rock tungsten mine resource has the potential to provide a further 10 years of mine life. Carbine Tungsten Limited has identified a zone above the water table in the existing open pit to commence mining.

Exploration of the depth extensions at Mount Carbine will be carried out after production from the resource has commenced. Carbine Tungsten Limited has exploration targets within the vicinity of Mount Carbine at Iron Duke (predominantly scheelite) and Petersen's Lode.

Uranium

Queensland contains 3% of Australia's known uranium resources and reserves and Australia is currently the world's second largest producer of uranium oxide (U_3O_8) behind Canada. Total uranium oxide content of Queensland's major deposits from all resource and reserve classifications is ›88 479 t (total). Queensland has been a significant past producer of uranium with the abandoned Mary Kathleen mine producing ~8882 t of U_3O_8 from 9.25 Mt of ore (Photograph 163). Queensland's major uranium resources are confined to Proterozoic deposits in northwest Queensland (*e.g.* Westmoreland and Valhalla) and Paleozoic deposits in northeast Queensland (*e.g.* Ben Lomond and Maureen) (Table 14). Renewed interest in uranium as an energy source has seen significant exploration interest in Queensland's numerous deposits since 2005.

Photograph 163: Mary Kathleen open cut (pictured F. von Gnielinski)

Uranium mineralisation was discovered at Westmoreland, 400 km north-northwest of Mount Isa, in 1956. Exploration delineated several significant centres of mineralisation, including the Redtree deposits (Garee, Huarabagoo, Jack/Redtree, Namalangi and Langi) Junnagunna, Junnagunna South, Sue and Outcamp. The primary uranium ore minerals are uraninite and coffinite, which are confined to coarse to gritty feldspathic sandstone in the uppermost unit of the Westmoreland Conglomerate (the basal unit of the Tawallah Group in the McArthur Basin) (Photograph 164). The most significant mineralisation is associated with an altered basic dyke system intruded along the Redtree structure. Rio Tinto Exploration Pty Ltd acquired the Westmoreland project area in 1997 but has since relinquished all tenure over the deposits. Current EPM14558 is held Tackle Resources Pty Limited, which has been acquired by Canadian company Laramide Resources Limited. Laramide considers the Westmoreland uranium project to contain a total JORC/NI 43-101 compliant resource, using a 0.02% U_3O_8 cut-off grade is an indicated resource of 18.7 Mt at an average grade of 0.089% U_3O_8, and inferred resources of 9.02 Mt at 0.083% U_3O_8 for a total resource of 51.9 Mlb of U_3O_8. Of this total, 62% is contained in Redtree, 16% at Huarabagoo and 22% at Junnagunna. 80 per cent of the resource is within 50 m from surface. The measured resource of 91 670 t at 0.12% U_3O_8 from Langi was not included in previous figures. A scoping study was completed in which the project was considered economically robust. The basis was production of around 3.0Mlbs of U_3O_8 annually from an open cut mine and production costs around US$20 per pound. The initial mine life is estimated as 11 years. The direct and indirect capital for the projects is estimated at US$214M. An updated scoping study is expected to be completed in 2014. Westmoreland is intended to be an open cut operation using conventional acid leaching and solvent extraction technology to produce greater than 3 million pounds per year. Positive metallurgical testwork gives a high uranium recovery of 90.6% and relatively low acid consumption. More recent uranium recoveries of 97% were confirmed by ANSTO in 2011/2012 with the use of a conventional mild acid leach route. Currently the company is looking at commencing production from an open pit mine in 2018 and processing on site.

Uranium mineralisation has also been identified at the Longpocket area, 7 km to the east, also held by Laramide Resources Limited. The main primary minerals are uraninite and coffinite and the mineralisation is amenable to open-cut mining. Currently

Table 14. Uranium deposits of Queensland

Deposit name		Resource	Contained U_3O_8 (t)
Ben Lomond area deposits	Ben Lomond	Indicated 1.328 Mt at 0.23% U_3O_8 Inferred 0.602 Mt at 0.18% U_3O_8	3101 1094
Mount Isa and Mount Isa West	Queens Gift	Indicated 0.65 Mt at 0.043% U_3O_8 Inferred 0.43 Mt at 0.043% U_3O_8	279 184
	Slance	Indicated 0.51 Mt at 0.062% U_3O_8 Inferred 0.22 Mt at 0.054% U_3O_8	316 118
	Eldorado North	Indicated 0.06 Mt at 0.066% U_3O_8 Inferred 0.17 Mt at 0.057% U_3O_8	39 96
	Citation/Mighty Glare	Indicated 0.17 Mt at 0.047% U_3O_8 Inferred 0.34 Mt at 0.052% U_3O_8	79 176
	Thanksgiving	Indicated 0.47 Mt at 0.047% U_3O_8 Inferred 0.66 Mt at 0.047% U_3O_8	188 310
	Bambino	Indicated 0.37 Mt at 0.039% U_3O_8 Inferred 0.67 Mt at 0.037% U_3O_8	144 247
Mount Margaret E1 Prospect (E1 Camp)	E1 East	Inferred 8.0 Mt at 0.01% U_3O_8	904
	E1 North	Inferred 7.9 Mt at 0.02% U_3O_8	1197
	E1 South	Inferred 10.3 Mt at 0.01% U_3O_8	1019
Laura Jean		Inferred 6300 m^3	10
Maureen area deposits	Central 50	Inferred 0.374 Mt at 0.16% U_3O_8	580
	Far West 5	Inferred 0.09 Mt at 0.12% U_3O_8	104
	Far West 7	Inferred 0.065 Mt at 0.09% U_3O_8	61
	Two Gee	Inferred 0.642 Mt at 0.12% U_3O_8	770
	Maureen	Indicated 3.124 Mt at 0.09% U_3O_8 Inferred 0.154 Mt at 0.11% U_3O_8	2811 169
Monakoff		Inferred 1.9 Mt at 0.02% U_3O_8	348
Valhalla area deposits	Anderson's Lode	Indicated 1.4 Mt at 0.145% U_3O_8 Inferred 0.1 Mt at 0.164% U_3O_8	2028 163
	Duke Batman	Indicated 0.5 Mt at 0.137% U_3O_8 Inferred 0.3 Mt at 0.11% U_3O_8	685 330
	Bikini	Indicated 5.8 Mt at 0.05% U_3O_8 Inferred 6.7 Mt at 0.05% U_3O_8	2882 3303
	Honey Pot Prospect	Inferred 2.6 Mt at 0.07% U_3O_8	1822
	Mirrioola	Inferred 2.0 Mt at 0.056% U_3O_8	1110
	Odin	Indicated 5.8 Mt at 0.059% U_3O_8 Inferred 8.2 Mt at 0.055% U_3O_8	3422 4551
	Skal	Indicated 14.3 Mt at 0.064% U_3O_8 Inferred 1.4 Mt at 0.052% U_3O_8	9152 726
	Valhalla	Measured 16.0 Mt at 0.0819% U_3O_8 Indicated 18.6 Mt at 0.084% U_3O_8 Inferred 9.1 Mt at 0.0643% U_3O_8	13 104 15 624 5851
	Watta	Inferred 4.2 Mt at 0.04% U_3O_8	1722

Table 14 (continued)

Deposit name		Resource	Contained U_3O_8 (t)
Westmoreland area deposits	Huarabagoo	Indicated 1.46 Mt at 0.08% U_3O_8 Inferred 2.4 Mt at 0.11% U_3O_8	1213 2622
	Redtree / Jack	Indicated 12.86 Mt at 0.09% U_3O_8 Inferred 4.46 Mt at 0.07% U_3O_8	11 572 2992
	Junnagunna	Indicated 4.36 Mt at 0.08% U_3O_8 Inferred 2.14 Mt at 0.08% U_3O_8	3535 1612
	Junnagunna South	Inferred 0.545 Mt at 0.06% U_3O_8	299
	Langi	Measured 91 670 t at 0.12% U_3O_8	110
	Outcamp	Inferred 1.11 Mt at 0.09% U_3O_8	945
	Sue	Indicated 0.41 Mt at 0.17% U_3O_8	697
Two Gee		Indicated 0.642 Mt at 0.12% U_3O_8	770

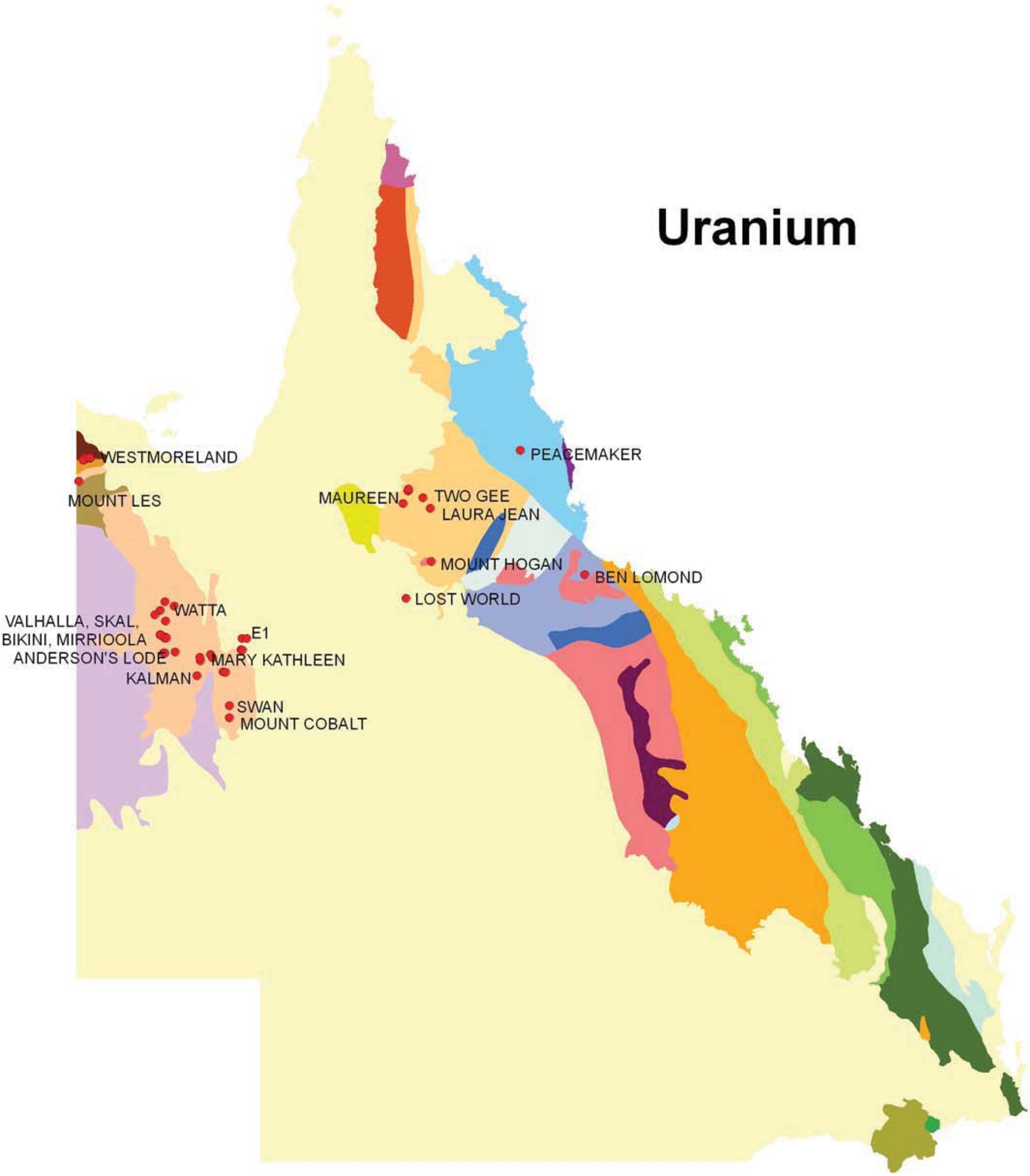
Photograph 164: Conglomerate ridges with sediment-hosted uranium mineralisation at Huarabagoo, Westmoreland (image courtesy of Laurie Hutton, GSQ).

the Laramide Resources is looking to further increase and improve the resource base, and has also identified significant gold mineralisation at Huarabagoo. Future work could define a gold resource in addition to uranium at Huarabagoo.

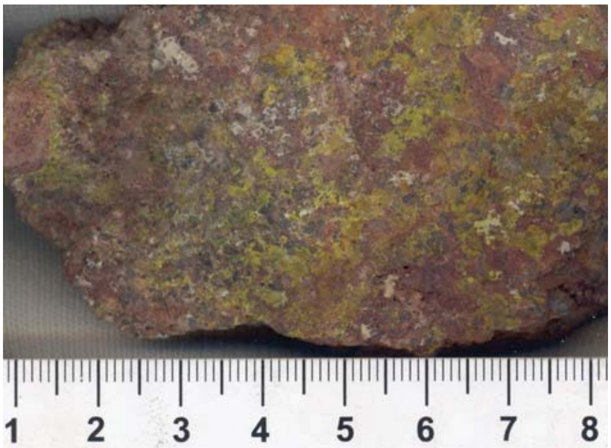
The Valhalla uranium deposit was discovered in 1954 and is near the Barkly Highway, 40 km north-northwest of Mount Isa. It is the largest of a number of shear-related uranium occurrences hosted by the Eastern Creek Volcanics in the Western Fold Belt Province. The primary uranium mineral at Valhalla is brannerite which occurs in a structurally-controlled sub-vertical body over 1 km long with an average width of 50 m. Valhalla has the potential to be mined by open-cut methods although the mineralisation can be very fine grained and also refractory. The deposit is hosted by highly altered tuff and shale. Summit Resources (Australia) Pty Limited obtained ownership of the prospect in 1992 and embarked on a drilling program that has delineated indicated and inferred resources of 23.7 Mt containing 21 143 t of U_3O_8. The best intersections and grades are at ~300 m below the surface (Photograph 165). Summit Resources and Paladin Energy Limited have completed further resource drilling and reported an updated combined measured, indicated and inferred resource of 43.7 Mt containing 34 579 t of U_3O_8. This resource is attributed to both companies at 50%.

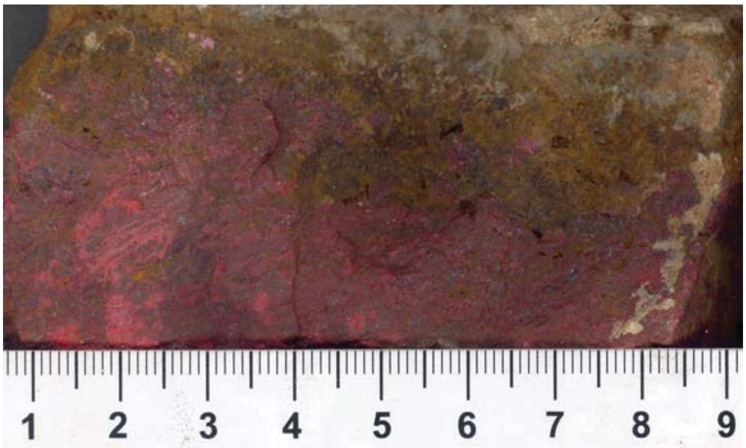
The other uranium deposits delineated, the largest of which are the adjacent Odin deposit and the Bikini and Skal deposits, could provide additional open-pittable mill feed to a future milling and processing operation at Valhalla. The Odin deposit, 1 km northwest of Valhalla, has an indicated and inferred resource of 14.0 Mt containing 34 579 t of U_3O_8. The Skal deposit, 10 km east of Valhalla, has an indicated and inferred resource of 15.7 Mt containing 9878 t of U_3O_8. These prospects are currently held by a joint venture

Uranium


WESTMORELAND
MOUNT LES
VALHALLA, SKAL,
BIKINI, MIRRIOOLA
ANDERSON'S LODE
WATTA
E1
MARY KATHLEEN
KALMAN
SWAN
MOUNT COBALT
MAUREEN
TWO GEE
LAURA JEAN
MOUNT HOGAN
LOST WORLD
PEACEMAKER
BEN LOMOND

Photograph 165: Drilling site of the Valhalla uranium prospect.





Photograph 166: High grade uranium mineralisation from Mary Kathleen open cut, sampled around 1980 from mining operations.

Photograph 167: High grade uranium mineralisation from Mary Kathleen open cut, sampled around 1980 from mining operations.

between Summit Resources and Paladin Energy Ltd. There is potential to significantly increase these resources, as both deposits remain open along strike and at depth. Summit Resources retains 100% ownership of the nearby Anderson's Lode, Bikini, Mirriola and Watta deposits, for which a combined indicated and inferred resource of 20.2 Mt containing 11 208 t of U_3O_8.was reported in 2012. Additional resources are known from Duke Batman and Honey Pot Prospect which were acquired from Fusion Resources Ltd by Paladin Energy Ltd in 2009.

The Mary Kathleen uranium deposit is hosted by metasediments of the Corella Formation in the Eastern Fold Belt Province in northwest Queensland. This skarn-hosted mineralisation is now thought to have formed by infiltration of metamorphic fluids along the Mary Kathleen Shear Zone during the Isan Orogeny. Controls on ore deposition were lithological. Open cut mining commenced at Mary Kathleen in 1953 and ceased in 1963. The mine was re-opened in 1975 and mining operations ceased in 1982 when the ore reserves were exhausted (Photographs 166 and 167). About 31 Mt was mined including 7 Mt of ore grading 0.12% U_3O_8 which yielded 8800 t of U_3O_8. The ore which mainly consisted of the rare earth mineral allanite and contained about 3% light rare earths which were not recovered. The uranium occurred mainly as uraninite inclusions in allanite and garnet. They have now been identified remaining in the former tailings dam. Small remnant uranium resources remain at Mary Kathleen. For more about Mary Kathleen refer to section ' Yttrium, heavy and light Rare Earth Elements (REE)'.

The French company Pechiney discovered the Ben Lomond uranium deposit in 1975. The deposit is located 50 km southwest of Townsville and is held by Mega Uranium Limited, a Canadian company. Total Mining Pty Ltd and Minatome Australia Pty Ltd explored and evaluated the deposit in detail between 1976 and 1982. The deposit is restricted to a zone of east–west-trending, steeply dipping intense shearing in the late Carboniferous Saint James Volcanics (Photograph 168), underling an unconformity with the non-mineralised Watershed North Rhyolite. Pitchblende and coffinite mineralisation is developed over a strike length of 500 m, width of 150 m and to a depth of 100 m. Indicated resources are 1.328 Mt at 0.23% U_3O_8 and inferred resources comprise 0.602 Mt at 0.18% U_3O_8. The resource also contains a substantial molybdenum credit at an average grade of 0.15% molybdenum and is one of the highest-grade per tonne uranium resources in Australia. The prospect was acquired by Canadian company Mega Uranium Ltd in 2005 and is being reassessed.

Photograph 168: Uranium mineralisation within shear zones in Saint James Volcanics at the Ben Lomond prospect.

Photograph 169: Secondary torbernite crystals from the Milo project.

The smaller Maureen uranium deposit, 35 km north-northwest of Georgetown in north Queensland, was discovered by Central Coast Exploration NL in 1971. Stratabound fluorite–uranium–molybdenite mineralisation is confined to relatively coarse, fluviatile arkosic sediments of the Gilberton Formation, which unconformably overlies Proterozoic metamorphics and underlies the Maureen Volcanic Group. The primary uranium mineral is uraninite, which is associated with fluorite. Indicated and inferred resources for the project total 3.278 Mt at 2980 t U_3O_8 and 2028 t Mo. The deposit could be mined by an open cut. The deposits are being explored by Mega Uranium Ltd, which acquired the project from Georgetown Mining Ltd. Some 30 km south and southeast of Maureen, four other uranium deposits (Central 50, Far West 5 & 7 and Two Gee) contain historical inferred resources aggregating to 1.17 Mt at ~0.10% U_3O_8 containing 1515 t U_3O_8.

Four deposits in the Mount Isa district which are 100% owned by Deep Yellow Ltd have inferred and indicated resources. Deep Yellow Limited acquired these deposits from Superior Resources Ltd in 2007 and since carried out exploration and resource estimation. However it is currently engaged in the process of divestment of its Australian assets in order to focus on its assets in Namibia, despite the Queensland Government announcement to overturn the ban on uranium mining. The deposits are interpreted to be associated with a number of shear-swarms and breccias hosted by volcanic rocks in the Western Fold Belt Province. Mineralisation of uraninite + brannerite is associated with chlorite, carbonate, and hematite and silica alteration. The combined indicated resource for the four deposits, Queens Gift, Slance, Eldorado North and Citation/Mighty Glare totals 1.39 Mt at 0.05% U_3O_8 containing 713 t of U_3O_8. The combined inferred resource comprises 1.16 Mt at 0.05% U_3O_8.containing 574 t U_3O_8.

A minor resource of uranium as a by-product has been reported by GBM Resources from the Milo project, which is discussed in the 'Yttrium, heavy and light rare earth elements (REE)' section. At the Milo No.7 mineral occurrence green torbernite crystals (secondary uranium phosphate) were observed in a historic mullock heap of heavily kaolinised metasediments and shales (Photograph 169).

At Elaine Dorothy, 6 km south of Mary Kathleen along the Mary Kathleen shear, China Yunnan Copper Australia Limited (70%) and Goldsearch Limited (30%) have discovered a multi-element mineralised system containing variable and quite high grades of copper, cobalt, gold, rare earths and uranium over significant widths. The rare earths and associated uranium-thorium mineralisation (Photographs 170 and 171), which is interpreted as a separate mineralising event that overlaps with the copper-cobalt-gold

Photograph 170: Drill core from Elaine Dorothy in quartz veined and foliated pyroxenite with an extremely high radioactive response (uranium mineralisation present).

Photograph 171: Drill core from Elaine Dorothy in coarse-grained massive sulphides in pyroxenite with an extremely high radioactive response (uranium mineralisation present).

mineralisation, is not included in the copper resource estimate. At the nearby Elaine South deposit, an inferred resource of 83 000 t at 280 ppm U_3O_8 and 3200 ppm total rare earth oxides (TREO) at a cut-off of 200 ppm U_3O_8 was calculated in March 2010. The resource is considered open at depth.

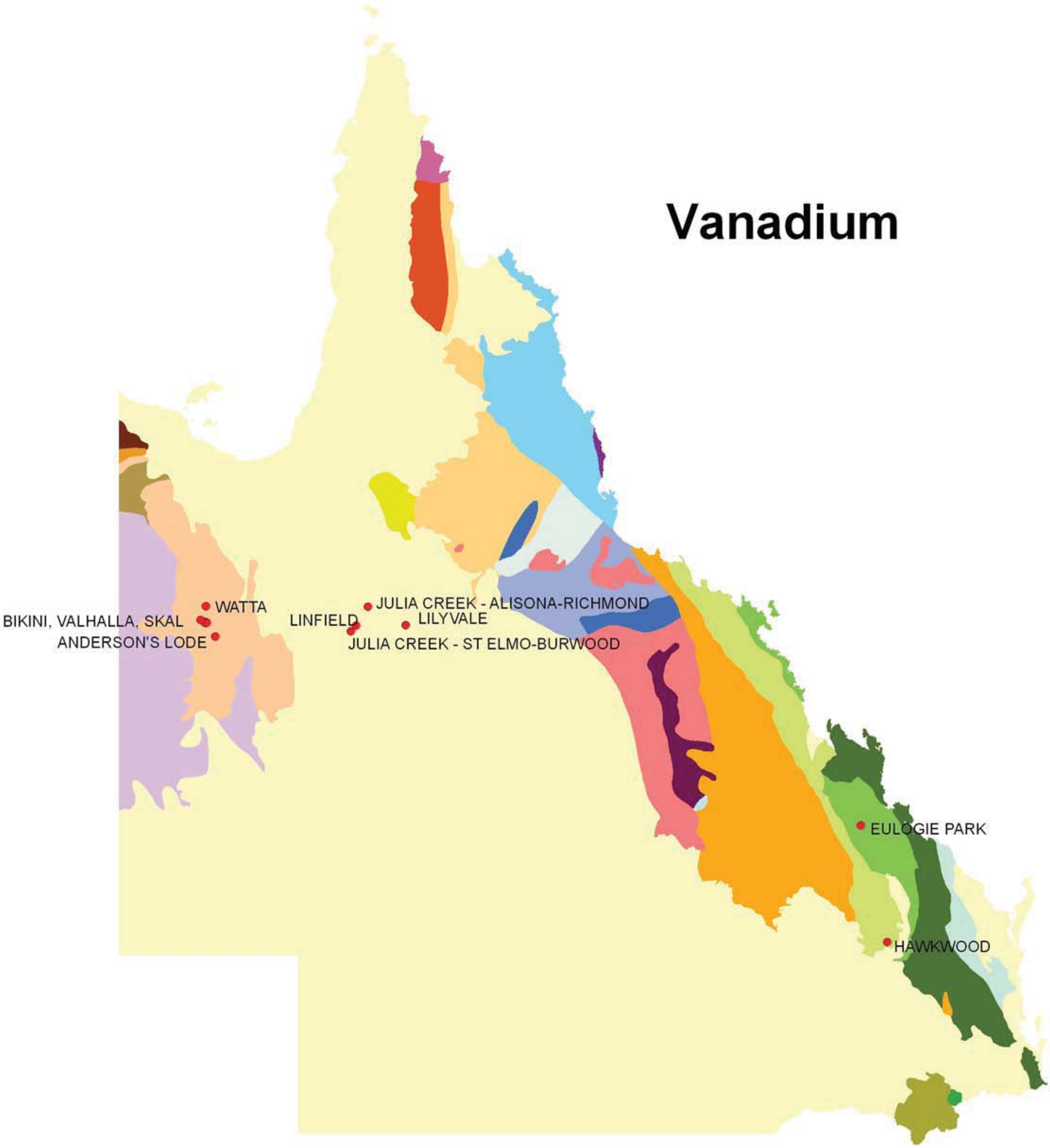
Vanadium

Vanadium is one of the most expensive elements to recover and economic ore generally grades at least 1.5% vanadium pentoxide. Most world production is obtained as a by-product of the treatment of uranium ores.

Queensland's combined resources contain 23.8 Mt of vanadium pentoxide, mainly from the Julia Creek area (Table 15). These near-surface resources occur in the extensive marine oil shale sediments of the Toolebuc Formation in northwest Queensland, that consist predominantly of black carbonaceous and bituminous shale with limestone lenses. The Toolebuc Formation is a flat-lying, Early Cretaceous sedimentary sequence that comprises an upper, coarse limestone-clay-oil shale unit and a lower, fine-grained carbonate-clay-oil shale unit. The oil shale units are composed of kerogen (the oil-bearing component), quartz, clays, calcite and minor pyrite. In the upper part of the Toolebuc Formation, oxidation has increased the concentration of vanadium pentoxide (V_2O_5) and produced a soft, friable limestone-clay mix. This ore type is known as soft oxide coquina and averages 0.25% V_2O_5. Coquina is a bedded limestone that consists predominantly of shells and shell pieces.

Fimiston Mining NL and Fiva Resources Corporation held tenements over the Julia Creek vanadium deposits and investigated the feasibility of mining the soft limestone-clay ore. Tests showed that the soft oxide coquina can be upgraded to a 1–2% V_2O_5 concentrate via simple wet gravity methods. Intermin Resources Ltd now holds the prospects and has carried out further drilling. This company has examined the feasibility of producing both vanadium and molybdenum from the deposits. The oxidised near-surface deposit has less oil content and therefore Intermin Resources Limited has completed an assessment to the scoping study and engineering design stage of the oxidised deposit. Since the moratorium on oil shale mining and processing was lifted, exploration has re-commenced.The Julia Creek combined (measured, indicated and inferred) resource for the soft oxide mineralisation defined in a small portion of the known mineralisation horizon at December 2012 is 5.3Bt at 0.375% V_2O_5 and

Vanadium



WATTA
BIKINI, VALHALLA, SKAL
ANDERSON'S LODE
LINFIELD
JULIA CREEK - ALISONA-RICHMOND
LILYVALE
JULIA CREEK - ST ELMO-BURWOOD
EULOGIE PARK
HAWKWOOD

Table 15. Vanadium deposits of Queensland

Name	Total recorded production	Contained metal in remaining resource	Principal mineralisation style	Formation/Province
Julia Creek Vanadium Molybdenum Prospect (Alisona-Richmond and St Elmo-Burwood and Lilyvale)		24 893 031 t V_2O_5 2 053 374 t MoO_3	Oxidised oil shale	Toolebuc Formation/ Eromanga Basin
Linfield		780 000 t V_2O_5	Oxidised oil shale	Toolebuc Formation/ Eromanga Basin
Valhalla, Bikini, Skal, Anderson's Lode			Iron oxide Cu-Au-(REE)	Eastern Creek Volcanics/ Leichhardt River Subprovince
Watta				Leander Quartzite/ Leichhardt River Subprovince
Eulogie Park			Stratiform mafic-ultramafic Fe-Ti-V (Bushveld)	Eulogie Gabbro/ Permo-Triassic Igneous Provinces
Hawkwood			Stratiform mafic-ultramafic Fe-Ti-V (Bushveld)	Hawkwood Gabbro/ Rawbelle Batholith

312 g/t MoO_3 for 19.99 Mt of contained vanadium pentoxide (V_2O_5). Additional resources quoted in 2009, which are listed on the data sheets, have not been quoted in this resource by Intermin Resources Ltd. The Linfield resource is 170 Mt at 0.46% V_2O_5 for 780 000 t of contained vanadium pentoxide (V_2O_5).

Uranium deposits in the Valhalla area, north of Mount Isa, are known to contain vanadium mineralisation. Drill intersections have included grades of 0.05 to 0.36% V_2O_5.

Minor low-grade vanadium mineralisation is associated with the Eulogie Park and Hawkwood layered gabbro complexes in central Queensland.

Yttrium, heavy and light Rare Earth Elements (REE)

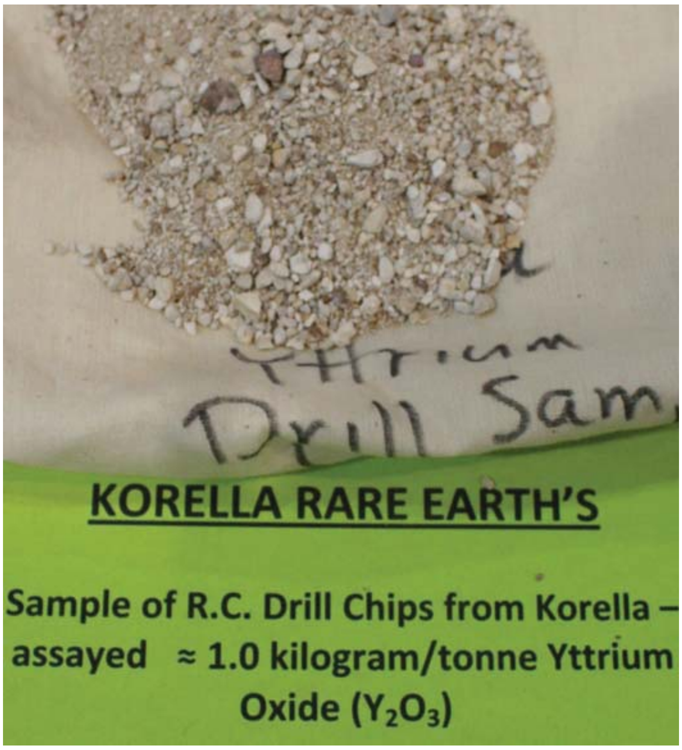
These metals are defined as group of 17 chemical elements in the periodic table, 15 of which are lanthanides. Scandium (discussed earlier with molybdenum) and yttrium are added to this group due to their similar properties and because they tend to form in the same deposits. This group of elements are becoming increasingly important commodities that have major strategic and green-energy implications. Yttrium has been identified as a strategic metal in Queensland.

Yttrium may be used in lasers as yttrium-aluminium garnet (YAG), yttrium vanadate (YVO_4) as host for europium in TV red phosphor, high-temperature superconductors and yttrium iron garnet (YIG) microwave filters. Neodymium is used in rare-earth magnets, lasers, violet colours in glass and ceramics, and in ceramic capacitors for advanced electronics. Dysprosium is also used in rare earth magnets and lasers.

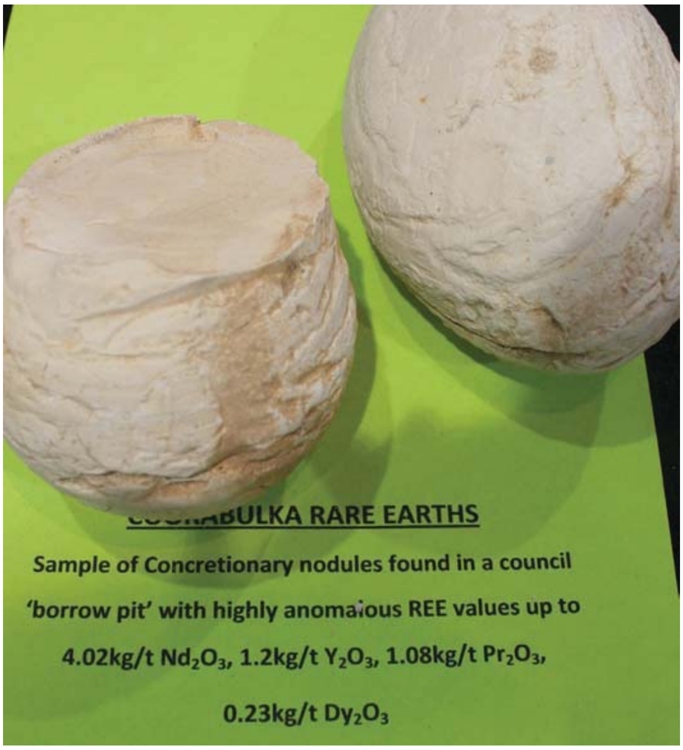
In 2010 detailed analysis of drill holes samples (drilled by Krucible Metals Limited) at the Korella deposit revealed a consistent blanket of yttrium enrichment lying immediately above the high-grade phosphate zone at Korella. The deposit yttrium is contained in the mineral xenotime (YPO_4) — a relatively pure phosphate/yttrium mineral that is amenable to gravity and/or flotation separation (Photograph 172). The yttrium inferred resource for Korella is estimated at 7.03 Mt grading 930 g/t Y_2O_3 containing 6 537.9 t of yttrium. This deposit is now owned by Australian New Agribusiness and Chemical Group Ltd since January 2014.

Additionally to the yttrium heavy rare earth deposit at Korella, Krucible Metals Ltd announced the discovery of svanbergite rich concretionary nodules (Photograph 173) in council road borrow pits at the Coorabulka deposit in 2012, containing neodymium oxide (Nd_2O_3), praseodymium oxide (Pr_2O_3) and Dysprosium oxide (Dy_2O_3). These elements are associated with strontium (up to 6.8%), phosphate (up to 2.07%) and barium (up to 4.2%) in the mineral svanbergite. Petrological investigations indicate the REE contained in the phosphate mineral florencite.

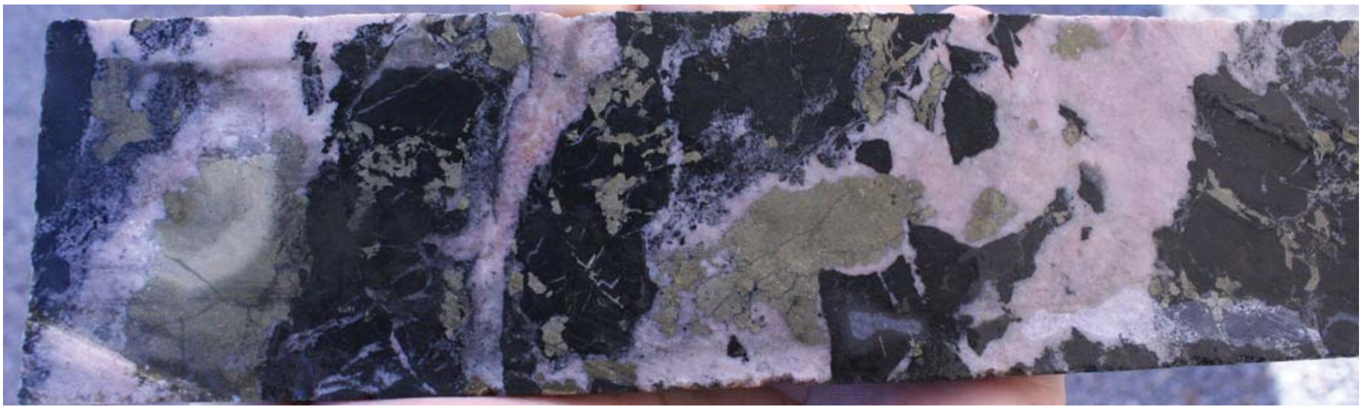
The Milo project is 20 km west of Cloncurry and is held by GBM Resources Limited since its discovery in 2010. The deposit is considered to comprise a multi-element and copper mineralisation, where the REE and yttrium mineralisation (REEY) appears to overprint and envelope the IOCG style Cu–Au–Ag–Mo–U–Co mineralisation (Photograph 174). The main mineralisation is considered to be fault related, possibly linked to the Cloncurry Flexure, a deep structural feature in the region. The mineralisation systems are hosted in highly brecciated and altered rocks affected by possible buried granite that gave rise to the IOCG & REE mineralisation. Drilling to date has delineated continuous Cu and REE mineralisation over a strike length of 1 km and up to 200 m wide. GBM Resources Limited has conducted a scoping study (finalised in January 2013) that supports progression to a pre-feasibility study and is to investigate funding opportunities. Production would focus on rare earth oxides with key credits for copper, phosphate and uranium. Average annual production of key commodities is estimated to be: 3500 t of total rare earth elements and



Photograph 172: R.C. drill chips of yttrium mineralisation contained in the mineral xenotime from the Korella Rare Earths prospect.



Photograph 173: Svanbergite-rich concretionary nodules from the Coorabulka deposit.



Photograph 174: IOCG style Cu–Au–Ag–Mo–U–Co mineralisation from the Milo project.

yttrium oxide (TREEYO) products, 5300 t of copper, 173 000 t of phosphate P_2O_5 (35%) and 927 000 pounds. of uranium as U_3O_8. The inferred resource of 187 Mt at 610 ppm total rare earth elements and yttrium oxide (Y_2O_3) (TREEYO) and 0.75% P_2O_5.,which is estimated to give a 11 year potential mine life. In addition there is an inferred copper resource is 88 Mt at 0.11% Cu, 60 ppm U_2O_3, 130 ppm Co, 65 ppm Mo, 0.04 g/t Au and 1.6 g/t Ag.

Rare earth elements have also been reported in conjunction with other hydrothermal – intrusive-related IOCG deposits. For example in 2010 ActivEx have reported an assay of 4538 g/t TREO with 64% HREO/TREO (heavy/trace rare earth oxides) from the Florence Bore Project, south of Cloncurry.

The Mary Kathleen deposit is hosted by metasediments of the Corella Formation in the Eastern Fold Belt Province in northwest Queensland. Mary Kathleen is now seen as a rare earth element deposit, after long research and exploration, in particular, in the tailings dam of the former uranium mine, which contains concentrated amounts of rare earth elements. The mineralisation is comprised of 3.0% rare earth oxides, 0.13% uranium oxide and 0.025% thorium oxide. The breakdown of the rare earth element oxides for Mary Kathleen has been recorded as 35% lanthanum oxide, 50% cerium oxide, 3% praseodymium oxide, 11% neodymium oxide and 1% others. This skarn-hosted mineralisation is now thought to have formed by infiltration of metamorphic fluids along the Mary Kathleen Shear Zone during the Isan Orogeny. Controls on ore deposition were lithological. Open cut mining commenced at Mary Kathleen in 1953 and ceased in 1963. The mine was re-opened in 1975 and mining operations ceased in 1982 when the ore reserves were exhausted. The ore which mainly consisted of the rare earth mineral allanite and contained about 3% light rare earths which were not recovered. The uranium occurred mainly as uraninite inclusions in allanite and garnet.

They have now been identified remaining in the former tailings dam. Small remnant uranium resources remain at Mary Kathleen. The Government calculated a grade-tonnage model through CSA Global for the tailings storage facility. 13 holes were drilled and an estimated exploration target identified of 5.5 to 7.5 Mt of tailings grading from 2 to 4% light rare earths with residual uranium grading 0.006% to 0.012% and thorium grading 0.015% to 0.03%. The proportions of the light rare earths are 50% cerium oxide, 35% lanthanum oxide, 11% neodymium oxide, 3% praseodymium oxide and 1% others. The area encompassing the Mary Kathleen open-cut and tailings that were held in Restricted Area 232 has been released for competitive tender after the Queensland Government assessed environmental and safety issues. The tender closed on 3 November 2014 and the successful tenderer will be granted an exploration permit for minerals with the intent to progress to a production lease and to also address the reduction of mining legacy issues on site. The land release area includes the Mary Kathleen open pit, six waste rock dumps, six stockpiles, a 30.7 hectare historic processing area and a 110.6 hectare tailings storage facility and evaporation pond area.

A similar rare earth element mineralisation is currently being explored by China Yunnan Copper Australia Limited (Chinalco) at the Elaine Dorothy deposit south of Mary Kathleen, along the Mary Kathleen shear. China Yunnan Copper Australia Limited (70%) and Goldsearch Limited (30%) have discovered a multi-element mineralised system containing variable and quite high grades of copper, cobalt, gold, rare earths and uranium over significant widths. The rare earths and associated uranium-thorium mineralisation, which is interpreted as a separate mineralising event that overlaps with the copper-cobalt-gold mineralisation, is not included in the copper resource estimate. At the nearby Elaine South deposit, an inferred resource of 83 000 t at 280 ppm U_3O_8 and 3200 ppm total rare earth oxides (TREO) at a cut-off of 200 ppm U_3O_8 was calculated in March 2010. The resource is considered open at depth.

Gemstones

Opals, sapphires and other gemstones are mined commercially in Queensland to supply world markets. Gemstone production in 2011–12 (2012–13) is mainly derived from sapphire (12.11%) (74.70%) and boulder opal (80.41%) (21.72%) mining operations. The remaining gemstone production comes from small quantities of zircon (4.39%) (2.11%) topaz (0.27%) (0.10%), and others (2.81%) (1.37%) which comprise unspecified amounts of agate, chrysoprase, aquamarine and garnet.

Queensland's gemfields also support a 'cottage' industry, where local stone is cut and polished for the domestic jewellery trade and tourist market. Tourist and recreational fossicking is welcomed in Queensland and many visitors come to the gemfields, where specific areas have been established to exclude larger machinery mining and allow smaller tourist fossicking activities.

Chrysoprase

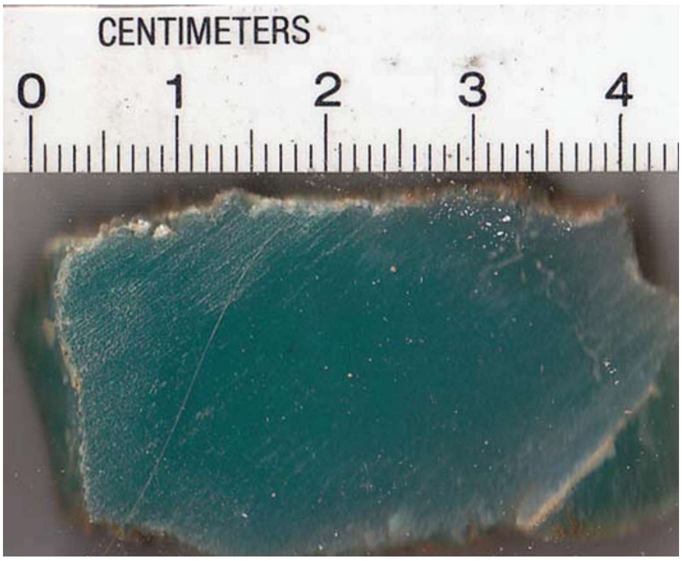
Australia is the world's principal producer of chrysoprase, and the major deposit in Australia is Queensland's Marlborough (Gumigil) Chrysoprase mine. No production figures for Queensland produced chrysoprase in 2008–13 are recorded. Queensland produced chrysoprase with a rough value of A$169 300 in 2007–08.

Chrysoprase is a translucent green chalcedony that owes its colour to traces of nickel oxide compounds (Photograph 175). It is usually translucent, but may become opaque in poorer quality material. The highest quality material is a rich apple green of even colour, without flaws, fractures, inclusions, cavities or other imperfections. Gem quality chrysoprase can be pale green, yellowish green, apple green, to deep green. Chemically chrysoprase is almost entirely composed of silicon dioxide (SiO_2), giving it a hardness rating of 6.5 to 7 on the Mohs scale. Chrysoprase is rare and is the most valuable of the chalcedony group. Being an important ornamental gemstone, it is fashioned principally into cabochons, beads and bangles, or is carved to produce jewellery and other objects. It is easily worked and takes a fine polish.

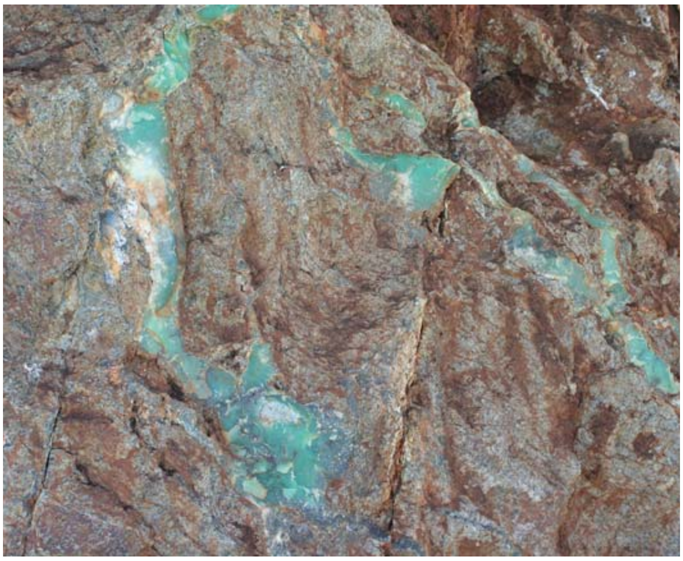
All major chrysoprase deposits in Queensland are in the Marlborough Block, about 90 km northwest of Rockhampton, and are associated with nickeliferous laterite that has formed from the weathering of serpentinites and ultrabasic rocks of the Paleozoic Princhester Serpentinite. Chrysoprase occurs as veins and nodules in the magnesite-rich saprolite zone (Photograph 176), underlying an iron-rich silica cap. During weathering, the silicate minerals decompose to iron oxides, releasing silica and nickel that migrate down through the developing laterite profile to precipitate as veins and nodules.

Gumigil Pty Ltd, a Hong Kong-based company, owns the Marlborough chrysoprase deposits (Photograph 177), 15 km south of Marlborough. The Gumigil and Currawong mines export the best quality chrysoprase in the world and have been producing chrysoprase for the past 27 years. Three other chrysoprase deposits occur adjacent to the Gumigil operations and are owned by Candala Pty Ltd. All three have been under evaluation for several years.

Queensland's total inferred chrysoprase resource is 1975 t, with 1660 t of this within Gumigil's Marlborough Chrysoprase deposit. This resource figure was calculated in 1998 and has been significantly depleted. Future chrysoprase production in Queensland is projected to last for at least 20 years, with exploitation of other smaller chrysoprase deposits.



Photograph 175: Chrysoprase from the Marlborough deposit.



Photograph 176: Chrysoprase veins in nickeliferous laterite from the Marlborough deposit.

Photograph 177: The Gumigil Marlborough open cut worked for chrysoprase.

Opal

Opal is Australia's national gemstone (Photograph 178). Australia produces 95% of the world's opal and the value to the Australian economy is unknown owing to the opal industry's fragmented nature and inadequate official records. Production figures of between $100 million and $200 million per annum for uncut gems are generally quoted. Estimates from the various State governments support the more conservative figure. Australia exports most of its opals to Germany, Holland, Japan, the USA and China. Queensland produced opal with a rough value of A$750 575 (A$571 278) in 2011–12 (2012–13).

Australia has three main types of natural precious opal, with varieties defined by both body tone and transparency. Varieties include black opal from Lightning Ridge in New South Wales, white opal from South Australia, and Queensland boulder or matrix opal. The term 'boulder opal' describes precious opal that occurs in deposits within weathered sedimentary rocks of Cretaceous age in western Queensland. Boulder opal is unique to Queensland. The boulder or matrix opal occurs as an infilling of pores and cavities or between grains of ironstone host rock (Photograph 179). The ironstone host rock is generally elongated or ellipsoidal in shape, forming concretions or boulders that range in size from less than a few centimetres to >20cm. Boulders may be confined to one or more layers, known as the boulder layer, or may be randomly distributed throughout the weathered sandstone. Smaller ironstone concretions up to 5cm across are known as 'nuts' and may host a kernel of solid opal or contain a network of thin veins of opal throughout the ironstone. Similar to other precious opal types, there are many varieties of boulder opals as defined by body tone, play-of-colour and transparency, including black boulder opal and dark or light boulder opal.

Photograph 178: Rough and polished Queensland opal (boulder opal) (image courtesy DNRM, Queensland Mineral and Petroleum Review, 2003).

Photograph 179: Numerous examples of polished boulder opal displaying some ironstone rock along margins (samples from GSQ's historical collection, image courtesy Paul Blake, GSQ).

Photograph 180: Small miner's opal mining claim near Quilpie.

Queensland's opal fields lie within a 300 km wide belt of deeply weathered Cretaceous sedimentary rocks known as the Winton Formation in the Eromanga Basin. This belt extends in a north-northwesterly direction from Hungerford on the New South Wales border to Kynuna in northwest Queensland, a distance of ~1000 km, and west of the townships of Cunnamulla, Quilpie, Longreach and Winton.

On average, individual opal fields cover areas of 0.05–5 km^2, with opal mineralisation occurring in flat-lying layers at depths of up to 30 m below the surface. Commonly, two or more levels of opal mineralisation may be present in any given field. Gem quality opals are seldom distributed evenly throughout a field. Distribution is sporadic and is usually related to structure or rock type, with rare rich pockets of opal. Opal mining is predominantly by open cut operations (Photograph 180) that involve overburden stripping to expose the ironstone boulders. Underground mining methods are applied with success in localised areas.

Exploration is continuing over potential opal-bearing country and an increasing interest from small exploration companies applying modern exploration techniques should lead to further discoveries. In addition to traditional opal fields, exploration for opal is also being carried out in the Hebel–Dirranbandi area near the Queensland – New South Wales border, where there is a 70 km northern extension of the Cretaceous Griman Creek Formation, host to the Lightning Ridge opal field. Detailed exploration in the Hebel–Dirranbandi area has revealed gem quality black opal and prospective geological conditions. Opal Horizon Ltd recently uncovered spectacular 'pipe' opal deposits at its Lina Glen project near Jundah in western Queensland.

Sapphire

Sapphire is a variety of the mineral corundum and one of Queensland's most important gemstones. Most of Queensland's sapphire production comes from the Anakie field, west of Emerald in central Queensland. Commercial mining has occurred in the Anakie field for more than 100 years. Mining in Queensland supplied world markets with sapphire worth A$113 055 (A$1 964 528) in 2011–12 (2012–13).

Sapphire deposits in Queensland are mainly associated with Tertiary and Quaternary alluvial deposits derived from the weathering and erosion of Tertiary alkali-volcanic rocks (basaltic lavas, pyroclastics and volcaniclastics) of the Eastern Australian Cainozoic Igneous Province. Varieties of sapphire recovered from mining include dark blue, multi-coloured (parti-colours) and fancy stones (Photograph 181). A large proportion of sapphires mined commercially are medium to dark blue, due to their high iron content. Most sapphires are 'heat treated' to improve clarity and colour. Only the blue stone is sold in volume to the world market. Although most sapphire miners operate on mining claims in the Sapphire and Rubyvale areas, a number of mining leases are held by the largest mechanised operation at the Australia Mine (Photograph 182). Production is made up of a significant quantity of smaller commercial size stone suitable for cutting into 2–3 mm calibrated stones for the mass jewellery market. The bulk of commercial sapphires produced in Queensland are exported to Thailand as rough stone with very little value adding done in Australia.

Tertiary-age sapphire-bearing paleodrainage systems in the Anakie field have been reworked by modern drainage systems to form the main sapphire-bearing alluvium. Remnants of older alluvium occur in many areas as primary, high-level gravels (known as wash by the miners) on elevated ridges between or adjacent to the present drainage. Sapphire-bearing alluvium may be exposed at the surface or covered by up to 20 m of barren overburden. Sapphires and associated heavy minerals are commonly concentrated in 'runs' along particular drainage channels. The character and size of sapphire grains, associated heavy mineral assemblages and

Photograph 181: Cut gold and blue sapphires from the central Queensland gem fields (image courtesy DNRM).

Photograph 182: (left) One of several deep open cuts down to the 'wash' levels of the alluvium at the Australia Mine; (right) mobile alluvial screening plant at Australia Mine.

detritus varies considerably. The probable original source of the sapphires is the Hoy Basalt, represented by a group of at least 60 eroded volcanic vent plugs that intrude the pre-Devonian Retreat Granite. The Hoy Basalt is characterised by porphyritic olivine and contains inclusions of basic plutonic rocks, especially peridotite.

Queensland sapphire mining varies from simple hand mining methods (suitable for working shallow surface wash deposits) to large-scale open cut operations employed on the deeper ground. Techniques for processing the wash to concentrate sapphires and heavy minerals range from rudimentary hand sieving and washing to mechanised plants. Gem-quality zircons and diamonds (rare) are recovered with the sapphires.

The largest single sapphire resource in Queensland is the Nardoo mine, which is in the Anakie field and contains a non-JORC reserve of 22 t of sapphires. The mine was run by Australis Mining Corporation Ltd, but leases have now lapsed.

The smaller Lava Plains field, between Greenvale and Mount Garnet in northeastern Queensland, differs markedly from the Anakie field because the basalt hosting the sapphires crops out at the surface. Sapphires in the Lava Plains field occur in modern eluvium, colluvium and alluvium derived from eruptive volcanics in the vicinity of a limited number of vents. The sapphires are hosted by brown and black clayey soils containing vesicular basalt rock fragments, basalt cobbles and boulders. Associated minerals in the wash include zircon, ilmenite, olivine, hematite and feldspar. The main mining areas are centred on Wyandotte Creek and Mines Hill.

The commercial production of sapphires in Queensland has been in decline since the late 1970s, and only intermittent improvements to prices and markets have occurred since. Around 2009 to 2011 the downturn in sapphire production was partially the result of increased production from low-cost sources such as Madagascar, Nigeria and Tanzania. The 2012–13 figures have shown a marked improvement in sapphire production.

Industrial minerals

'Industrial minerals' is a collective term for minerals used in the glass, ceramics, refractory processes, paper, paint, plastics, abrasives, chemical, foundry, fertiliser and cement and construction industries, but also in mineral-processing facilities such as refineries and smelters. Queensland is a significant producer of industrial minerals. Generated value of the total 'industrial minerals' in 2011–12 (2012–13) comprises A$ 531 915 291 (A$445 585 130). Note these figures include titanium minerals as variance to quoted figures in the DNRM Queensland Annual Mineral Summary statistics. The main industrial mineral resources in Queensland are bentonite, diatomite, dolomite, kaolinite, limestone, magnesite, perlite, phosphate, salt, silica sand, wollastonite titanium minerals and zeolite, each of which are described separately below.

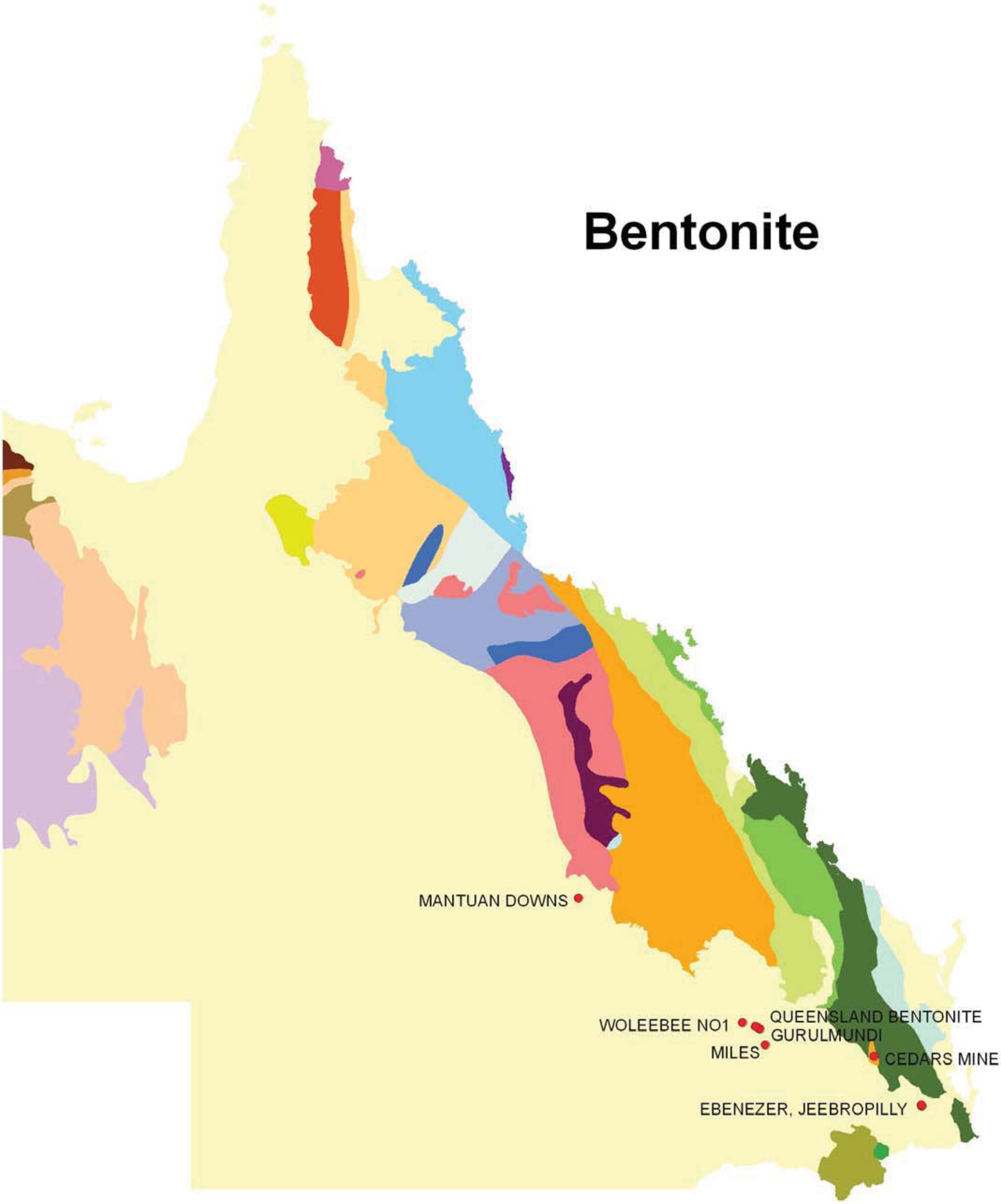
Bentonite

Queensland is the major bentonite producing state in Australia, with production from large, shallow open cut deposits in the State's southeast. Bentonite production in Queensland was 37 585.3 t (68 220 t) in 2011–12 (2012–13). Known resources and reserves contain ~59.4 Mt of bentonite (Table 16).

Table 16. Significant bentonite deposits of Queensland

Name	Location	Total historical production (t)	Total resource (Mt)	Company	Comments
Cedars Mine	10km SW of Yarraman	122 782	0.2	PCP Douglass Pty Ltd	Used as a stock feed, in air filter in septic systems and sewage pumping plants, and as an odour absorbent in chicken manures, pellet binder and in refractories, 17 years mine life. No recent production.
Ebenezer (sodium bentonite)	10km SE of Ipswich	133 537	1.9 (estimated in 1999)	Clay Resources Company, a subsidiary of Ebenezer Mining Company Pty Ltd	By-product of coal mining. Used in stock feed, pet litter, civil engineering, dam sealing and wine making
Gurulmundi and Gurulmundi North (sodium bentonite)	Gurulmundi township, 30km north of Miles	1 128 850	12	Unimin Australia Ltd	Australia's largest producer, 120 000tpa capacity processing plant. Bentonite used for drilling mud, civil engineering applications, pet litter and as a binder for foundry sands and stock feed
Jeebropilly Bentonite (calcium-magnesium bentonite)	7km SW of Ipswich	68 268	Not reported	Jeebropilly Collieries Pty Ltd	Stockpile of Ca–Mg bentonite
Mantuan Downs	135km SW of Emerald	2213	15	Pacific Enviromin Ltd	Montmorillonite clay capable of upgrading to sodium bentonite. Mining commenced in April 2008.
Miles (sodium bentonite)	5 km SW of Miles	135 678	3.3	Bioclay Pty Ltd trading as Miles Bentonite	Stock feed and pet litter
Queensland Bentonite (high swelling sodium bentonite)	36km NW of Miles and 6km W of Gurulmundi	108 925	12	Volclay International Ltd	
Woleebee No.1 (sodium bentonite)	28.9km SW of Wandoan	171 797	Not reported	Unimin Australia Ltd	No recent production

Bentonite


MANTUAN DOWNS
WOLEEBEE NO1
QUEENSLAND BENTONITE
GURULMUNDI
MILES
CEDARS MINE
EBENEZER, JEEBROPILLY

Bentonite deposits form *in situ* by the alteration of minute glass particles in volcanic ash or tuff beds that were deposited in sedimentary sequences characterised by low energy depositional environments and temperate climatic conditions. Bentonite deposits are hosted by and associated with argillite, mudstone, siltstone, sandstone, tuff, agglomerate, ignimbrite, marl, shale, zeolite beds and coal. World-wide, most economic bentonite deposits are of Cretaceous age or younger. However Queensland occurrences are mainly of Jurassic age.

Bentonite is an absorbent clay mineral with unique swelling properties and a wide range of industrial applications in drilling and construction/civil projects, foundry, cat-litter, stock feed and dam sealing. The applications for bentonite are based on the chemical activity provided by the cation exchange characteristics. The most common and commercially significant bentonites are sodium, calcium and calcium-magnesium varieties. Queensland's major bentonite deposits are all principally sodium bentonite. Premium grade sodium bentonite has exceptional water absorbency and cation exchange capacity. The value (grade) of the product depends on the type of impurities, colour, size of clay particles, cation exchange capability, rheological properties and structure of the clay.

The largest bentonite resources in Queensland are in the Miles–Gurulmundi region of the Darling Downs, 300 km west of Brisbane. The sodium bentonite (which is the most commercially significant form of bentonite) occurs as lenticular, bedded deposits near the top of the Late Jurassic Orallo Formation, just below its contact with the Cretaceous Mooga Sandstone. Seams of bentonite also occur in the Middle Jurassic Walloon Coal Measures at the Ebenezer coal mine (Photograph 183). Bentonite deposits also occur in deeply weathered and altered acidic volcanic sediments of the Tertiary Main Range Volcanics at Yarraman, southeast of Kingaroy and 130 km northwest of Brisbane.

Photograph 183: A bentonite seam in the Walloon Coal Measures at the Jeebropilly open-cut coal mine, Rosewood (image courtesy DNRM, Queensland Mineral and Petroleum Review, 2002.)

Sibelco Australia Pty Limited, which mines the Woleebee No.1, Gurulmundi and Gurulmundi North deposits, is Australia's largest bentonite producer, after acquiring these operations from Unimin Australia Limited in 2011. Their plant has a 120 000 tpa capacity and produces a range of sodium bentonite products. A pet litter production plant has also been installed. The sodium bentonite is processed on site and sold locally or transported to the port of Brisbane for export.

Amcol Australia Pty Limited, a subsidary of Amcol International Corporation, operates the nearby Queensland Bentonite mine (36 km northwest of Miles), which produces a high swelling sodium bentonite through its 80 000 tpa processing plant. Once mined, the sodium bentonite is sun dried, processed, and packaged on site. It is sold into a broad range of domestic and international markets that include exploration drilling, construction/civil, foundry, cat litter, stock feed, dam sealing, wine clarification plus other niche markets.

The smaller producer Bioclay Pty Limited reported production of sodium bentonite from the Miles bentonite deposit southwest of Miles. This bentonite is used primarily for stock feed and pet litter and is processed in a plant with a 20 000 tpa capacity. Resources are claimed to be sufficient for next 20 years at current production rates. Modest production also occurred from the Cedars mine, approximately 10 km southwest of Yarraman, where the sodium bentonite is formed through weathering and alteration of acid volcanic sediments, probably deposited in a lacustrine environment (Photograph 184). This small mine is operated by PCP Douglas Pty Limited.

Jeebropilly Collieries Pty Ltd produces minor quantities of Ca–Mg bentonite from stockpiles near Ipswich.

Pacific Enviromin Ltd (through its subsidiary Ipoh Pacific Resources Pty Ltd) commenced mining calcium bentonite at Mantuan Downs, 78 km south of Alpha, in central Queensland in April 2008, with a total production of 2213 t of calcium bentonite up to 2010. No production was recorded between 2011 and 2014. The Mantuan Downs calcium bentonite deposit has an inferred resource of over 17 Mt of high-grade calcium bentonite in two main flat-lying bentonite beds. This deposit is held by Australian Pacific Coal Limited. The Upper Bentonite Zone is the thickest and has an average cation exchange capacity quality of 102 meq/100 g where it is 4 to 4.5 m thick (close to the centre of the deposit). The Lower Bentonite Zone has similar quality bentonite with an average cation exchange capacity of 90 meq/100g and ranges in thickness from 2 to 4 m and is continuous

Photograph 184: Cedars mine open cut, source of sodium bentonite from flat-lying altered volcanic sediments formed in a lacustrine environment.

throughout the deposit. Australian Pacific Coal Limited has developed calcium bentonite based technologies for the improvement of the environment. These technologies include remediation of heavy metal contaminated soils, the removal of carcinogenic compounds from high temperature smoke, the global licence for absorption of oil spills in water, increasing productivity through bentonite blending for fertiliser, and the reduction of methane emissions in livestock.

The major market being targeted is excess fertilizer run-off from farming lands along the Queensland coast. Generally positive results from field trials have enhanced the long term prospects for use of calcium bentonite in this application. Commercial considerations for primary producers in these regions mean that changes to traditional farming practice are only likely to happen in response to Government pressure to fix this problem. Based on prior research which highlighted the benefit of bentonite in enhancing soils and composts, the company also focused on the agriculture sector end users in broad acre, high value market gardens, and feed lots. While feedback from field trials has generally been positive, the reticence of primary producers to change long term farming practice has slowed market take up.

The outlook for Queensland's bentonite resources is mixed, with sales growth dependent on further penetration of export markets and the development of new applications for bentonite products.

Diatomite

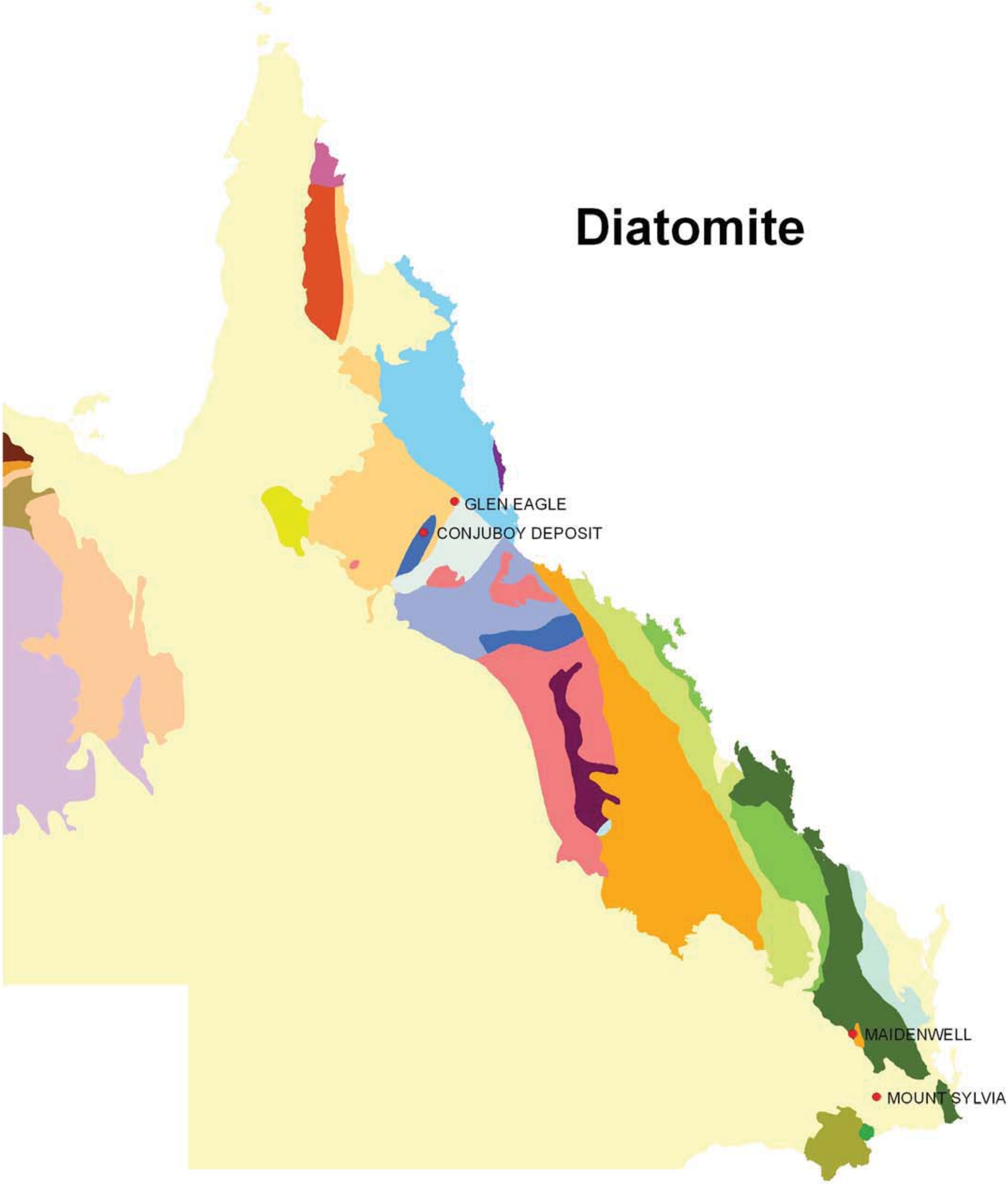
Diatoms are microscopic, unicellular aquatic plants related to algae and have siliceous cell walls (Photograph 185). As diatoms die and sink through the water column, accumulations of siliceous sediments form on the sea or lake floor and are preserved in geological history. Consolidated deposits of these siliceous sediments are called diatomite and unconsolidated deposits are referred to as diatomaceous earth. Diatomite is chalk-like, soft, friable, very fine grained and earthy. Diatomite is usually light in colour, ranging from buff to grey, white when pure and very rarely black.

Commercial diatomite products come in a great variety of grades. Principal factors affecting diatomite grade are size, shape, arrangement, silica content and impurities, brightness and abrasive hardness. Diatomite may be calcined to remove organic material, increase pore size and enhance the filtration rate. Most filter grade diatomite is calcined.

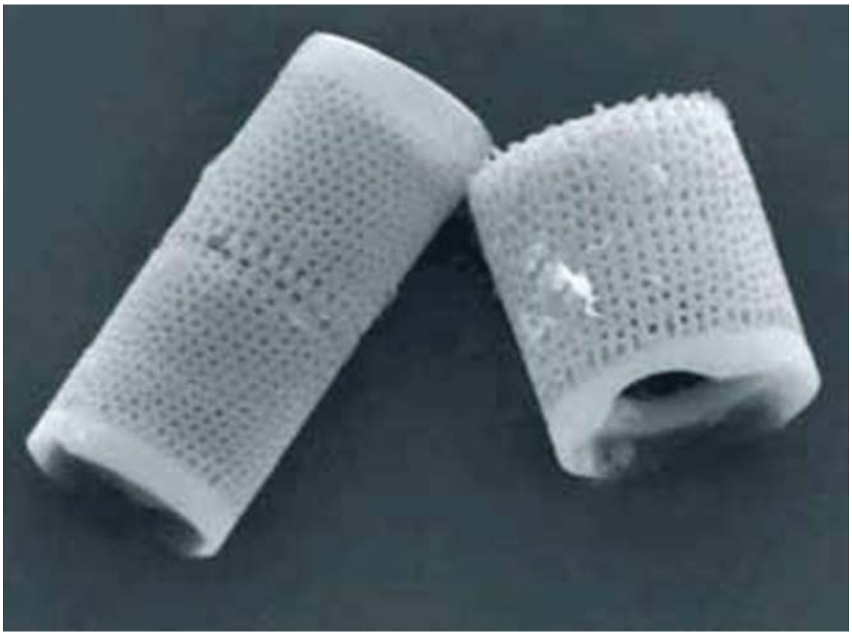
Queensland diatomite production totalled 861 t (9 238 t) in 2011–12 (2012–13) and came from the Mount Sylvia and Maidenwell deposits. Total resources are not known.

Mount Sylvia, near Gatton 35 km southeast of Toowoomba, is a lacustrine style deposit that occurs as thin lenses (averaging ~2 m thick) formed when basalt lava flows of the late Oligocene to early Miocene Main Range Volcanics dammed local drainages (Photograph 186). It comprises small cylindrical *Melosira* plus some colloidal fines and occasional sponge spicules in a white, dense rock containing relatively little opaline material. The diatomite is processed on site by calcining to temperatures of about 450°C. A number of products are produced that absorb up to 200% water and oil and have been developed to supply niche markets in the pesticide industry, horticulture where it is used in soil conditioning, absorbent material for cat-litter and chemical spillage, and filters for oils and beverages. Mount Sylvia Diatomite has also developed diatomite–molasses products for stock feed. Mount Sylvia has never been drilled and fully evaluated, but the company assumes reserves in excess of 600 000 t, which is sufficient to maintain a mining operation for a considerable time into the future at plant capacity of 3000 t per year (Photograph 187). Mount Silvia also produces palagonite, a mixture of smectite clays and poorly crystalline feldspars that occurs within the basalt overburden and is recovered to supply niche markets as an organic soil conditioner. Road base from the basalt is also a significant income generator.

Diatomite



Photograph 185: Diatomite frustlules (25 to 30 microns long) from the Conjuboy diatomite deposit (image courtesy DNRM, Queensland Mineral and Petroleum Review, 2002).



Photograph 186: Lacustrine style bentonite deposit overlain by basalt lava flows at Mount Sylvia bentonite mine.

Photograph 187: Mount Sylvia bentonite processing and drying plant.

Photograph 188: Maidenwell processing plant (image courtesy Jim Lam, DNRM).

Photograph 189: Bentonite rock from the Maidenwell deposit (image courtesy Jim Lam, DNRM).

Diatomite has also been mined (Photograph 188) in recent years from the Maidenwell deposit, 26 km southwest of Nanango. This lacustrine deposit formed within the Main Range Volcanics (Photograph 189). The diatomite from this deposit is used largely as a soil conditioner in the local grape and nursery industries.

The Conjuboy deposit, near Conjuboy homestead 45 km northwest of Greenvale, is the largest known diatomite resource in Queensland. The deposit is operated by Greenvale Silicon Pty Limited. This lacustrine deposit consists mainly of the cylindrical diatom *Melosira* in a poorly cemented horizon, interbedded with clay sand and conglomerate lenses. Typically, diatomite at Conjuboy is 20–25 m thick beneath 3–4 m of sandy clay, diatomite and basalt rubble. It is exposed in the beds of creeks that cut the Quaternary basalt cover. A measured and indicated resource of 2.25 billion cubic metres has been identified, and a reserve and resource update is in progress. The deposit has been tested for the potential to produce high quality filter grade and human health products and has been shown to exceed the requirements of the brewing industry in terms of product quality. In recent years considerable work has been done on evaluating the potential to use diatomaceous earth as a source for silicon fertiliser. Following successful laboratory tests, extensive field trials have now been carried out in Australia, India, Indonesia and Saudi Arabia with extremely good results. Agripower has developed a high quality silicon fertiliser that is certified for organic input in Australia and the USA and has demonstrated not only increased crop yields but of equal importance, increased quality of crops and at the same time lowering the requirement for chemical based fertilisers. The raw diatomite is transported by road from the mine site to the Charters Towers processing facility, a distance of approximately 300kms. Agripower has commissioned the first stage of the processing facility which has allowed production at the rate of approximately 100 000 tpa of agricultural grade product. Having established the market, the second stage of the facility build is expected to commence in 2015 at the rate of approximately 150 000 tpa of agricultural grade product. Agripower has established sales and marketing offices in India, China, Indonesia, Malaysia, Saudi Arabia, Egypt, Turkey and Morocco.

The Glen Eagle deposit, 77 km northeast of Conjuboy, has a potential, but poorly defined resource of 10 Mt of diatomaceous earth.

Dolomite and earthy lime

The term 'dolomite' is usually applied to rocks that consist of >50% carbonate minerals and in which magnesium exceeds calcium. Rocks with less magnesium content are termed dolomitic limestone. Commonly, dolomite is associated with limestone, and can represent diagenetic or metasomatic replacement of limestone (dolomitisation).

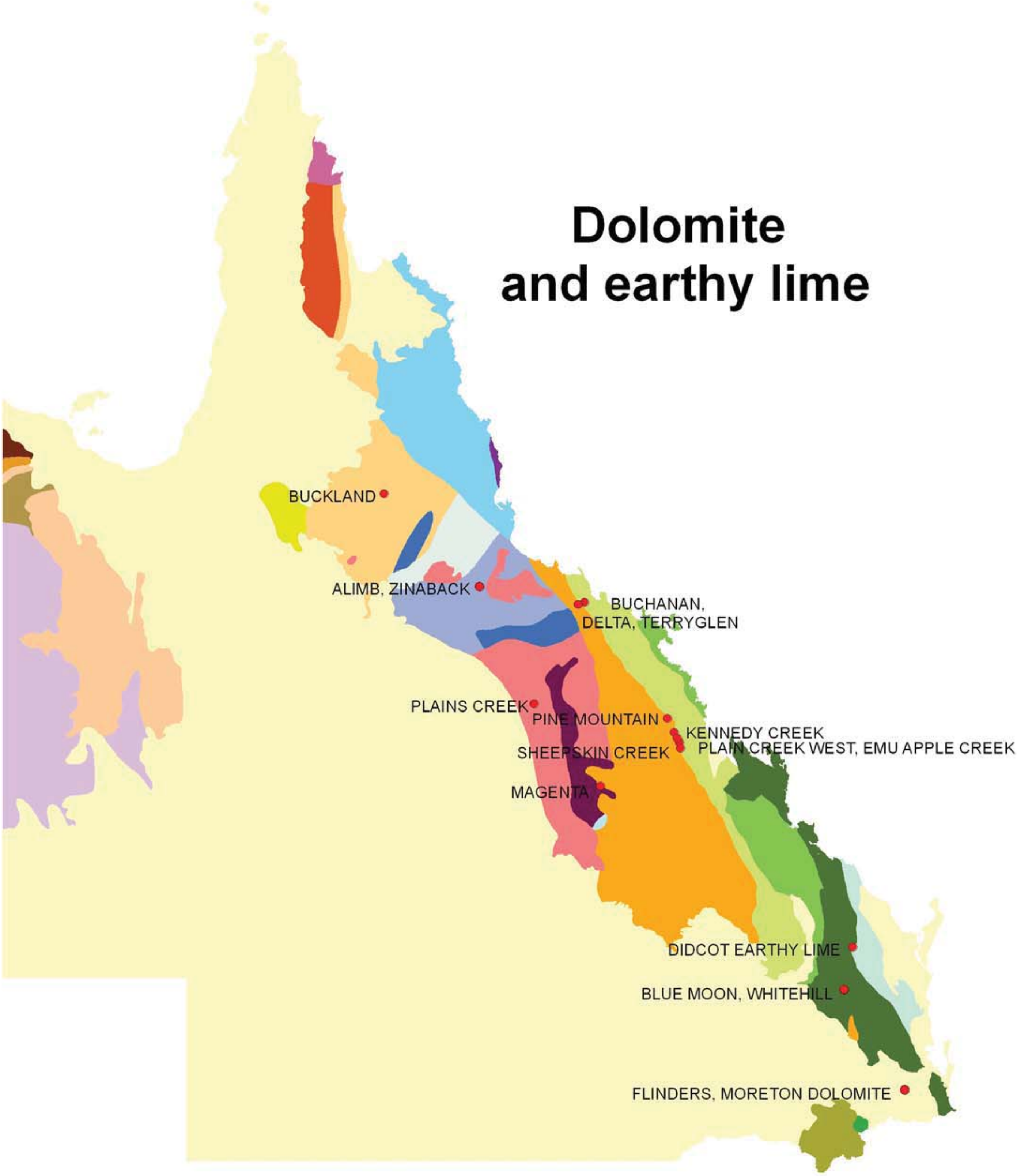
Earthy limes contain a mixture of calcium and magnesium carbonate and clays and commonly form from the weathering and surface enrichment of intermediate to basic volcanic rocks.

Numerous dolomite and earthy lime deposits occur scattered along the east coast of Queensland. These small deposits have been surface mined for low-grade calcium-magnesium material for agricultural purposes, primarily in the sugar cane industry. Some of the state's producers include Flinder's Dolomite Pty Ltd, Zinaback Pty Ltd and Moreton Dolomite Pty Ltd (Photograph 190). Production in 2011–12 (2012–13) totalled 39 981 t (10 103 t*) of dolomite and agricultural lime* (Table 17).* reporting for these figures is incomplete.

The Wilkins family in the last decade have grown their agricultural lime business under the names Mirriwinni Lime Pty Ltd and Zinaback Pty Ltd though lease purchases and exploration in north and far north Queensland and have a controlling share of the market in the region. The company now mines produces and supplies a variety of natural fertilizers relating to the agricultural lime

Table 17. Dolomite and earthy lime deposits of Queensland

Name	Location	Total historical production (t)	Known resources	Host rocks/Province
Alimb	74km NW of Charters Towers	104 944.5		Allingham Formation/ Nulla Basalt Province
Blue Moon	19km NW of Wondai	22 569.3		Main Range Volcanics/ Main Range Volcanic Subprovince
Buchanan	24.2km SSE of Home Hill	72 901.2		/Kennedy Province
Buckland	12.2km WNW of Mount Garnet	196 085		Undara Basalt/ McBride Basalt Province
Delta	27km S of Home Hill	41 590		Kennedy Province
Didcot Earthy Lime	29km ENE of Gayndah	19 396.6		Mount Marcella Volcanics/ South-East Queensland Volcanic and Plutonic Province
Emu Apple Creek	47km SW of Carmila	6014	103 530t earthy lime	Mount Benmore Volcanics/ Connors Subprovince
Flinders	20km S of Ipswich	214 095		Flinders Dolomite/ Amberley Basin
Kennedy Creek	70km SW of Sarina	6230		Lizzie Creek Volcanics/ Connors Subprovince
Magenta	11km SE of Clermont		50 000 000t earthy lime/dolomite	Clermont–Springsure Basalt Province
Moreton Dolomite	24.6km S of Ipswich	31 557		Flinders Dolomite/ Amberley Basin
Pine Mountain	17km ESE of Nebo	17 820.1		Cainozoic Basalt Provinces
Plain Creek West	46km W of Carmila		364 131t earthy lime	Mount Benmore Volcanics/ Connors Subprovince
Plains Creek Dolomite	180km S of Charters Towers		50 000t dolomite	Quaternary alluvium
Sheepskin Creek	50km W of Saint Lawrence		Confidential	Lizzie Creek Volcanics/ Connors Subprovince
Terryglen	26.5km S of Home Hill	20 122.5		Kennedy Province
Whitehill	19km NW of Wondai	18 373.8		Main Range Volcanics/ Main Range Volcanic Subprovince
Wadley Lease	25km S of Ipswich	7299.5		Flinders Dolomite/ Amberley Basin
Zinaback	72km NW of Charters Towers	69 613.3	450 000t earthy lime/dolomite	Allingham Formation/ Nulla Basalt Province


Dolomite
and earthy lime
BUCKLAND
ALIMB, ZINABACK
BUCHANAN,
DELTA, TERRYGLEN
PLAINS CREEK
PINE MOUNTAIN
KENNEDY CREEK
PLAIN CREEK WEST, EMU APPLE CREEK
SHEEPSKIN CREEK
MAGENTA
DIDCOT EARTHY LIME
BLUE MOON, WHITEHILL
FLINDERS, MORETON DOLOMITE

Photograph 190: Dolomite and palygorskite (bottom levels) mined from Wadley Lease by Moreton Dolomite.

industry. It also sources magnesite and magnesium oxide from QMAG at Kunwarara, rock phosphate from Incitec Pivot and diatomite from Conjuboy for direct sale or in the production of its blend range. The company holds limestone leases at Chillagoe (also produces wollastonite) near Mount Garnet, Christmas Creek 40 km east of Greenvale, Laroona 110 km east-southeast of Greenvale and Mount Molloy, dolomite leases at Hillgrove 110 km southeast of Greenvale, Gunnawarra 35 km south-southwest of Mount Garnet and gypsum leases centred 110 km southwest of Winton. The company has plants at Chillagoe, Mount Garnet, Biboohra near Mount Molloy, Black River near Townsville and Winton. The agricultural lime industry has expanded as farmers realised the benefit of the use of lime, dolomite, Ca-Mg blends, gypsum and latterly wollastonite on strongly acidic agricultural soils in Queensland and these businesses have developed to supply it. There is also the important continuing application of lime in the treatment of acid sulphate soils.

Fluorite

Fluorite is a common accessory mineral in many replacement and intrusive-related deposits in Queensland. The major known fluorite resources are in north and northwest Queensland. Queensland's known fluorite resources total 1 982 094 t.

The Laura Jean deposit east of Georgetown contains an inferred resource of 1500 t of fluorite. The mineralisation occurs within a faulted and brecciated dacite dyke zone cutting Silurian granite adjacent to the edge of the Newcastle Range Volcanic Group. The fluorite breccia is radioactive and a resource of 10 t of U_3O_8 was also noted for this deposit. The Maureen uranium deposit north of Georgetown and related stratabound uranium deposits also contain fluorite, but no figures are available.

A fluorite–magnetite skarn at the Ironstone Leases, 9 km southwest of Mount Garnet, contains an inferred and indicated resource of 613 300 t at 10.8% fluorite. The Mistake intrusive-related fluorite–tungsten lode near Petford contains an inferred resource of 50 800 t at 25% fluorite. Quartz-fluorite veins at Mount Victory, 28 km north-northeast of Lyndbrook Siding, contain an inferred resource of 3000 t of fluorite. A similar size resource occurs at the Jacques deposit, 36 km west-southwest of Munderra.

The Mount Garnet tin project is largely based on the Gillian, Pinnacles and Deadmans Gully/Windermere tin and fluorine-bearing wrigglite magnetite skarns. These deposits are held by Consolidated Tin Mines Limited. The Pinnacles project is 24 km east-northeast of Mount Garnet. The indicated and inferred resource at Pinnacles (Wafer–Sniksa–Hartog–Llahsram) is 7.04 Mt at 0.30% Sn and 19.55% Fe and 5.80% fluorine.

Fluorite occurs associated with copper skarn mineralisation at the Beacon Prospect, 33.3 km west of Cloncurry. Inferred resources are 1.3 Mt at 40% fluorite and 3 Mt at 0.2% Cu.

Kaolin

Queensland's known major kaolin resources and reserves total 2.95Bt (Table 18). The majority of these resources occur within a geological estimation of the Pennefather River resource. Queensland kaolin production in 2011–12 (2012-13) was 0 t (357 t).

Kaolin is a soft, fine, non-swelling white clay consisting mainly of kaolinite ($Al_4Si_4O_{10}(OH)_8$). It is used for the manufacture of paper, ceramics, rubber, paints, plastics, cosmetics and refractory products. Differences in kaolin products are due to property variations such as degree of crystallinity, particle size, shape and distribution. Crystallinity impacts on the brightness, whiteness, opacity, gloss and viscosity properties of kaolin. Particle size, shape and distribution influence the smoothness, optical, deformation and flow properties of kaolin.

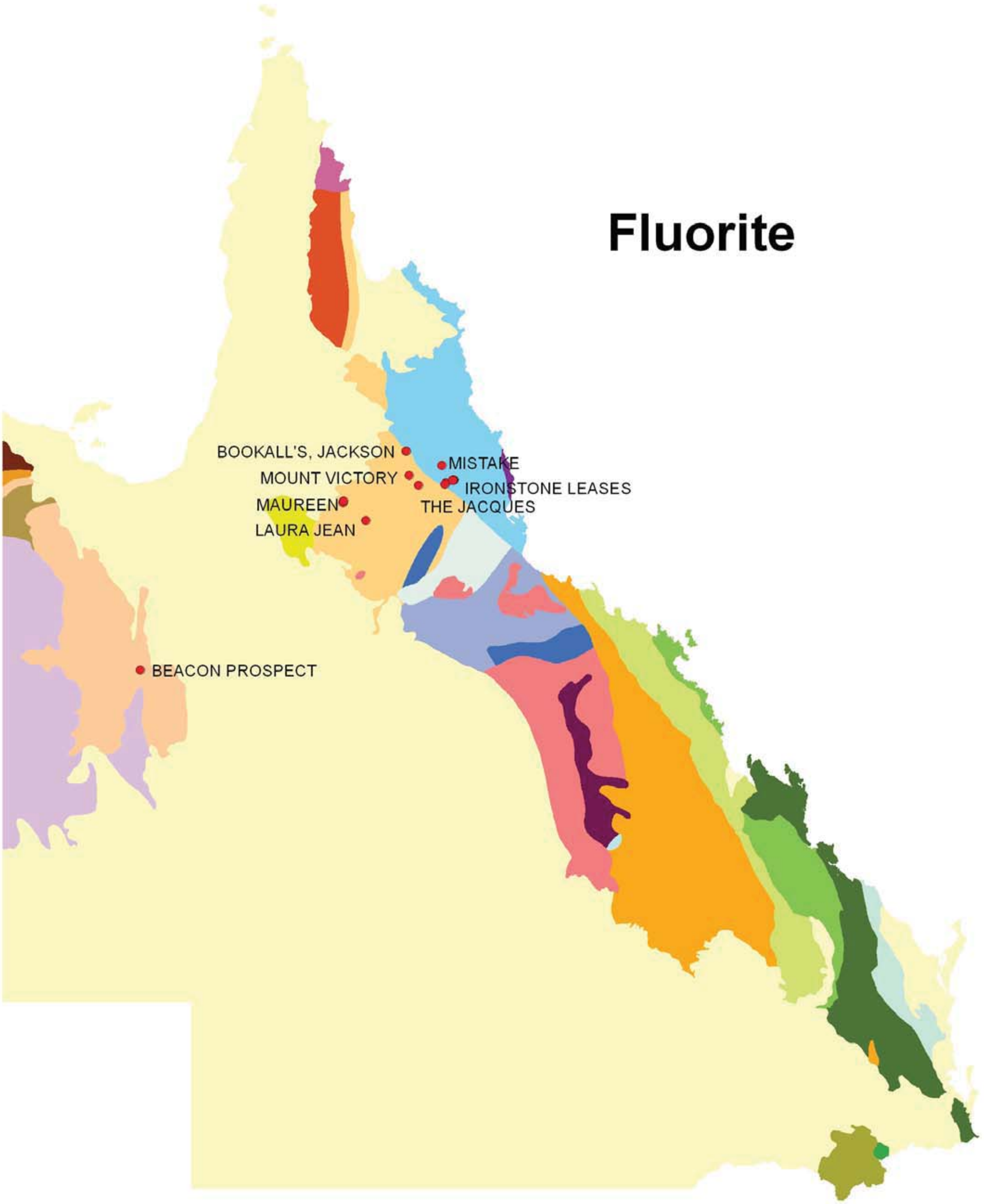

Fluorite
BOOKALL'S, JACKSON
MISTAKE
MOUNT VICTORY
IRONSTONE LEASES
MAUREEN
THE JACQUES
LAURA JEAN
BEACON PROSPECT

Table 18. Kaolin production and resources in Queensland

Deposit name	Location	Company	Total resources	Total historical production and comments
Duaringa Kaolin	West of Rockhampton	Queensland Zeolite Pty Ltd	1 Mt	15 970 t; no production since 2002
Kendall River	105 km west of Coen, 150 km south of Weipa	Kendall Resources Ltd	Confidential	Mining lease applied for; feasibility study in progress.
Nyora	15 km south of Kingaroy	Sibelco Australia Ltd	Confidential	85 431.3 t; operating mine — production commenced in 1992, no production records since 2011.
Pennefather River	North of Weipa	Cape Alumina Pty Ltd	2.8 Bt	No current exploration.
Ravensbourne	Esk area, west of Brisbane	Hanson Construction Materials Pty Ltd	Confidential	30 754 t kaolin, 81 401 t brick clay; Production commenced in 1996; no production since 2006.
Skardon River	85 km north of Weipa	Minerals Corporation Ltd through its subsidiary Skardon River Kaolin Pty Ltd.	9.24 Mt	5766 t; operating mine — production commenced in 1998, recommenced in 2003 until 2008, plant removed and being replaced with bauxite facility. Kaolin on stockpile.
Weipa	5.7 km west-north-west of Weipa airstrip	Comalco Aluminium Limited	48 Mt	Kaolin production from the Weipa mine is recorded for 1986–1996 and totalled 971 200 t; kaolin production ceased in 1996.
Winter No 1	13 km south-west of Kingaroy	Sibelco Australia Ltd		12 426 t; no production since 2002.

Primary kaolin deposits form from the alteration of feldspar-rich parent rocks through either weathering or hydrothermal alteration processes. Both processes leach most mobile elements from the parent rock, leaving the constituent clay elements of silicon, aluminium, oxygen and hydrogen. Ultimately, the weathered/altered product of most rock-forming minerals is kaolin. Secondary kaolin comprises sedimentary deposits formed from the alteration of pre-existing sediments or the direct deposition of kaolin from transported material.

Substantial kaolin resources occur along the western side of Cape York Peninsula, in the Kingaroy district (150 km northwest of Brisbane) and at Duaringa in central Queensland.

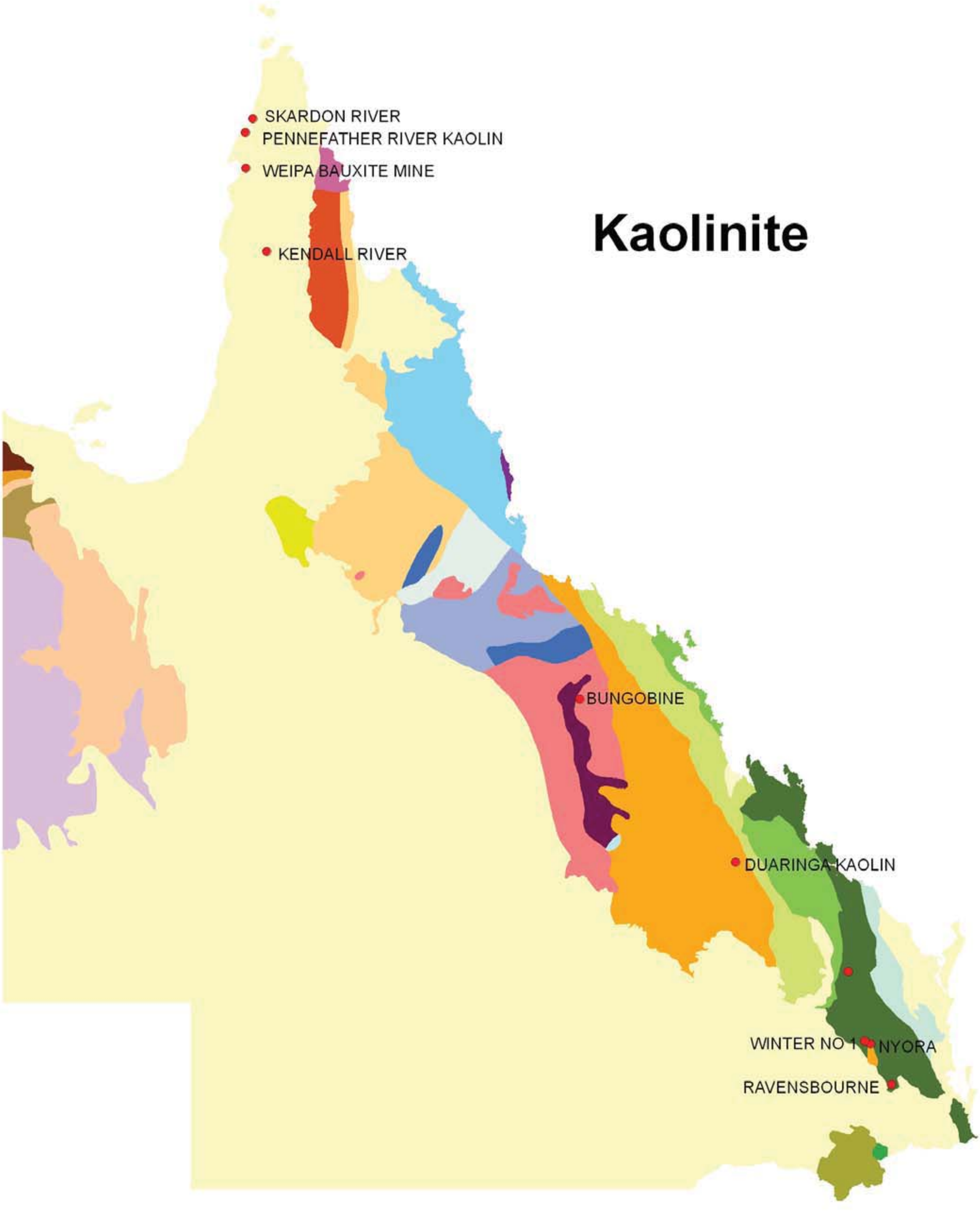
Queensland's largest kaolin deposits are associated with the Tertiary laterite profiles that formed the extensive bauxite deposits along the western side of Cape York Peninsula. Weipa, Skardon River, Kendall River and Pennefather River are the main kaolin deposits and occur in the Tertiary Bulimba Formation of the Karumba Basin.

At Weipa, Comalco Aluminium Ltd mined kaolin from extensive kaolin horizons underlying the bauxite resources between 1986 and 1996. The kaolin deposits occur as discontinuous clay lenses about 2–3 km long, 300 m wide and 4.5 m in average thickness. They occur in the pallid zone of the laterite profile. Mining was carried out using surface mining methods, once the overlying bauxite layer had been removed. Comalco Aluminium Ltd estimated that 12 Mt of proved and 36 Mt of probable kaolin reserves remain at Weipa.

The Skardon River deposits comprise sandy kaolin lenses within the pallid zone of a laterite weathering profile and are underlain by a weakly kaolinitic aquifer. The aluminium and iron content of Skardon River kaolin are reportedly lower than at Weipa. Skardon River contains a proved reserve of 0.7 Mt at 95% percent finer than 45 microns, probable reserve of 2.1 Mt at 92% finer than 45 microns, indicated resource of 0.9 Mt at 78% finer than 45 microns and an inferred resource of 10.4 Mt at >65% finer than 45 microns.

Minerals Corporation Ltd purchased the operation (Photograph 191) through its subsidiary Skardon River Kaolin Pty Limited from Australian Kaolin Ltd after they were placed in receivership in May 1999. Minerals Corporation placed all of its clay assets into Australian China Clays Limited. The plant was recommissioned and regular production of kaolin products commenced in late 2003. Minerals Corporation Limited had set up a plant with design capacity for 175 000 tpa for fully processed clays and was focused on building sales to about 30 000 tpa until 2008. An unincorporated joint venture agreement signed with ACC EcoMinerals Limited during 2009 recognised Gulf Alumina as the joint holder of the Skardon River mining and exploration tenements with rights to explore for, and develop, all bauxite in the area. The objectives of the joint venture allowed the sharing of common expenditure and existing infrastructure. However, this agreement was terminated in September 2011 when Gulf Alumina became the sole holder of the mining and exploration tenements including the associated site infrastructure and improvements at Skardon River. As a bauxite miner, Gulf Alumina has changed the focus of the operations to mining bauxite and the kaolin overburden is to be stockpiled.

The Kendall River kaolin deposit is 110 km west of Coen in Cape York Peninsula. The current operator is Gulf Minerals Pty Limited. In 2000 the company demonstrated the homogeneity of the crude kaolin and calculated total resources of about 100 Mt of de-gritted crude high-quality kaolin, which occurs in a channel-fill depression. The kaolin layers average about 12 m in thickness with


Kaolinite
SKARDON RIVER
PENNEFATHER RIVER KAOLIN
WEIPA BAUXITE MINE
KENDALL RIVER
BUNGOBINE
DUARINGA KAOLIN
WINTER NO 1
NYORA
RAVENSBOURNE

Photograph 191: The Skardon River kaolin processing plant in 2003, before it was removed around 2008 (image courtesy DNRM, Queensland Mineral and Petroleum Review, 2003).

a shallow overburden. The crude ore brightness is 82% to 88%, and the brightness for processed kaolin was 88% to 90%. Testing of the kaolin for the paper coating market has demonstrated superior qualities to other kaolin products in Australia, United States and Brazil. Since 2008, the Kendall River Kaolin Project has been fully funded through Beijing and Hong Kong sources. Gulf Minerals Pty Limited has applied for an MDL over the area and the deposit is expected to be developed in the near future.

The Nyora kaolin deposits are 200 km northwest of Brisbane and comprise two distinct deposit types — massive kaolinised granites with 20–30% kaolin and kaolin-rich bedded sediments of the Tarong Basin with 60–80% kaolin. The bedded kaolin deposits formed in a lacustrine environment and could be primary weathering products of shales or secondary deposits of reworked kaolin clay. Mining operations comprise two open cuts that expose 3–8 m thick clay seams. This deposit is owned and operated by Sibelco Australia Ltd, which is Australia's largest diversified processor and supplier of industrial minerals to the Australian, New Zealand and Asian markets.

The Duaringa kaolin deposit consists mainly of opaline silica and kaolinite and was mined from two open cuts by Ausorb (a subsidiary of Supersorb Minerals NL). This deposit is a highly leached rock formed during lateritisation of Tertiary rhyolitic tuff beds in the Duaringa Basin. The tuffs were probably derived from volcanic activity in the Clermont – Peak Range – Minerva Hills area. Lateritisation has concentrated opaline silica and kaolinite. Mined material contained 30% kaolin cemented by secondary opaline silica and was a porous, lightweight material with a bulk density of ‹0.70 and an average absorbency of 50% when milled. The silica gives the kaolin high strength, producing hard, non-draining granules that do not turn to mud when wet. The deposit is now held by Queensland Zeolite Pty Ltd.

A small but significant kaolinised granite resource has been mined by Pioneer Concrete (Queensland) Pty Ltd at Ravensbourne, 34 km northeast of Toowoomba.

Considerable potential exists for the discovery of more kaolin deposits in the Kingaroy and Ravensbourne areas, the Surat Basin and Cape York Peninsula.

Limestone and marble

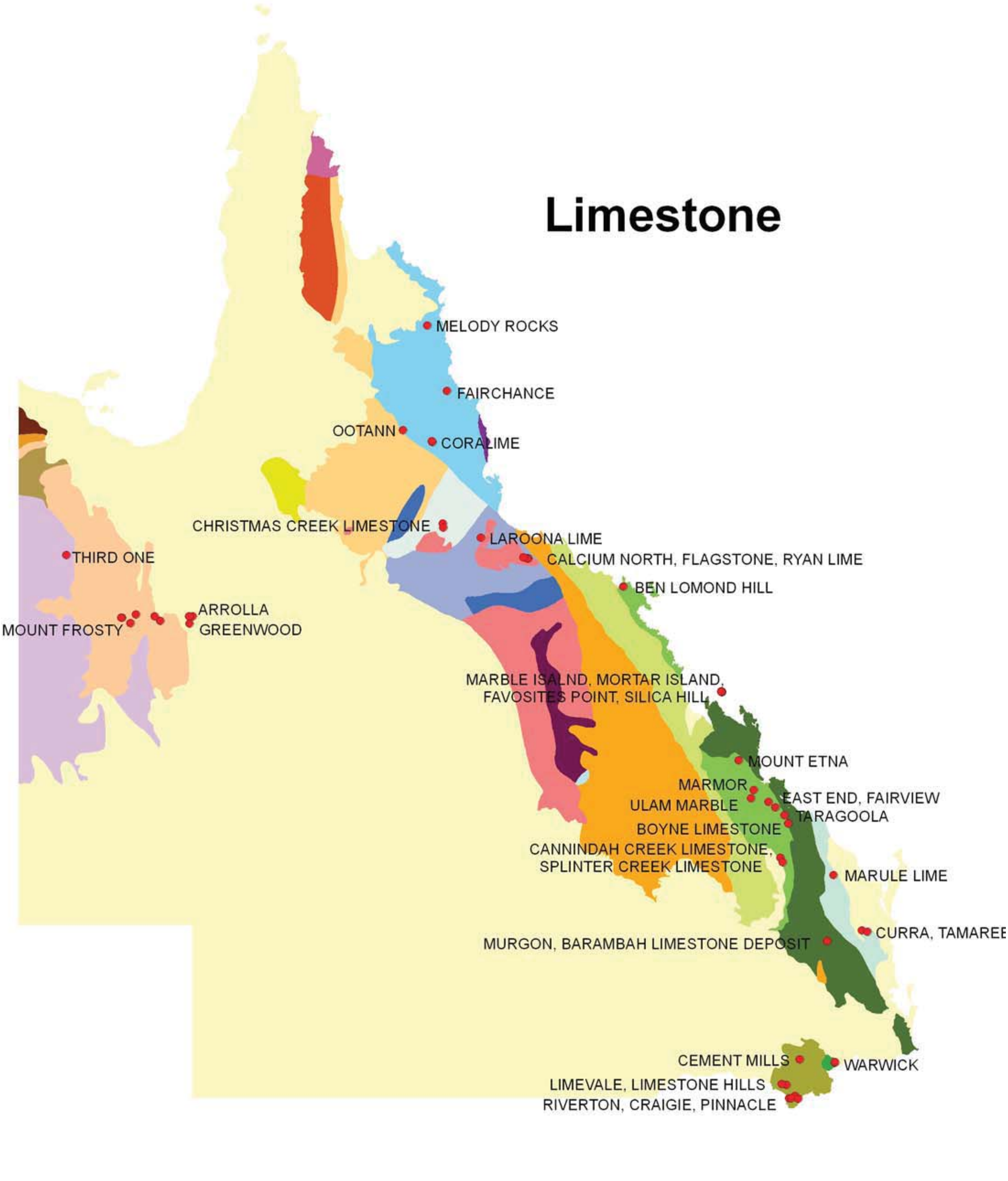
Queensland production of limestone in 2011–12 (2012–13) was 3.282 Mt (3.514 Mt). Current resources and reserves total ›1.09Bt (Table 19). Queensland limestone is mainly used for cement manufacturing, agricultural purposes, acid neutralisation and as a metallurgical flux.

Limestone usually forms in marine environments by the accumulation of calcium carbonate in the form of shells and skeletons in layered beds. Direct precipitation of calcium carbonate from seawater, partly triggered by biogenic activity, can also form limestone.

Major limestone deposits in Queensland are restricted to specific geological ages and formations. During the Late Silurian to Middle Devonian, significant amounts of calcium carbonate were deposited in the Tasman Fold Belt of eastern Queensland.

Demand for limestone is related to economic growth and expansion in limestone mining is expected to parallel industrial growth in Queensland. With ›1Bt of *in situ* limestone resources, Queensland is well positioned to meet future limestone demands.

In 2011–12, the major limestone mining operations were at East End (Mount Larcom), Taragoola, O'Dea Extended, Ulam, Murgon and Cement Mills. Limestone was also quarried at Christmas Creek, Coralime, Fairchance, Laroona, Calcium North, Marule, Ootann, Riverton and Ryan Lime.



Limestone
MELODY ROCKS
FAIRCHANCE
OOTANN
CORALIME
CHRISTMAS CREEK LIMESTONE
LAROONA LIME
CALCIUM NORTH, FLAGSTONE, RYAN LIME
THIRD ONE
BEN LOMOND HILL
ARROLLA
MOUNT FROSTY
GREENWOOD
MARBLE ISALND, MORTAR ISLAND,
FAVOSITES POINT, SILICA HILL
MOUNT ETNA
MARMOR
ULAM MARBLE
EAST END, FAIRVIEW
TARAGOOLA
BOYNE LIMESTONE
CANNINDAH CREEK LIMESTONE,
SPLINTER CREEK LIMESTONE
MARULE LIME
CURRA, TAMAREE
MURGON, BARAMBAH LIMESTONE DEPOSIT
CEMENT MILLS
WARWICK
LIMEVALE, LIMESTONE HILLS
RIVERTON, CRAIGIE, PINNACLE

Table 19. Major limestone deposits in Queensland

Deposit name	Total historical production (t)	Total resources (Mt)	Host formation/ Province
Arrolla		8.25	Toolebuc Formation/ Eromanga Basin
Ben Lomond Hill		0.285	Edgecumbe beds/ Campwyn Subprovince
Boyne Limestone		100	Yarwun beds/ Rockhampton Subprovince
Buckland	15 464		Undara Basalt/McBride Basalt Province
Calcium North	440 442.3	1	Burdekin Formation/ Burdekin Basin
Calcium Quarries	9 482 750		Burdekin Formation/Burdekin Basin
Cannindah Creek Limestone		83.29	Rockhampton Group/ Rockhampton Subprovince
Cement Mills	1 626 666.9	Confidential	Texas beds/ Texas Subprovince
Christmas Creek Limestone	680 294.6	Not reported	Perry Creek Formation/ Camel Creek Subprovince
Coralime	229 100.8	Not reported	Chillagoe Formation/ Hodgkinson Province
Craigie Limestone Deposits		1.3	Texas Province (Block)
East End	31 462 436 (limestone) 4 437 345 (structural clay)	120	Erebus beds/ Mount Holly Subprovince
Fairchance	206 545.8	Not reported	Hodgkinson Formation/ Hodgkinson Province
Fairview Limestone		29	Mount Holly beds/ Yarrol Province
Favosites Point		0.254	Erebus beds/ Mount Holly Subprovince
Flagstone		34	Burdekin Formation/ Burdekin Basin
Greenwood	684 470.8	Confidential	Toolebuc Formation/ Eromanga Basin
Laroona Lime	59 835.8	Not reported	Mount Podge Limestone/ Burdekin Basin
Lime Products Marble Quarry	22 793	0.2	Texas beds/ Texas Subprovince
Limestone		3.8	Perry Creek Formation/ Camel Creek Subprovince
Limestone Hills		2.4	Texas beds/ Texas Subprovince
Limevale Quarry	40 978	15	Texas beds/ Texas Subprovince
Magee Creek Marble Deposit		0.083	Texas beds/ Texas Subprovince
Marble Island	3048	0.122	Erebus beds/ Mount Holly Subprovince
Marmor	1 814 691	5.2	Mount Alma Formation/ Rockhampton Subprovince
Marule Lime	52 962	0.4	Gympie Group/ Gympie Province
Melody Rocks		100	Hodgkinson Formation/ Hodgkinson Province
Miamba Limestone deposit		0.25	Texas beds/ Texas Subprovince
Mortar Island	300	0.67	Mount Holly beds/ Yarrol Province
Mount Etna	729 370	70	Mount Alma Formation/ Rockhampton Subprovince
Murgon	1 323 085.4	3.1	Maronghi Creek beds/ Yarraman Subprovince
O'Dea Extended	1 583 554	0.85	Rosenthal Creek Formation/ Silverwood Province
Ootann	210 189.4	35	Chillagoe Formation/ Hodgkinson Province
Pinnacle Limestone Deposit	92 661	2	Texas beds/ Texas Subprovince

Table 19 (continued)

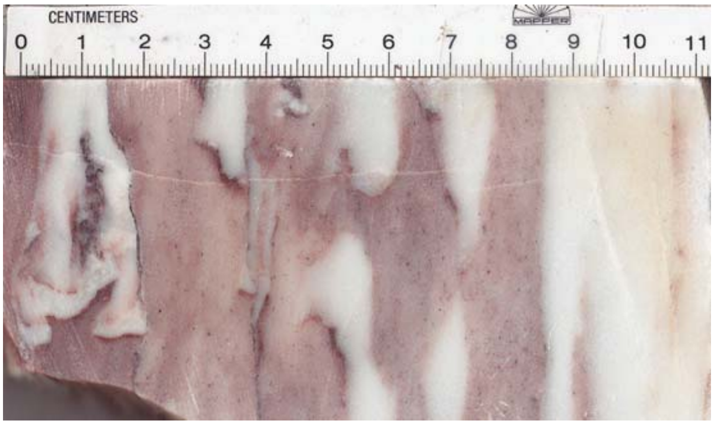
Deposit name	Total historical production (t)	Total resources (Mt)	Host formation/ Province
Pipersleigh Marble Deposit		0.165	Texas beds/ Texas Subprovince
Riverton Quarry	1 530 904	400	Texas beds/ Texas Subprovince
Silica Hill		1.991	Erebus beds/ Mount Holly Subprovince
Splinter Creek Limestone		78.6	Splinter Creek Formation/ Rockhampton Subprovince
Taragoola	7 899 979.8	Not reported	Calliope beds/ Calliope Subprovince
Third One (Undilla)	179 359.8	10.65	V-Creek Limestone/ Georgina Basin
Ulam Marble	2 414 429.3	Not reported	Ginger Creek Member/ Mount Morgan Subprovince
Warwick Plant	102 608	0.5	Rosenthal Creek Formation/ Silverwood Province

Photograph 192: East End limestone mine open cut (image courtesy Patrick Carr, GSQ).

The East End mine is near the township of Mount Larcom, 24 km from Gladstone, and was developed in 1964. Mining operations commenced in 1980. It is Queensland's largest limestone mining operation (Photograph 192) and supplies raw material (Photograph 193) to a plant at Fishermans Landing, Gladstone. In 2005, Queensland Rail constructed a 12 km rail link loop between the East End Mine and the Fishermans Landing site. Block trains of custom-designed wagons transport raw material, which includes impurities such as clay, to the Fisherman's Landing plant daily. Total production from East End between 1996 and 2012 was slightly over 27.6 Mt of crushed limestone. The deposit owner, Cement Australia Group, is owned by Holcim and the Heidelberg Cement subsidiary Hanson. Holcim, a company based in Swizerland and Hanson each have a 50% share of the Cement Australia Group. At Fishermans Landing, Cement Australia operates the largest cement kiln in Australia and uses state-of-the-art technology. This plant processes limestone, clay, silica sand and ironstone to manufacture cement and clinker that is sold throughout Australia and overseas. The production capacity is over 1.6 Mt per year of cement. Lime is also produced at the Fishermans Landing plant in a refurbished cement kiln, supplying up to 250 000 t of lime per year to Queensland's sugar, mining and aluminium industries. The existing mine currently produces approximately 2.5 Mtpa of limestone and clay. At this rate of mining it is estimated that the overall mine life will continue for 55 to 70 years. The mine life could be further extended by the relocation of mine infrastructure, while at the moment a new mining lease has been applied for adjacent to the current lease.

The Ootann lime works, which are operated by Phoenix Lime Pty Limited, are about 34 km south-southeast of Chillagoe and the products generally used for agricultural applications. A resource of 35 Mt is reported for this deposit. In May 2007, the operation was bought by Metallica Minerals Limited to supply lime and limestone for the company's then proposed Nornico project (now changed in format to the Sconi scandium nickel cobalt and project). Limestone was to be used with the high-pressure acid leaching operation. The Company's Star River limestone deposits are also located within a granted Mining Lease, 130km via road from SCONI, providing a further limestone resource for SCONI.

Taragoola (or Calliope), 25 km southwest of Gladstone, produces lime for cement, agriculture, metallurgical ore and other uses, was run by a family owned company Frost Enterprises since 1966. Sibelco Australia Limited has taken over operations since 2012. The open cut quarry supplies about 1 Mt of varying grades of crushed limestone per year, much of which is railed to Queensland Alumina Limited's refinery in Gladstone. At least 140 000 t of slaked lime annually is used in the production of alumina. Sibelco Australia Limited also supplies crushed limestone to state and local government departments and the construction, industrial and agricultural industries, as well as kiln stone for Cement Australia's Fishermans Landing plant. The product is transported off-highway by 50 t dump trucks to a 350 t per hour crushing plant. The finished product is dispatched by road and rail to customers from Proserpine to Brisbane.



Photograph 193: Some varieties of limestone from the East End open cut (above and right).

Photograph 194: Sibelco's Riverton limestone plant viewed from the limestone quarry.

In southeast Queensland, limestone is mined 25 km south of Warwick, near Texas at Riverton (Photograph 194), and 10 km south of Murgon (Photograph 195). These operations have also been acquired by Sibelco Australia Limited in 2012. At Riverton the limestone is light to dark grey in colour and is associated with the limestone members of the Texas beds. The interlinked quarries are suitable for large scale quarrying with minimal overburden. Fracturing of the limestone makes it not suitable for dimension stone applications. An informal resource of 400 Mt to an 80m depth was given in 1973. The limestone production is supplied to a range of users in agricultural lime, animal stock-feed, glass (I-O Brisbane, formerly ACI), plastic, rubber and cement manufacturing (Sunstate Cement and Cement Australia), construction, and environmental water-treatment applications. The annual production of limestone from this region depends on the level of industrial manufacturing, agricultural and construction activities.

Various marble occurrences related to major limestone deposits adjacent to intrusive rocks throughout Queensland were exploited in the early 1920s for dimension stone purposes. Two deposits that are currently being worked are the Bajool deposit and the Chillagoe marble quarries.

Marble occurs within the late Silurian to Early Devonian Chillagoe Formation to the northwest and southeast of Chillagoe. There are numerous individual quarries, but over the years the development of the marble industry has been difficult. The quality of the marble is variable with a variety of coloration, grain size and translucency. Supply and demand conditions are also difficult to judge since building stone types are subject to fashion trends. Although freight costs from Chillagoe are on the high side for lower-grade stone, the region is supporting an export industry (from the port of Brisbane) for higher-grade stone with unique qualities peculiar to Chillagoe. Cairns Marble Australia Pty Limited was established in 1989 and is the main operator in Australia. The company has factories in Chillagoe and Cairns (Photograph 196) producing various end products including marble blocks for export. Europe, in

Photograph 195: The Murgon limestone open cut in 2005.

Photograph 196: (left) Automated slab polisher at Cairns Marble & Granite's workshop (=trade name for Cairns Marble Australia Pty Ltd); (centre) showroom at Cairns Marble & Granite display of tiles, furniture and sculptures made of Chillagoe marble; (right) slab cutting box at Cairns Marble Australia Pty Ltd's Chillagoe processing facility.

particular Italy and Germany, was the main market destination. Between 2000 and 2014 a total amount of 12 248t of dimension stone was produced from various open cuts associated with Chillagoe Marble Australia Pty Limited.

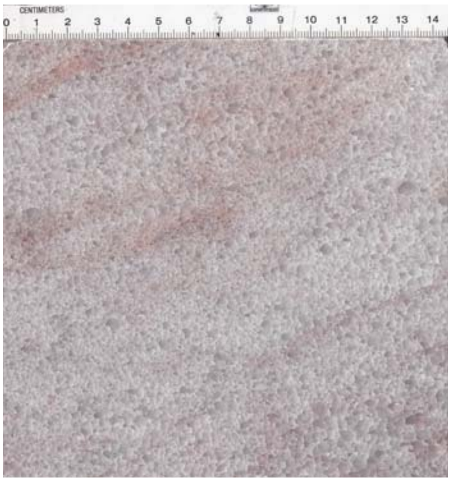
Thirteen high quality marble reserves include the Bianca (white fine marble, Photograph 197a), Champagne 1 & 2 (white, cream and pink marbles, Photograph 197b), 5-Storey quarry (pink crystalline marble, Photograph 197c), Orazia Gold (light grey to cream marble with limonite breccia infill, Photograph 197d), Aquamarina (coarse blue crystalline marble, Photograph 197e), White Pearl (very coarse crystalline marble, Photograph 197f), Wollastonite Pit (light grey and white marble with skarn minerals like wollastonite and vesuvianite present, Photograph 197g), Black Ice (very fine silicified black limestone, Photograph 197h), T-Tree and Bianca Mist (mostly white marble), Dreamtime-Airport (Photograph 197i) and Emperador (both marble breccias with a black, red and white colorations). On average the marble is retrieved from surface down to an average depth of 50m, depending on fracturing, surface karsting and weathering. Car-sized blocks (Photograph 198a) are cut *in situ* in the quarries (Photographs 198b,c,d) and trucked to the factories for slabbing and polishing or exported as blocks to cutting centers like Carrara Quarries in Italy.

Australian Fine Grain Marble is also looking to export blocks of high-grade Chillagoe marble, but no information is available to date.

The Bajool marble deposit, 18 km south of Bajool in central Queensland, is operated by Omya Australia Pty Ltd, a subsidiary of Sibelco Australia Limited. The deposit was mined in the 1920s for dimension stone that was widely used in Government buildings in Brisbane under the name 'Ulam Marble'. In the 1960s, larger open cuts (Photograph 199) and a plant were developed for mining (Photograph 200) and crushing marble to stone dust (used as a fire suppressant in underground coal mines), agricultural lime products and for export. Particular care was taken then (and also by the current owners) to preserve the historical dimension stone workings, including 'Ulam Quarry' (Photograph 201). Recently the focus has changed and Bajool is the sole supplier of a high purity crushed 'white calcite' product, which is shipped from Gladstone to the company's Geelong plant in Victoria and for export to other Australian and overseas ports. The Geelong facility was established in 1993 and expanded in 1995 to include wet milling operations and currently receives about 130 000 t per year from Bajool. The Geelong plant produces slurry products for copy paper as well as paper and cardboard coating. Additionally, it produces a range of high brightness industrial fillers and extenders for Victoria's manufacturing industry, and two products that are specifically manufactured for the food industry.

a

b



c

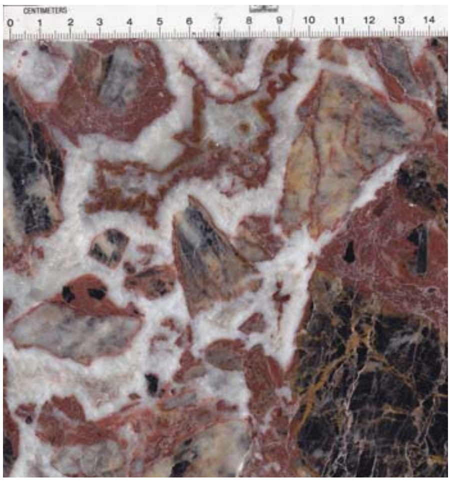
d

e

f

g

h



i

Photograph 197: (a) White fine-grained marble (trade name: Bianca) within the Chillagoe Formation, from Bianca Quarry; (b) White to cream-coloured marble (trade name: Gold Drop) within the Chillagoe Formation from the Champagne 2 quarry; (c) Fine to medium grained pink crystalline marble within the Chillagoe Formation from the 5-Storey quarry; (d) Light grey to cream-coloured marble with limonite breccia infill (trade name: Oracia Gold) within the Chillagoe Formation from the Oracia quarry; (e) Medium to coarse-grained light to dark blue crystalline marble (trade name: Aquamarina) within the Chillagoe Formation from the Aquamarina quarry; (f) Very coarse-grained crystalline white marble (trade name: White Pearl) within the Chillagoe Formation from the White Pearl quarry; (g) Variably grained light grey and white marble within the Chillagoe Formation, which contains skarn minerals like wollastonite and vesuvianite. The marble also contains common medium-grey metasediment clasts and shows signs of brecciation. The marble originates from the Wollastonite pit. (h) Very fine to fine-grained black limestone (trade name: Black Ice) with megafossils (bivalves) at the top level in outcrop (not in the photograph). This limestone is also part of the Chillagoe Formation originating from the Black Ice pit. (i) A marble breccia hosted in the black limestone with recrystallised white calcite and red iron-oxidised carbonates (Trade name: Dreamtime, also called Airport, since this stone was used at the terminal of Cairns International Airport). This marble has been cut from surface outcrop. A small pit is referred to as Airport pit.

Photograph 198: (a) White marble blocks stockpiled for future use at the White Pearl quarry; (b) the Aquamarina quarry; (c) the 5-Storey quarry; (d) the Bianca quarry.

Photograph 199: The Bajool Marble East pit.

Photograph 200: Crushing operations at Bajool Marble mine.

Photograph 201: The historic Ulam Marble quarry, source of some building stone in the Brisbane CBD in the early 1900s.

Magnesite

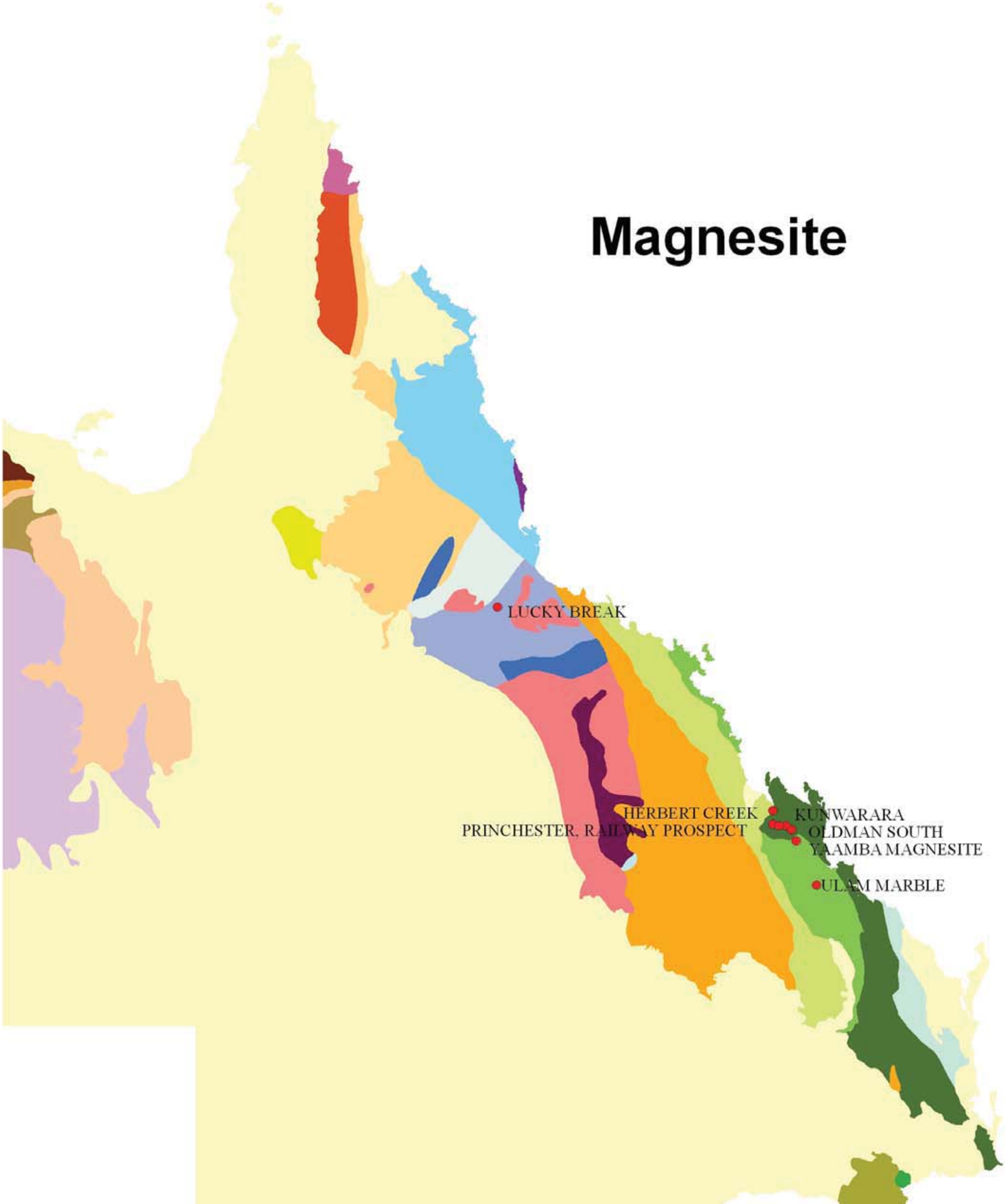
Queensland's current magnesite resources and reserves total >239 Mt. Magnesite commonly occurs in veins and irregular masses derived from the alteration of serpentinite through the action of groundwater containing carbonic acid. Magnesite formed in this manner has a compact cryptocrystalline form.

Queensland's major magnesite deposits all occur in Tertiary sedimentary basins north of Rockhampton. The only operating mine, Kunwarara (Photograph 202), which is operated by Queensland Magnesia Pty Ltd (QMAG), a subsidiary of Sibelco Australia Limited, is considered to be the world's largest known resource of cryptocrystalline nodular magnesite — a high quality ore. The Kunwarara mine is based on the Kunwarara and Yaamba magnesite deposits, which extend from 40 to 70 km north of Rockhampton beneath a relatively flat, black-soil covered plain (Photograph 203). Up to 2012 production totalled 7 823 252 t of magnesite.

Production in 2011–12 (2012–13) was 587 688 t (503 735 t). The ore is crushed, scrubbed, and screened with heavy media separation and optical sorting before transportation by road to the Parkhurst processing plant (Photograph 204) in Rockhampton.

Queensland Metals Corporation discovered the Kunwarara nodular magnesite deposit in 1985, with high-grade 'bone-type' magnesite delineated in five main zones, and produced the first magnesite in 1991. Late Tertiary to Quaternary sediments deposited in a fluvial environment host the deposit. The source of the magnesium carbonate is the weathering of serpentinised ultramafic rocks that form low hills adjacent to the deposit. A former north-flowing meandering river system that drained an area of magnesium-rich ultramafic rocks deposited magnesite within river gravels and sands. The Herbert Creek, Marlborough, Oldman South and Yaamba magnesite deposits formed in a similar environment. The deposits occur in an irregular channel over 30 km long, and range in width from 500 m to 3 km. Within the deposit boundary, high-grade areas of high density 'bone-type' magnesite with low iron, nodular, cryptocrystalline characteristics provide the raw material for the production of high-quality refractory

Magnesite


LUCKY BREAK
HERBERT CREEK
PRINCHESTER, RAILWAY PROSPECT
KUNWARARA
OLDMAN SOUTH
YAAMBA MAGNESITE
ULAM MARBLE

Photograph 202: The Kunwarara Magnesite plant operations (image courtesy DNRM, Queensland Mineral and Petroleum Review, 2003).

Photograph 203: Light-coloured magnesite nodular horizon under black clay-soil overburden at Pit 23, Kunwarara Magnesite mine.

Photograph 204: Parkhurst magnesia processing plant near Rockhampton.

magnesia. The world-class *in situ* resources of medium- to high-grade cryptocrystalline magnesite at Kunwarara (29.3 Mt of contained magnesite, including Oldman South) place Queensland in a prime position to take up a significant world market share of magnesium production in the future.

The QMAG company website stated in 2010 that identified resources at Kunwarara exceed 87 Mt of 'run of mine' ore. QMAG commenced mining at the Yaamba magnesite deposit, about 40 km north-northwest of Rockhampton, in September 2010. Approximately 3 Mtpa of ore is mined from Kunwarara and 1 Mtpa from Yaamba. Currently the overall operation has a total ore reserve of about 430 Mt magnesite grading 35% magnesite, although the overall resource is much larger.

The Princhester Magnesite deposit has indicated and inferred resources of 2.53 Mt of magnesite, formed by *in situ* weathering of the Princhester Serpentinite.

Palygorskite

Production figures for Queensland in 2011–12 (2012–13) totalled 1 000 t (637 t). Moreton Dolomite Pty Ltd holds mining leases (Wadley Lease) on the Flinders Dolomite Ridge (Photograph 205). A stratigraphic sequence of palygorskite clay (Photograph 206) overlies the Walloon Coal Measures, and is overlain by dolomite with portions of silcrete The contact with the basement is characterised by a weathered pebbly interval. The palygorskite is generally a lightweight, buff to off-white coloured clay band, 1 to 3 m thick.

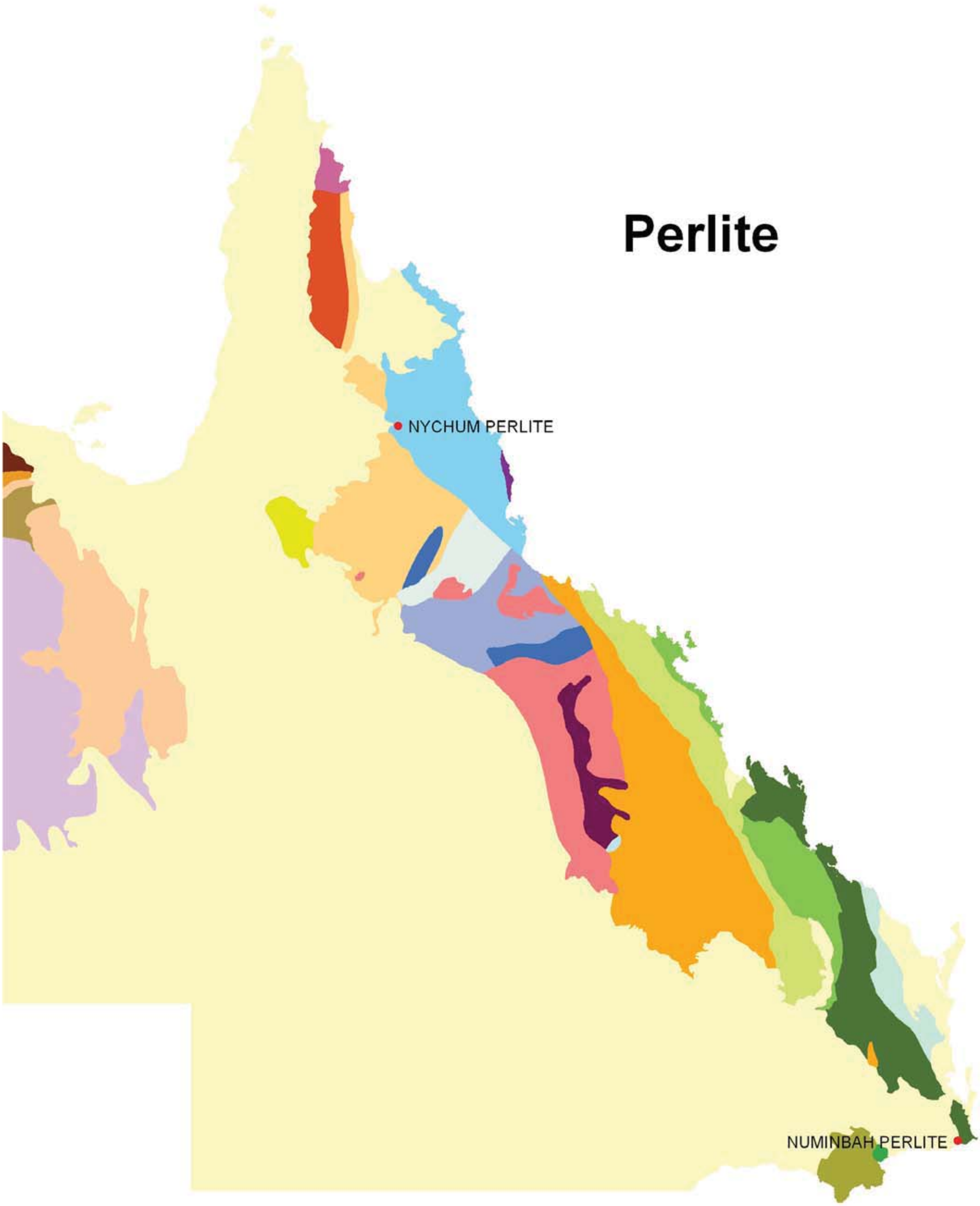
Photograph 205: A white palygorskite clay is overlain by dolomite in the open cut on the Wadley Lease on the Flinders Dolomite Ridge.

Photograph 206: Machinery at the Moreton Dolomite Leases

Perlite

Total Queensland perlite production in 2011–12 (2012–13) was 940 t (1 300 t). This small level of production understates the significant known resources at the Nychum deposit in north Queensland, which is considered to be the largest perlite deposit in the world.

Perlite is a form of volcanic glass that expands by up to 30 times its original volume when heated to temperatures between 727°C and 1127°C (Photograph 207). Expansion occurs by the vaporisation of the 2–6% combined water in perlite's structure, producing a light cellular material with excellent insulating properties. Expanded perlite has a very low thermal conductivity and a loose weight



Perlite
NYCHUM PERLITE
NUMINBAH PERLITE

Photograph 207: Making crushed perlite expand under red heat (demonstration only),

Photograph 208: The Nychum perlite open cut, north of Chillagoe.

that can be as low as ~40 kg/m^3. Commercially, any volcanic glass that will 'pop' on heating to form a lightweight frothy material is called perlite. Perlite is used as a refractory mineral, an insulator, as a filter medium and in horticulture. Queensland perlite is of a high quality compared with similar quality products that are available only from Mexico.

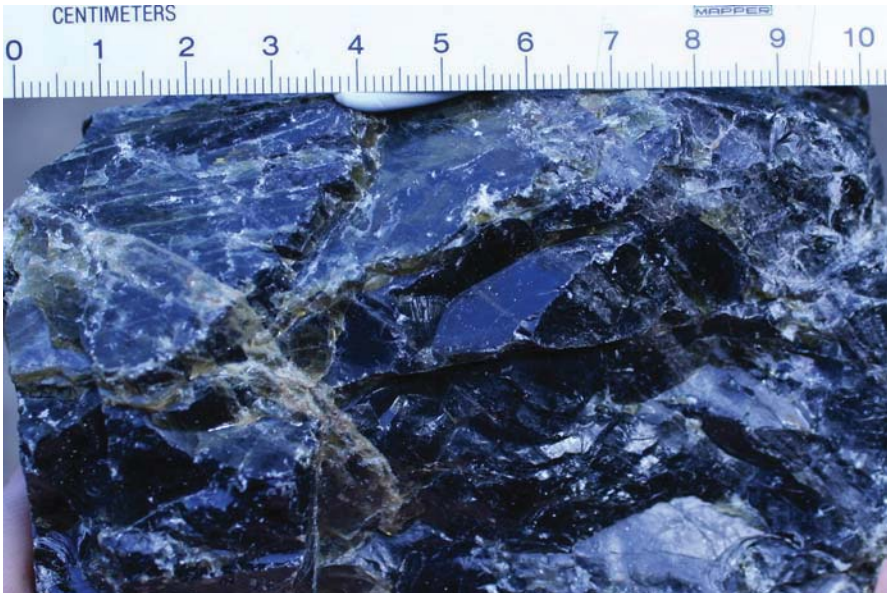
Perlite is often associated with Tertiary age rhyolitic lava flows. Two major perlite deposits are currently being mined in Queensland — the large Nychum (Wrotham) perlite deposit (Photograph 208), 50 km northwest of Chillagoe in far north Queensland, and the smaller Numinbah (Agee) deposit in the McPherson Range, southeast of Beechmont in southern Queensland.

The Nychum deposit, which is mined by Australian Chillagoe Perlite Pty Ltd, is 6.5 km long, 3 km wide and 30 m thick, with outcropping material displaying a thin bloom of aluminium oxide, the only indication of weathering. The perlite (Photograph 209) occurs as discrete layers in the Early Permian Nychum Volcanics of the Kennedy Province. The resource at Nychum may contain up to 700 Mt. Current mining is by small open cut techniques. The perlite is trucked to the processing plant in Mareeba (Photograph 210), where it is crushed to various sizes and heated to induce expansion. Nychum expanded perlite is brilliant white in comparison with the grey colour of Numinbah perlite. Present perlite processing is achieving an expanded product with a density of ~50 kg/ m^3. Perlite from Nychum is also used as ultra-lightweight aggregate in plaster and concrete, as a prime ingredient in insulating board and ceiling tiles, and as loose fill insulation. Expanded perlite products are graded into seven grain sizes from jumbo to ultra-fine.

Another company, Au Silica, has three granted mining leases under the name Perlco Pty Limited in the same perlite horizon. Au Silica is conducting research and development with a view to establishing markets for their products, bearing in mind the remote location of the deposit.

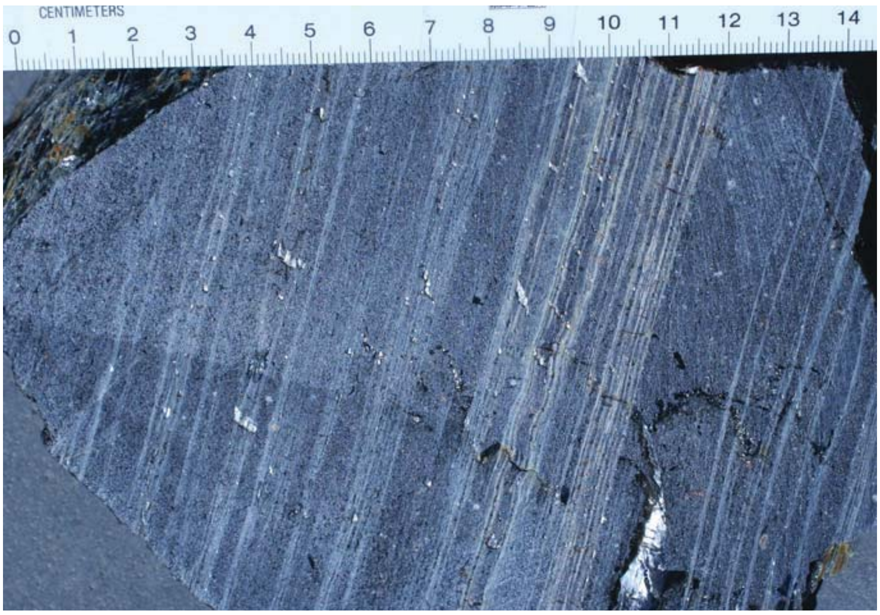
The Numinbah underground perlite mine is 30 km southwest of the Gold Coast. The deposit, which is mined by X-Cut Tunnelling Pty Limited, occurs as thin zones of volcanic glass (Photograph 211) within the volcanics of the Lamington Group of the Tertiary

Photograph 209: Dark green Nychum perlite.



Photograph 210: The 'Chillagoe' perlite processing plant in Mareeba.

Photograph 211: Cut banded perlite from Numinbah.



Lamington Volcanic Subprovince (Eastern Australian Cainozoic Igneous Province). Up to 2014 about 15 000–20 000 t of perlite was stockpiled at a time from campaign-style open cut and underground mining operations; the ore is crushed, screened, dried and bagged on site. Intermittent mining has occurred for ~30 years. The perlite was expanded in Sydney after road transport from the mine. Since January 2014, the perlite has been expanded at a plant at Carole Park in Brisbane and has a variety of uses (see under Nychum). Since moving the processing from Sydney to Brisbane X-Cut Tunnelling is hoping to expand production to some 5000 tpa to 7000 tpa. Numinbah perlite contains the ideal amount of water for expansion and produces a physically strong product. At temperatures above 850°C, the water vaporises and causes the perlite to soften and expand creating small glass-like bubbles and producing an exceptionally lightweight material. Expansion produces a 15 to 25-fold increase in volume.

Phosphate

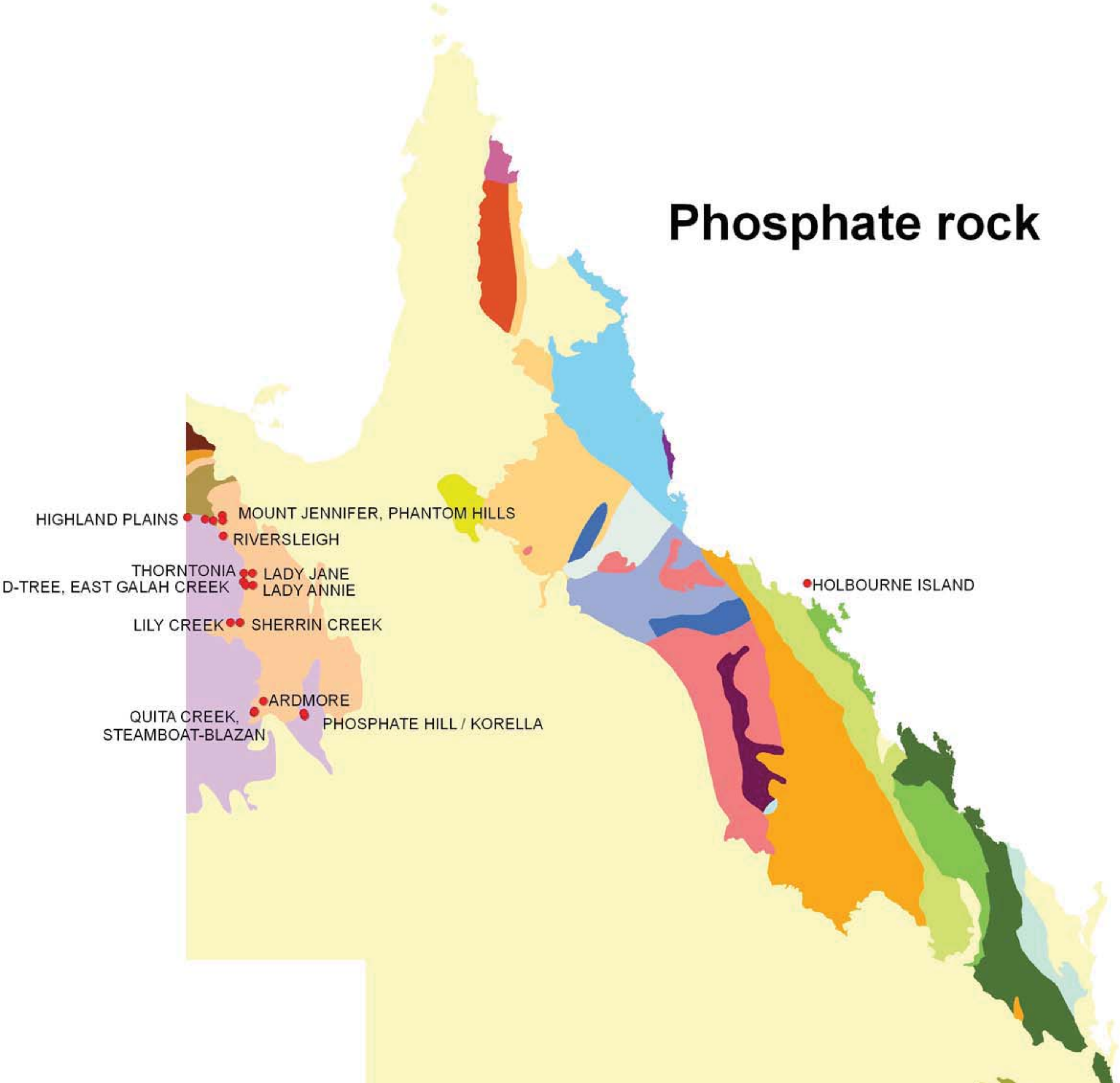
Total phosphate production in Queensland in 2011–12 (2012–13) was 883 047 t (2 062 509 t) of phosphate rock that was processed into diammonium phosphate and monoammonium phosphate. All of this production came from the Phosphate Hill operations in northwest Queensland. Queensland's known phosphate rock resources total about 3 billion tonnes from a series of large marine sedimentary phosphorites that are hosted by Early to Middle Cambrian rocks of the Georgina Basin (Table 20). The Beetle Creek Formation is the main host and consists of a sequence of phosphatic siltstone (phosphorite) and chert that overlies limestone, sandstone and conglomerate. Only the Phosphate Hill deposit is currently being mined (Photograph 212). The phosphate rock ore is a sequence of gently dipping phosphorite-bearing sandstone and siltstone beds about 10 to 15 m thick. The phosphate rock is first beneficiated using a crush and washing process and then fed to an acid plant where it is dissolved in sulphuric acid to produce phosphoric acid. The by-product gypsum is stockpiled. Commercial phosphate rock is calcium phosphate together with various impurities, including calcium and magnesium carbonates, iron oxides, clay, silica and fluorine. The major use of phosphate rock is in the manufacture of fertilisers.

Phosphate rock was produced at Phosphate Hill from 1975 to 1978 by Broken Hill South. Phosphate Hill is a large open cut phosphate rock mine and vertically integrated fertiliser business, 135 km south-southeast of Mount Isa. The operation is Queensland's most significant industrial mineral operation in terms of production value and is Australia's largest fertiliser manufacturer and supplier. WMC Ltd acquired the deposit in 1980 and a subsidiary, Queensland Phosphate Ltd, resumed production from 1981 to 1983. In 1996, WMC Fertilizers commenced development of a new mine at Phosphate Hill with the construction of an acid plant at Mount Isa and ammonia, phosphoric acid, beneficiation and granulation plants at Phosphate Hill. Production commenced in January 2000.

Table 20. Major phosphate deposits in Queensland

Deposit Name	Total Historical Production (t)	Total phosphate rock resource (Mt)	Total Contained Phosphate (Mt)
Ardmore		47	7.33
Babbling Brook Hill		38	6.38
D-Tree		305	45.83
East Galah Creek		20.7	3.79
Highland Plains		84	11.26
Korella		19.3	3.67
Lily Creek		191	28.46
Mount Jennifer		20.7	3.16
Mount O'Connor		15	2.61
Paradise North (Lady Jane)		193	34.74
Paradise South (Lady Annie Phosphate)	64 663	198.6	25.32
Phantom Hills		45.4	7.26
Phosphate Hill	26 299 256.7	127.6	29.65
Quita Creek		30	2.23
Riversleigh		11.4	1.64
Sherrin Creek		175	28.88
Steamboat – Blazan Creek (& Dry Branch)		24	4.25
Thorntonia		47.4	8.56

Phosphate rock



Photograph 212: Mining phosphate rock from flat-lying phosphatic siltstone within the Beetle Creek Formation at Phosphate Hill (image courtesy David Carmichael, 2007, DNRM).

Photograph 213: Ammonium phosphate fertiliser stockpiled at Phosphate Hill (image courtesy David Carmichael 2007, DNRM)

Processing of phosphate rock involves reacting phosphoric acid with liquid ammonia in different proportions to produce high analysis monoammonium phosphate (MAP) and diammonium phosphate (DAP) fertilisers. BHP Billiton acquired the Phosphate Hill operation in 2005 and sold it to Incitec Pivot Ltd in August 2006. Besides Phosphate Hill, Incitec Pivot Ltd currently holds a significant deposit at Ardmore, 70 km west of Phosphate Hill.

The established processes at Phosphate Hill convert phosphate rock into high-quality ammonium phosphate fertiliser for domestic and export markets in a vertically-integrated operation (Photograph 213). This includes the facilities listed above, as well as storage and port facilities at Townsville. Anhydrous ammonia is manufactured by combining hydrogen extracted from natural gas sourced from long-term gas supply agreements and nitrogen from the air. In 2006 BHP Billiton reported combined (measured, indicated and inferred) resources for Phosphate Hill at 127 Mt at 23.3% P_2O_5 before selling the operation to Incitec Pivot Ltd. Incitec Pivot Limited, although a publicly listed company on the Australian Stock Exchange, has not published resource figures. The last publicly available JORC compliant resource for Phosphate Hill dates from BHP Billiton's Annual Report 2006 and quotes a proved reserve of 29 Mt at 24.6% P_2O_5 and a probable reserve of 52 Mt at 24.3% P_2O_5 (Geoscience Australia, 2011). The total production from Phosphate Hill reached 22.28 Mt to date.

In May and June 2014 Incitec Pivot Limited carried out major maintenance with some $80m of expenditure. The company sees going forward challenges from the impact of gas cost increases from February 2015 and obtaining sulphuric acid supply following the closure of the copper smelter at Mount Isa in 2016.

Interest in phosphate exploration has steadily increased since 2007. Summit Resources Ltd holds the Babbling Brook Hill and Riversleigh deposits. Legend International Holdings Incorporated has been investigating the D-Tree, Highland Plains, Lady Annie, Lady Jane, Lily Creek, Quita Creek, Sherrin Creek and Thorntonia deposits. D'Aguilar Gold Ltd carried out drilling at D-Tree.

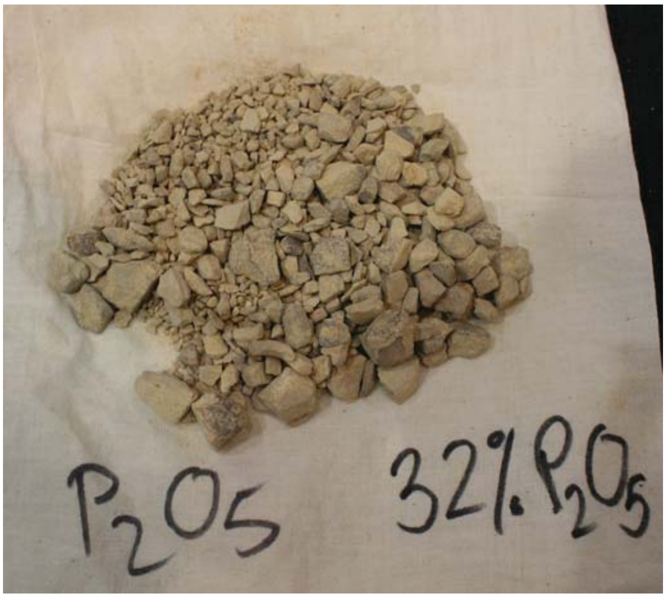
The Paradise phosphate project 115 km north of Mount Isa occurs within an outlier of the Georgina Basin. During the early 1970s the main deposit at Paradise South was investigated by BH South Pty Ltd with a pilot plant processing 100 t per day. At that time it was known as the Lady Annie phosphate project and the Paradise North deposit was known as Lady Jane. In February 2012, following a review, Legend International Holdings transferred its phosphate assets to a 100% owned subsidiary company, Paradise Phosphate Pty Limited. In 2012 a proven and probable reserve of 198.6Mt of phosphate rock yielding 25.32Mt of contained phosphate at 3.5% P_2O_5 cut off was reported. Other phosphate deposits held by the Paradise Phosphate Pty Ltd are the D-Tree deposit, Highland Plains, Lily, Sherrin Creek and Quita Creek.

Various studies were completed by Legend International Holdings, mainly involving the mining and beneficiation processes. The feasibility study by partner Wengfu Group Limited of China projected a 30 year mine life based on a proven and probable 'mineral reserve' of 55.5 Mt grading 33% P_2O_5 (defined as recoverable rock concentrate post-screening and processing through the flotation beneficiation plant). The beneficiated phosphate concentrate at 32% P_2O_5 would be transported to the Mount Isa Phosphate Fertilizer Complex at a rate of 1 Mtpa if the product is trucked (60 year mine life) or at a rate of 2 Mtpa (30 year mine life) if a slurry pipeline is used. This complex will include a 600 000 tpa sulphuric acid plant, a 300 000 tpa phosphoric acid plant, a 600 000 tpa ammonium phosphate plant and a 15 000 tpa aluminium fluorine plant. The products are to be railed to the port of Townsville for export.

Initially Paradise Phosphate Pty Ltd plans to mine 1 Mtpa of direct shipping ore from Paradise North at an average grade of about 28% P_2O_5 and commence shipments to customers in the Asian and Australasian region by the second quarter of 2014. Prior to achieving this, the company aims to complete a feasibility study by the second quarter of 2013 and convert the known high grade ore, currently estimated at 7.3 Mt at 28.1% P_2O_5 of combined (indicated and inferred resources), within the core of the Paradise North deposit into an ore reserve.

Krucible Metals Limited identified a phosphate resource in Korella, about 5 km south of the Incitec Pivot Limited Phosphate Hill mine in 2008, which forms a north-trending corridor within the upper portion of the Beetle Creek Formation. Korella has an inferred phosphate resource of 19.3 Mt grading 19.0% P_2O_5.

Photograph 214: Phosphate rock sample from Krucible's Korella project



The high grade phosphate ore (Photograph 214) is direct shipping quality and has the potential to be mined at the beginning of the project for 6 years based on 600 000 tpa, whereas the lower grade ore has the potential to be mined for a further 12 years and possibly upgraded by a beneficiation process. The phosphate deposit was sold to the Australian New Agribusiness and Chemical Group Limited in January 2014. An enriched layer with yttrium contained in the phosphate mineral xenotime (YPO_4), is present as an enriched layer overlying the high-grade phosphate (see 'yttrium and rare earth elements' section). The Australian New Agribusiness and Chemical Group Ltd has entered into a joint investment cooperation agreement with ZLD International Holdings Limited for development of the Korella deposit and the company has stated that it intends to commence mining sometime in 2015.

Salt

Queensland salt production in 2011–12 (2012–13) was 101 120 t (126 839 t). Primary salt production is sourced from Port Alma 35 km southeast of Rockhampton. Port Alma is Australia's largest producer and refiner of solar salt operating the Port Alma salt works and Bajool refinery. Cheetham Salt Limited is a wholly-owned subsidiary of CK Life Sciences Int'l., (Holdings) Inc a Hong Kong-based company who purchased the operation from the Ridley Corporation Limited in March 2013. Production has since resumed after several years of being on care-and-maintenance. The operation is now managed on the normal salt production cycle of two years, with high-quality salt grown in the crystallisers that is suitable for refining or bulk dispatch. A new management plan was implemented to secure both stock harvested on the bank and unharvested stock in the crystallisers to prevent a recurrence of losses.

Ridley Corporation Limited has also sold its former salt field assets at Bowen to Advanced Algal Technologies, parent of the purchasing entity Futura Holdings Qld with a view to producing Spirulina and Chlorella algae on a large commercial scale. Advanced Algal Technologies has said the acquisition of the Bowen salt works would make the company the largest production facility of algae in the world.

The Boree Salt Member, known for its significant salt and potash potential, is 50 km south of Blackall. This unit hosts the Adavale deposit (salt and potash) formerly held by Sirius Minerals. This salt formation, which was identified from petroleum drilling and seismic surveying, is Devonian in age and restricted to the eastern edge of the Adavale Basin. Company's with exploration ground in the region are now Underground Storage Solutions Pty Limited, Mineore Pty Limited, and Reward Minerals Limited. Interpretation of the 2D seismic data was carried out and reprocessing of the data has produced a new robust model of the Boree Salt Member. With this new interpretation, an approximate resource of 100Bt of salts has been estimated by RPS Boyd PetroSearch. Key challenges in the area are the availability of water in sufficient quantities to use in the proposed extraction process and securing access to infrastructure. In August 2010, the company entered into an agreement with Sino-Agri Mining Industry Co Ltd to investigate into the development of the project. In September 2011 Sirius Minerals comissioned a research study to explore how synergies between potash solution mining and coal seam gas industries could enable more sustainable deveolpment options for the Adavale project. The potential exists to directly use the wastewater from coal seam gas extraction for potash solution mining. This water source provides a unique benefit in that the salt content of the wastewater could actually improve the recovery rate of potash and therefore improve the economics of potash extraction. The Adavale deposits could also provide salt for the manufacture of caustic soda which is utilised in substantial quantities at the Gladstone Alumina operations of Comalco Ltd and imported.

Silica and foundry sands

Queensland silica and foundry sand production in 2011–12 (2012–13) was 2.27 Mt (2.37 Mt), of which 77.7% (77.7%) came from the Cape Flattery operations in far north Queensland. Current Queensland resources and reserves of silica and foundry sands total >1.9Bt (Table 21).

Silica sand deposits fringe the Queensland coastline as Pleistocene to Holocene coastal deposits that extend up to 12 km inland and average 25–30 m in thickness. Large sand masses form as high transgressive or parabolic dunes, as beachridge barriers or as tidal delta sands.

Beach ridge barrier deposits form parallel to the coast, incorporating former beach strand lines. Large transgressive parabolic sand dunes were initiated by blowouts of beachridges and have evolved under conditions of persistent southeasterly winds on an exposed coastal aspect, with sand supplies continually provided by an erosional shoreline during marine transgressions.

The Cape Flattery Silica Mine is Queensland's largest producer of silica sand since it commenced operations in 1967 and has total resources of 1.2 billion tonnes. The mine is wholly owned by the Mitsubishi Corporation since 1977 and was enhanced with a deep water jetty in 1987. The resource occurs within a large dunefield that covers ~580 km^2 north of Cooktown and consists predominately of white, sharp featured, transgressive, elongate-parabolic active dunes stabilised by vegetation (Photograph 215). The dunes occupy a low interdune sandplain that is 5–10 m above sea level and are interspersed with numerous dune lakes and swamps. High-grade silica (99.9% SiO_2) sand is produced and exported from Cape Flattery wharf. The company reports that the estimated resource of silica sand on their leases is 200 Mt. About 1.5 Mt of silica sand is exported annually to markets in the glass, foundry and chemical industries (Photographs 216 and 217).

High dune mining commenced on North Stradbroke Island, 35 km east of Brisbane in 1978 and subsequently mining has developed a number of orebodies on the significant silica sand resources. Mining is carried out at the Myora and Vance deposits. These occur in deeply leached, older Holocene and Pleistocene sand masses with a podsolic soil profile with a deep A2 layer of pure silica sand that is the focus of mining operations. Sibelco Australia Limited acquired the operations in 2012. The silica sand operation at Vance produces high-quality silica which is used in glass manufacture including bottles (such as at the local glass O-I plant at West End in Brisbane), windscreens, plasma TV screens and solar panels. After processing, the silica sand is trucked to Hospital Point at Dunwich and barged to Brisbane for export and domestic sales.

Silica sand mining also occurs at the Iveragh deposit at Tannum Sands, 20 km southeast of Gladstone. This deposit is an old beachridge barrier system and contains a 4 Mt resource. The sand is used in the manufacture of cement clinker at Gladstone.

The Mourilyan sand deposit, near Innisfail in north Queensland about 100 km southeast of Cairns, is a complex comprising an inner and outer beachridge barrier. The Mourilyan Sand deposit is located 13 km by road from Mourilyan Harbour. The inner beachridge barrier is Pleistocene in age and is locally covered by low, degraded transgressive dunes. The outer beachridge barrier is of Holocene age. Samples collected by Pioneer Concrete Pty Ltd in the 1980s all contained >99% silica. Calcifer Industrial Minerals Pty Ltd has applied for mining leases over this deposit, which contains an indicated 10.74 Mt of silica sand. The deposit contains a JORC compliant resource of 6.74 Mt of silica sand which is 99.83% pure in its raw state. The high purity sand is in considerable demand for the manufacture of new LCD television screens, optical lenses, paint filler, and many other low-end products. Prior to its current merger with Magnolia Solar Corporation, several Japanese and Korean corporations had expressed interest in involvement with developing the deposit. The existing Port of Mourilyan, which was established as the main sugar shipping facility in far north

Silica and foundry sands

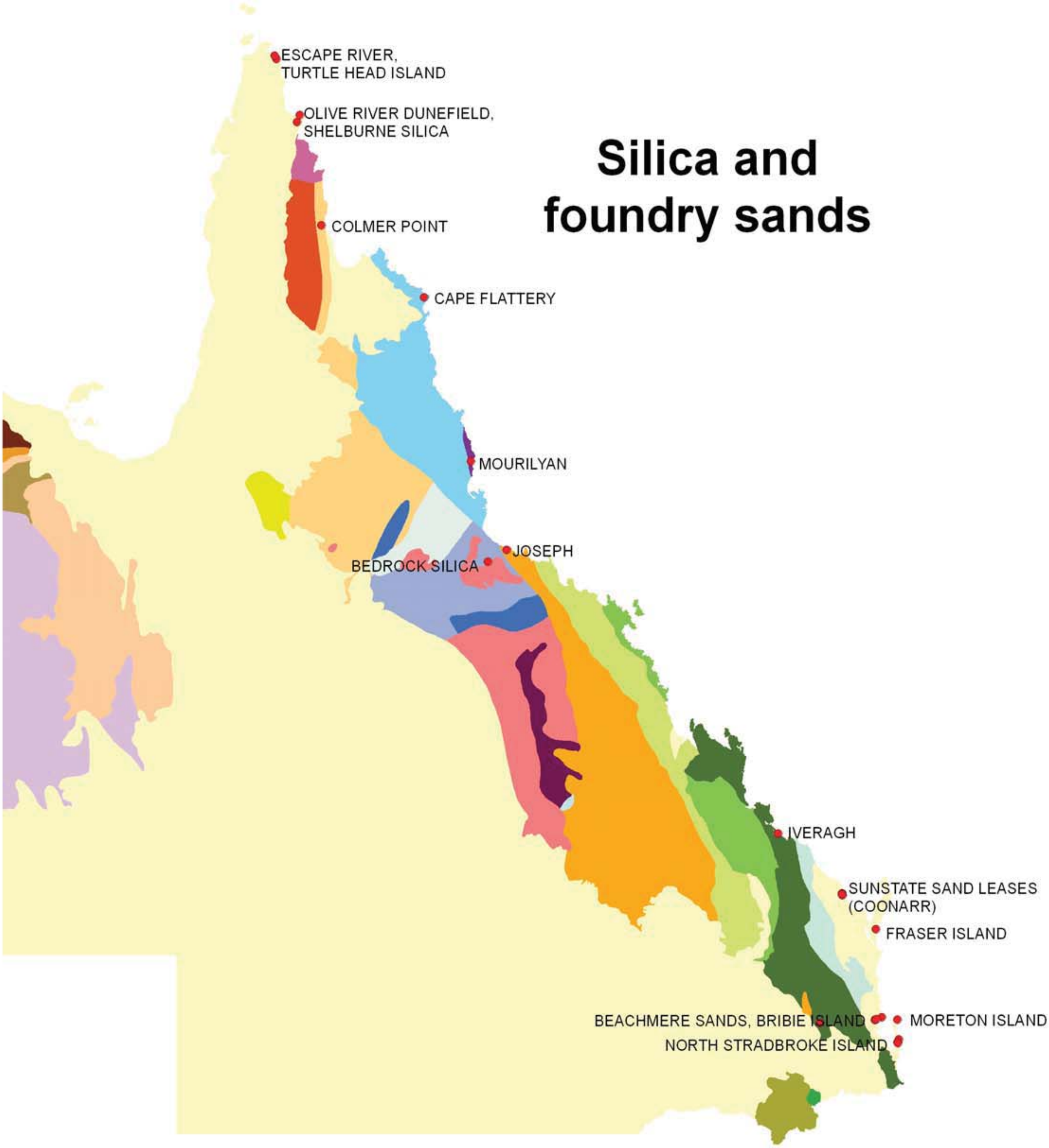


Table 21. Major silica and foundry sand deposits in Queensland

Deposit name	Total historic production (t)	Total resources (Mt)
Amity	-	32
Beachmere Sands	-	Confidential
Bedrock Silica	27 914.5	Not reported
Blockade	70 945	Not reported
Bribie Island Foundry Mould Sand	15 070	0.025
Cape Flattery Silica Mine	47 949 552.6	1200
Chinaman	45 523	Not reported
Colmer Point	-	192
Coonarr Creek	145 823.9	Confidential
Escape River Area	-	30
Iveragh	2 417 359	4
Moreton Island	-	407
Mourilyan Silica Sand	-	10.74
Myora	-	10
Ningi D Sand	-	Confidential
Olive River Dunefield	-	48.76
Shelburne Silica	-	8.76
Southern Pacific Sands	424 620	9.75
Sunstate Sand Leases	145 823.9	Confidential
Toowoomba Foundry Coonarr Sand	8655.3	Not reported
Vance	1 644 386	Confidential

Queensland, is now only utilised about 3 months a year and could be developed to handle silica sand exports via an existing railway running immediately adjacent to the deposit.

The Olive River Dunefield forms a roughly triangular-shaped, low coastal plain on the east coast of Cape York Peninsula. This dunefield extends along the coast from Olive River north to Shelbourne Bay and inland up to 15 km. It is Quaternary in age and overlies Jurassic to Cretaceous, flat-lying quartzose sediments of the Carpentaria Basin. The deposit contains both active and older stabilised lateritised parabolic dunes that are aligned with the prevailing southeast winds. The dunes consist almost entirely of quartz sand, with a heavy mineral content of 0.024–0.206% (mainly ilmenite and zircon). The total silica sand resource, including the Shelburne Silica deposit, is estimated as 1.95Bt and is within National Parks and Restricted Areas. Paleodune and beach ridge silica sand deposits, with substantial ilmenite, rutile and zircon, also occur within a Restricted Area near Colmer Point, northeast of Coen.

Smaller but significant sand resources are also mined at Coonarr (20 km southeast of Bundaberg), at Ningi (50 km north of Brisbane), on Bribie Island, and west of Townsville (Bedrock Silica).

Earth Commodities Pty Ltd operation at Coonarr Creek is 20 km southeast of Bundaberg. This sand is pure white, high-grade silica of about 99.8% SiO_2 with traces of aluminium oxide and iron oxide. The most recent estimates of available coarse sand put the volume at about 480 000 t. A plant was constructed in 2001 with a capacity of 100 000 tpa and the company provides its customers with quality silica sands in various grades from 250 microns to 5 mm pebbles for a broad market including foundry and epoxy industries, architectural coatings, pool and decorative finishes. The most recent estimates of available coarse sand put the resource at about 480 000 t, although some of the resource has since been mined.

The Ningi silica sand-mine operation, about 50 km north of Brisbane, produces a range of quality silica sands for the construction, foundry, filtration, glass manufacture, golf course, sports ovals and specialty sands industries. This deposit is held by Southern Pacific Sands Pty Limited. The silica sand deposits are a mixture of fine bay sands and coarse river sands, allowing the company to provide a wide range of silica sand particle sizes for specific clients. The company indicates that with significant proven reserves security of a long term supply of product can be provided to customers. The main product streams consist of washed classified

Photograph 215: The white silica sand dunes of Cape Flattery (image courtesy Bob Bultitude, GSQ).

Photograph 216: Bulk loading of sillica sand in conveyor belt to the wharf at Cape Flattery (image courtesy DNRM, Queensland Mineral and Petroleum Review, 2002).

Photograph 217: White sand dune sands held by vegetation at Morgans Landing, Cape Flattery.

sand, dried processed sands, bio-retention filter media and screened soils which are sold to a diverse customer base from metal casting foundries, concrete and asphalt batching plants, the civil construction industry, local and international supply of golf course construction and maintenance material, through to locomotive grit for Queensland Railways.

In recent years lump silica has been mined in Queensland. Buck quartz from the waste dumps of Mount Carbine were found to be of interest for the lump silica market. A newer deposit has been developed at Lighthouse near Mount Surprise.

Mount Carbine Quarries Pty Ltd produced lump silica processing the waste dump of the old tungsten mine operations. In 2011–12 (2012–13) a total of 77 598 t (78 231 t) of lump silica was produced as flux. These figures originate from Mount Carbine only.

The Lighthouse quartz deposit is about 30 km southwest of Mount Surprise and held by Singapore-based Solar Silicon Resources Group Pte Ltd. The quartz pipes occur as two small prominent hills containing high-purity quartz grading 99.8% SiO_2 (Photograph 218). A resource of 1.83 Mt has been delineated and the Solar Silicon Resources Group Pte Ltd estimates a further resource of 3 to 5 Mt. Mining at Lighthouse began in mid-2011 and the mining capacity has varied up to 1000 tonnes a day. Processing is a simple acid wash to clean the surface and the company trucks the quartz to Townsville for shipping. Early efforts by the company to commercialise the deposit were based on selling the unrefined quartz to silicon smelters in China for silicon metal manufacture but following the global financial crisis the market had almost disappeared. At this time there was an increasing demand for much higher value processed high-purity quartz products such as solar grade crucible sand and semiconductor grade silica products and the company made a business decision to commercialise this market, during which time it collaborated with Chinese Japanese and Korean entities. Solar Silicon Resources Group Pte Ltd established a test plant facility in Melbourne to develop the ability to manufacture a high-purity quartz sand from the deposit and has successfully produced solar grade high purity quartz sand at a minimum purity level of 99.997+% SiO_2 for export to Japan, Korea and China. It is believed that the company has the capability to beneficiate this product to semiconductor grade high purity quartz sand (99.999+% SiO_2 purity). In September 2014 Solar Silicon Resources Group Pte Ltd signed a share exchange agreement with Magnolia Solar Corporation, a USA-based company, to merge their business interests and assets. Solar Silicon Resources Group Pte Ltd is now a wholly-owned subsidiary of Magnolia Solar Corporation. The merged entity plans to become a dominant supplier of high purity quartz sand to the solar, semi-conductor and high-end electronics industries, and to further develop advanced new solar technologies and plans to change its name to High Purity Quartz Technologies (“HPQT”). Lesser-value uses include feedstock for silicon smelters, epoxy moulding compounds, industrial fillers, fused quartz glass and LCD glass substrates.

Photograph 218: Two quartz bluffs at Lighthouse quartz deposit, with crushed and screen material in foreground.

Sodium bicarbonate

The Grafton Range sodium bicarbonate deposit is 15 km northeast of Roma and held by Australian Pacific Coal Limited. The project covers part of the Surat Basin, where elevated concentrations of sodium bicarbonate occur in the Precipice Sandstone aquifer which in the Grafton Range area is at about 1100 m depth. An estimated 2.2 Mt of *in situ* bicarbonate in brine has been estimated. Using resource information obtained from petroleum and gas wells drilled in the area during 1969–93, independent experts engaged by Australian Pacific Coal prepared a preliminary commercial feasibility analysis of the project. However, Australian Pacific Coal is seeking to divest this project.

Structural clay and shale

Structural clays and shale are of particular importance in centres of high-urban density. Production figures for Queensland in 2011–12 (2012–13) totalled 318 638 t (465 943 t) for brick and paver clay and shale materials.

Several structural clay-mining operations supply different brickworks distributed across metropolitan Brisbane, in suburbs including Rochedale (Austral), Darra (Boral), Dinmore (Claypave) and Oxley (PGH). The Darra, Dinmore (Photograph 219) and Oxley plants utilise blends incorporating clay and shale from the old open cuts (Photograph 220) in the Ipswich Coal Measures; the Rochedale plant only uses non coal bearing clay and shale. The Warwick brick works produce the traditional dry pressed brick. Clays and shale are usually blended to manufacture a large range of bricks and paving products of different colours and textures. These are kiln-fired at temperatures of about 1100°C (Photograph 221). The total tonnage of clay produced to supply the local brick industry is about 1 Mtpa valued at about $7 m. Yearly production of structural clay depends on the local level of commercial and domestic construction activity. Major brickworks operations around Brisbane have recently been consolidated to reduce operating costs, such as closure of the PGH Strathpine brickworks in 2006, the upgrade of the PGH Oxley site, the closure of a plant at Darra in 2011 and the closure of the Austral Dinmore site in 2012. In addition, the PGH Cooroy Brickworks and QC Bricks in Bundaberg closed in mid-2010 because of declining markets.

A joint venture that will be owned 60 per cent by CSR and 40 per cent by Boral is expected to be completed in the first half of 2015. Boral chief executive, Mike Kane, said, with Australian brick manufacturing being challenged as a result of a reduction in brick usage and high input costs, the joint venture will allow us to drive efficiencies across the combined network of operations, creating a more sustainable business.”

Photograph 219: Automated cutting of clay pavers prior to kiln firing at Claypave’s Dinmore plant

Photograph 220: One of several clay pits within the Dinmore clay mining leases

Photograph 221: Clay pavers stacked loosely for firing in Kiln train at Claypave's Dinmore plant

As discussed in the limestone section, the East End mine at Mount Larcom is the largest limestone mining operation in Queensland supplying raw materials for cement production. This operation also supplied slightly over 4.4Mt of structural clay as raw material to a plant at Fishermans Landing, Gladstone between 1996 and 2012.

Rutile, ilmenite and zircon

Mineral sands, or heavy mineral sands, are sand-sized minerals with a high specific gravity. Rutile, ilmenite and zircon are the major economic components of Queensland's heavy mineral sands. Monazite is also commonly present. In 2011–12 (2012–13), Queensland mineral sand deposits produced 59 716 t (6 133 t) rutile, 60 897 t (83 731 t) zircon and 179 177 t (151 450 t) ilmenite. Over 99% of ilmenite came from North Stradbroke Island. Queensland's total resources and reserves are 8.06 Mt rutile, 6.95 Mt zircon and 45.75 Mt ilmenite but the majority of these resources are now alienated (Table 22). From 2013, Goondicum will boost the ilmenite production for the state.

Heavy mineral sands occur in the Pleistocene and Holocene coastal beach and dune systems that commonly fringe the Queensland coastline. These deposits are composed almost entirely of quartz, with a heavy mineral content of 1–1.5%. The same dune systems are also the prime source of high purity silica sand for glass and foundry use, as discussed in the silica sand section of this report.

The Urquhart Point mineral sands project is 3 km southwest of Weipa. The rutile and zircon concentrations occur in sand dunes and strandlines along the coast with an average depth of 2 to 3 m. Oresome Australia (a wholly-owned subsidiary of Metallica Minerals Ltd) has completed a positive feasibility study for a 5 year mine based on current ore reserves. A 50% interest is being earned by a private Chinese investor, Ozore Pty Ltd, who is funding bringing the mine into production by mid-2015. The project is estimated to produce 20,000 tpa of zircon and rutile for direct export from the Embley River. The measured resource is 1.781360 Mt of mineral sand containing 6.851% of heavy mineral sand containing 122 090 t of heavy mineral with 9.8% zircon, 12.0% rutile and 12.4% ilmenite. The indicated resource is 1.305680 Mt of mineral sand containing 4.70% of heavy mineral sand containing 62 150 t of heavy mineral with 11.4% zircon, 10.9% rutile and 13.2% ilmenite. The proved ore reserve is 967 000 t at 10.6% heavy mineral containing 1.2% zircon, 1.4% rutile and 1.4% ilmenite and the probable ore reserve is 210 000 t at 4.8% heavy mineral containing 0.9% zircon, 0.6% rutile and 0.7% ilmenite. The ore reserves are based on a zircon equivalent cut-off grade of 0.90% and the mineral resource is constrained by the Mining Lease, environmental buffers and a cut-off grade of 2% heavy mineral sand. It is estimated that the project will produce 87,000 t of concentrate with an average grade of 14.8% zircon, 17.3% rutile and 16.2% ilmenite.

Oresome Australia is exploring the Cape York coastline for mineral sands elsewhere with some success, including the discovery of zircon-rich sands at the T16 deposit, about 60 km southwest of Bamaga (160km north of Urquhart Point) announced in early 2014.

High dune mining commenced on North Stradbroke Island, 35 km east of Brisbane, in 1978. Sibelco Australia Limited acquired the operations around the mineral sand deposits in dune systems on North Stradbroke Island from Consolidated Rutile Ltd in 2012 and currently mine the Yarraman deposit, which is expected to close in August 2015. About 50 Mt of ore are dredged annually. The Enterprise deposit (Photograph 222) is expected to operate at least until 2035. Total production from Enterprise between 1996 and 2012 yielded 637 246 t of rutile concentrate, 552 344 t of zircon concentrate and 1 573 757 t of ilmenite concentrate. Concentrates are transported by barge to a dry mill plant at Pinkenba (Photograph 223) near the mouth of the Brisbane River, yielding about 200 000 t of ilmenite, 70 000 t of rutile and 50 000 t of zircon for export through the port of Brisbane. Most of the ilmenite and rutile is processed into various titanium products, namely titanium metal for aerospace, flux core welding products and titanium dioxide for paint pigments and the zircon is used in the ceramic industries. About 50 Mt of ore is dredged annually and is expected to decrease marginally once Yarraman ceases operation.

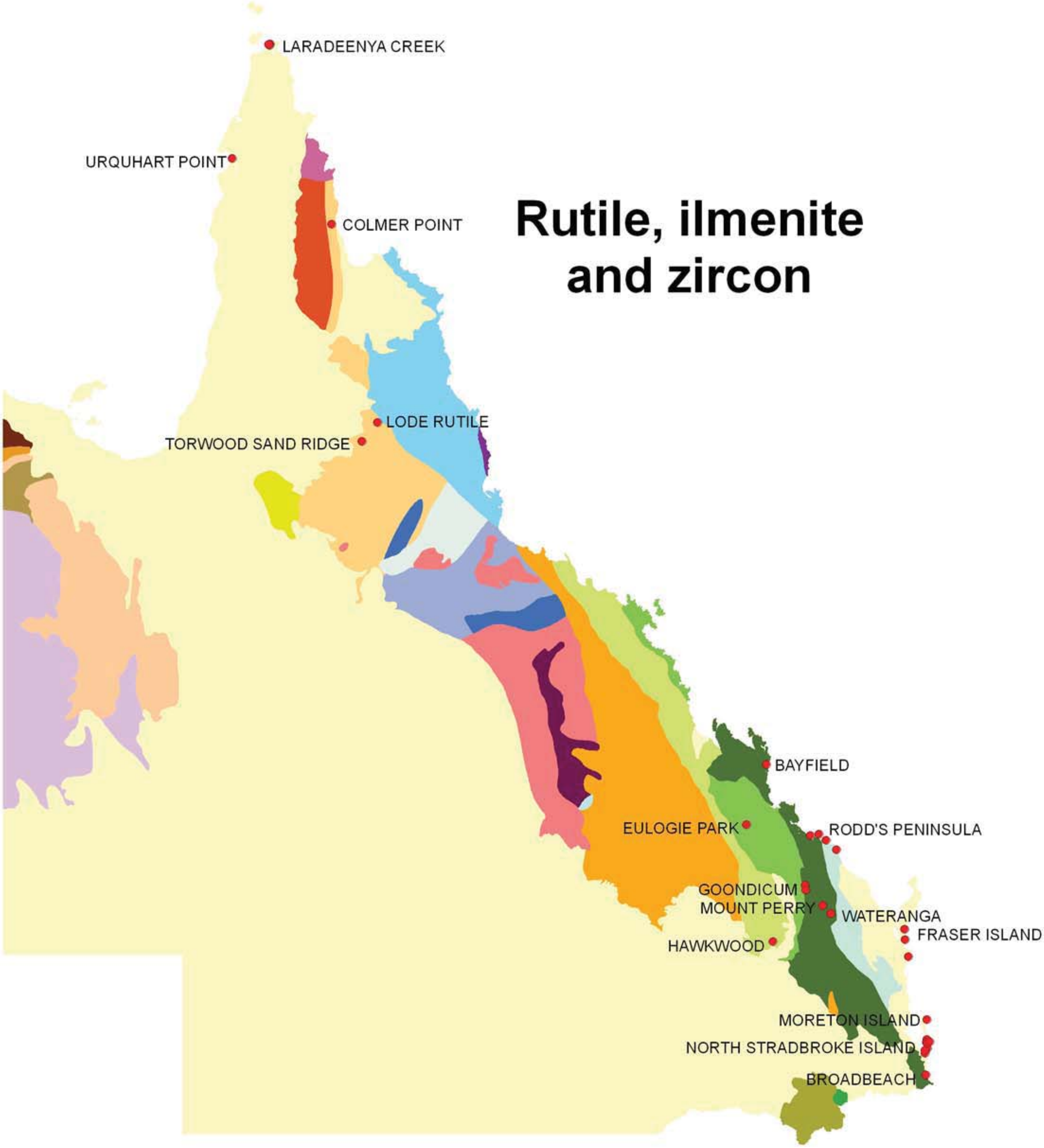
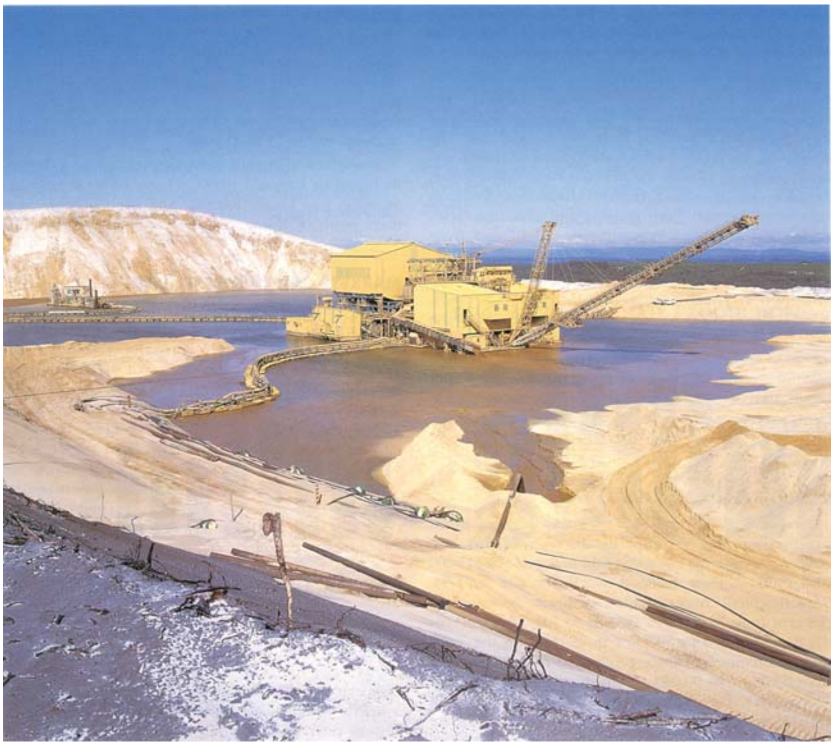

Rutile, ilmenite and zircon
LARADEENYA CREEK
URQUHART POINT
COLMER POINT
LODE RUTILE
TORWOOD SAND RIDGE
BAYFIELD
RODD'S PENINSULA
EULOGIE PARK
GOONDICUM
MOUNT PERRY
WATERANGA
FRASER ISLAND
HAWKWOOD
MORETON ISLAND
NORTH STRADBROKE ISLAND
BROADBEACH

Table 22. Major rutile, ilmenite and zircon deposits in Queensland

Deposit Name	Total resources (Mt)			Comments
	Rutile	Ilmenite	Zircon	
Bayfield	3.7	21	3.7	Within national park
Colmer Point	0.36	4.08	1.02	Within Restricted Area 460
Enterprise	1.29	4.74	1.09	Operating mine — North Stradbroke Island
Eulogie Park Prospect				103Mt resource — grade not reported
Fraser Island — Seventy-Five Mile Beach	0.87	2.91	0.89	Within national park
Goondicum Crater Ilmenite	0.45	1.01		Operating mine; resource also contains 0.5Mt apatite and 2.5Mt feldspar
Jack Goody (Goondicum Alluvial)		8.28		Alluvial material downstream from Goondicum Crater
Middle Island (including Rodd's Peninsula and Rocky Point)	0.05	1.52	0.13	Within national park and urban development
Mount Perry Rutile Prospect	1.51			Current exploration by Lihir Gold Ltd
Urquhart Point				Cape York, western coastline, undifferentiated resource 2.8Mt at 7.0% heavy minerals
Yarraman	0.33	0.80	0.25	Operating mine — North Stradbroke Island



Photograph 222: The mineral sands dredge on Stradbroke Island around 2005 (image courtesy DNRM 2005).

Several alluvial, eluvial and/or associated hard rock ilmenite resources have been delineated in central and southeast Queensland. The alluvial and eluvial deposits are derived from the weathering of ilmenite-bearing gabbros.

The Goondicum Project is 30 km due east of Monto was operated by Belridge Enterprises Pty Ltd between 2009 and June 2013 (Photograph 224). The Goondicum Crater alluvial and eluvial placer ilmenite deposit was derived from erosion of the Goondicum Gabbro, which contains ilmenite and titano-magnetite in both massive forms and as individual crystals. The weathered horizon containing significant ilmenite, apatite, titano-magnetite and feldspar mineralisation is up to 25 m thick (Photograph 225). Massive forms occur as oxide-gabbro 'reef' systems, and individual crystals occur in zones of high-grade ilmenite and titano-magnetite within the gabbro. Ilmenite at Goondicum Crater is high in titanium and low in chromium, thorium and uranium. Monto Minerals commenced treating eluvial material from the Goondicum Crater through a pilot plant to produce sample product for supply to potential buyers. Commercial operations commenced in 2007 but the mine, operated by Monto Minerals, closed in 2008 due to

Photograph 223: Rutile, zircon and ilmenite products undergo final separation and clean-up at the dry mill at Pinkenba (image courtesy DNRM, Queensland Mineral and Petroleum Review, 2002).

Photograph 224: The new ilmenite, zircon and rutile processing plant at the Goondicum Crater near Monto.

Photograph 225: Exposure of weathered ilmenite, zircon and rutile in decomposed gabbro and pegmatite dykes within the Goondicum Crater.

problems with the treatment plant. Monto Minerals was developing four distinct mineral products, namely, ilmenite, feldspar, apatite and titano-magnetite. In 2009, the RMM Capital group, of Brisbane, took control of Monto Minerals and renamed the company Belridge Enterprises Pty Ltd (Belridge). Belridge commissioned a redevelopment study aimed at recommencing mining and processing operations. A block model for new resource estimation was created. At a zero net value per block, comparable to a break-even cut-off grade of 4% ilmenite equivalent, the indicated plus measured resource is estimated at 51 Mt, averaging 4.1% ilmenite, 1.9% apatite and 2.5% titano-magnetite. The plant was constructed in 2012 and the first ilmenite shipment was exported in November 2012. At the current export rate of 7 000 t ilmenite per month, the mine would generate 84,000 tpa of ilmenite for export to Japan, Korea and China and have a life of about 25 years. About 4000 tpa of apatite rock is also produced and sold in Australia. Belridge had to close the operations in June 2013 due to falls in the price of ilmenite. Melior Resources bought the Goondicum project in May 2014 and commenced a refurbishment of the mill in August 2014 with a view to boosting the plant throughput by 50% to 2.8 Mtpa. They also plan to build a new access road to reduce haulage distances by about 100 kilometres. Following the refurbishment which will take about 8 months the open pit mine will produce about 200,000 tpa of ilmenite and associated apatite.

The Eulogie Park deposit, also in central Queensland, consists of eluvial, alluvial and flood plain mineral sands derived from the ilmenite-bearing Eulogie Park Gabbro.

The Wateranga project is 30 km southeast of Mount Perry, in southeast Queensland. The deposit comprises eluvial alluvial and hard-rock deposits of high-alkali feldspar, apatite, ilmenite and mica, with minor corundum, zircon, rutile, scandium and magnetite. These deposits are associated with the Wateranga Gabbro and also grade 30 ppm scandium. Queensland Industrial Minerals Limited has been carrying out feasibility studies and mine planning. Mining at a rate of 3.75 Mtpa would produce 500 000 tpa of mineral concentrate containing ilmenite, feldspar, magnetite, zircon, rutile, corundum and mica, and have a mine life in excess of 30 years. Some of the resources are affected by the impoundment boundary of the Paradise Dam. A combined resource of 204 Mt of unconsolidated material with a composition of 5% ilmenite, 0.2% zircon, 20% feldspar, 0.8% apatite and 0.1% rutile was delineated by Queensland Industrial Minerals Pty Ltd in 2008. Queensland Industrial Minerals Limited has completed process plant design work and is waiting for a mining lease to be granted and upon grant is expected to commence construction of a mine.

Hard rock rutile resources at Mount Perry consist of disseminated, very fine-grained rutile and zircon needles and inclusions in quartzite and quartz-sericite altered acid volcanic rocks of the Aranbanga Volcanic Group. This deposit was being explored by Lihir Gold Ltd (after its merger with Equigold NL), but no activities have been registered since 2008.

Wollastonite

Wollastonite ($Ca(SiO_3)$) is used in ceramics and paint, as a substitute for asbestos, and a welding flux. Wollastonite is also used in several rapidly growing industries, particularly plastics, and these are expected to grow in world demand over the coming years. Queensland has numerous undeveloped wollastonite deposits that have primarily formed within skarn mineral assemblages. The largest wollastonite deposits (Photograph 226) are scattered along the outcrop extent of the Chillagoe Formation (Hodgkinson Province) where granitic intrusions have developed broad zones of skarn-related calc-silicate alteration (*e.g.* Black Creek). No serious attempts have been undertaken to define the wollastonite resources of Queensland.

Photograph 226: The pen marks area in photograph showing wollastonite mineralisation in Chillagoe marble from the Wollastonite pit, owned by Chillagoe Marble Australia Pty Ltd.

Zeolite

Three significant zeolite resources have been recognised in Queensland, namely, the Willows Zeolite Mine, Avoca and Springvale. These deposits are altered waterlain ash-fall tuffs of the Ducabrook Formation in the Drummond Basin in central Queensland. Total known Queensland zeolite resources and reserves are ~18.5 Mt. In 2011–12 (2012–13) a total of 540 t (685 t) of zeolite was produced.

Zeolites are hydrated aluminosilicate minerals of the alkaline and alkaline-earth metals. By having an open crystalline framework with a network of channels and cavities, zeolites possess a very large surface area. This large surface area gives them great absorptive properties. Fluids with molecules too large to enter the channels are excluded, enabling the zeolite to act as a molecular sieve. The crystal structure has a net negative charge, so it can adsorb and exchange positively charged cations. These crystal structure properties, combined with high surface areas, give zeolites a high cation exchange capacity. Chabazite and clinoptilolite are the two out of the 48 minerals in the zeolite group that have commercial applications. Naturally-occurring commercial zeolites are used world-wide in pet litter, animal feed, horticultural applications, wastewater clean-up, odour control, gas absorbents, catalysts, oil absorbents, aquaculture and water purification. Animal feed, horticultural and pet litter applications dominate demand.

The Avoca zeolite mining and exploration project is about 125 km southwest of Emerald. The project is held by Zeolite Australia Pty Ltd. An approximate resource of over 18.5 Mt is estimated over areas under the company's tenures. The deposits occur generally in altered water-lain ash-fall tuff of the early Carboniferous Ducabrook Formation in the Drummond Basin. The deposit has been mined intermittently on a small scale to supply emerging local markets. Zeolite Australia is currently conducting further exploration with sampling and testing, investigating mining feasibilities to produce zeolite products for export. The ore contains up to 65% Ca-type clinoptilolite with quartz and smectite as accessory minerals.

Queensland Zeolite Pty Ltd is a small intermittent zeolite producer, operating the Willows zeolite mine (Photograph 227) in the same area and from the same formation as the Avoca zeolite operation. The flat-lying, very fine grained, red, banded water-lain ash-tuff (Photograph 228) is recovered in small open cuts, crushed and bagged for sale. Production was recorded from Willows in 2014.

Subeconomic zeolite has been recorded as cavity-fill (Photograph 229) and the groundmass of volcanic lavas, altered granites, and volcaniclastic rocks in Queensland.

Photograph 227: Queensland Zeolite's processing plant at Willow zeolite mine.

Photograph 228: Open cut at Willow zeolite mine exposing flat-lying, very fine-grained water-lain ash-tuff beds.

Photograph 229: Zeolite crystals in basalt from the Main Range Volcanics, near Toowoomba.

Oil shale

(updated by R. McIver & G. Pope)

Oil shale is a fine-grained, compact sedimentary rock that contains solid combustible organic matter in a mineral matrix, collectively termed kerogen. Upon distillation, the shale yields paraffins and olefins. Oil shale deposits consist of carbonaceous material such as liptinite macerals derived from spores, pollen, leaf and stem cuticles, resins, fats, algal remains and macerated shreds. They form from accumulations of organic matter in marine, lacustrine and restricted estuarine environments, preserved under anaerobic conditions. Liptinite-dominant accumulations have high hydrogen content.

Oil is released when oil shale is heated to approx 500°C — the oil yield is greater with increasing hydrogen-carbon ratio of the parent kerogen. Oil produced from oil shale can usually be processed by conventional refining methods following stabilisation.

Queensland's identified oil shale resources contain 22.96 billion barrels of oil from 51.46 billion tonnes of oil shale resource (3219 GL) (Table 23).

The major deposits are of three types:

- Torbanite deposits in Permian coal measures. Macerals include telagininite, liptinite and alginite (large thick-walled algae).
- Deposits of Tertiary lamosites, which are kerogen-bearing alumina-silicate dominated shales in Tertiary basins and host Queensland's major oil shale resources. Macerals include lamalginite (small thin-walled algae) and minor alginite.
- Cretaceous deposits of mixed oil shale content in calcareous rocks of the Eromanga Basin. Macerals are a mixed assemblage (telalginite and bituminite).

The only significant Permian torbanite deposit in Queensland is at Alpha in central Queensland. This deposit lies within the axis zone of the Glen Avon Syncline, a southwest-plunging structure on the eastern flank of the Galilee Basin, and is within the Colinlea Sandstone, a 150 m thick sequence of cross-bedded sandstone with minor conglomerate, siltstone and mudstone.

Tertiary lamosite oil shale deposits formed in basins near Queensland's eastern coastline and in the Duaringa area in central western Queensland. The three Duaringa deposits are the Duaringa – Northern Area, Duaringa – Central Area and Duaringa – Southern Area and occur within the Tertiary Duaringa Basin. These deposits are now held by Queensland Energy Resources Ltd.

The Bungobine oil shale deposits, west-northwest of Mount Coolon, were discovered by International Mining Corporation NL in 1980. Six occurrences have been delineated in a 50 km^2 sub-basin of Tertiary Suttor Formation beneath 40–50 m of poorly consolidated cover rocks and sediments. The oil shales comprise both lignite-rich and algal-rich varieties. Oil content is variable, but the highest yields have come from brown algal-rich shales. The shale oils are highly aliphatic, with an average H:C ratio of 1.7 and relatively low N and S contents. Water content is high. These deposits are now held by Austral Dutch Kaolin Pty Ltd, which is also interested in kaolin beds associated with the oil shale sequence.

The Lowmead oil shale deposit occurs within a small Tertiary Basin southeast of Miriam Vale in southern Queensland. This basin is ~17 km long and up to 3 km wide. The Lowmead Formation is an interbedded sequence of claystone, oil shale, carbonaceous oil shale and sandstone (Photograph 230). The oil shale is massive to finely laminated and beds are up to 50 m thick.

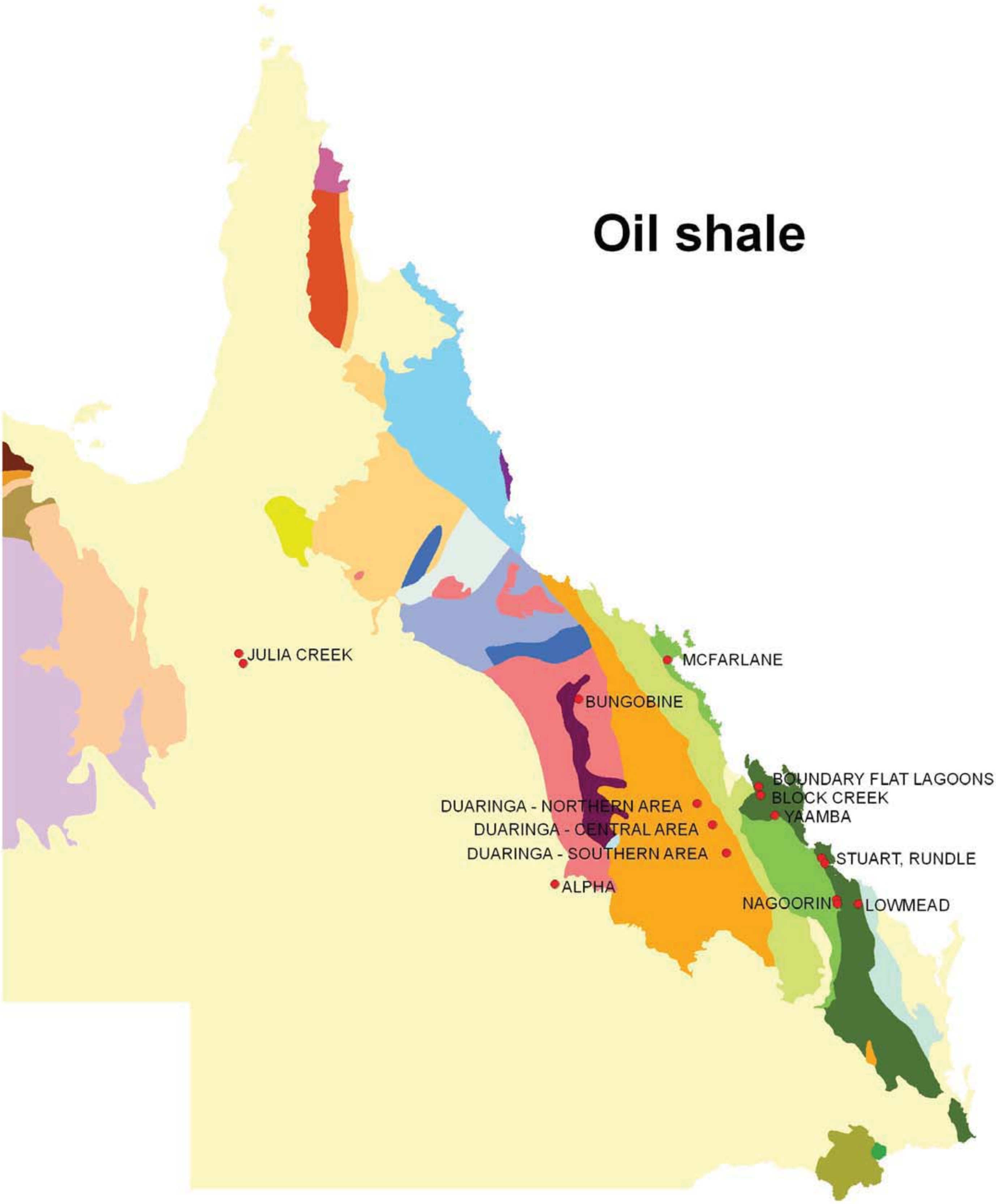

Oil shale
JULIA CREEK
MCFARLANE
BUNGOBINE
BOUNDARY FLAT LAGOONS
BLOCK CREEK
YAAMBA
DUARINGA - NORTHERN AREA
DUARINGA - CENTRAL AREA
DUARINGA - SOUTHERN AREA
STUART, RUNDLE
ALPHA
NAGOORIN
LOWMEAD

Table 23. Oil shale deposits of Queensland

Deposit Name	Total oil shale resource (billion tonnes)	Total shale oil (billion barrels)	Age	Depositional environment	Oil shale type
Alpha Oil Shale		0.08	Permian	Non-marine	Torbanite
Block Creek	1.2	0.5	Tertiary	Lacustrine to estuarine	Lamosite
Boundary Flat Lagoons	1.9	0.7	Tertiary	Lacustrine to estuarine	Lamosite
Bungobine	0.17	0.15	Tertiary	Lacustrine	Lamosite
Duaringa — Northern, Central and Southern	7.4	2.5	Tertiary	Lacustrine to estuarine	Lamosite
Julia Creek	2.05	0.85	Cretaceous	Shallow marine	Mixed
Julia Creek Oil Shale	0.24	1.88	Cretaceous	Shallow marine	Mixed
Lowmead Oil Shale — Northern Deposit	1.7	0.7	Tertiary	Lacustrine to estuarine	Lamosite
McFarlane	13	4.8	Tertiary	Lacustrine to estuarine	Lamosite
Nagoorin	5.7	2.4	Tertiary	Lacustrine to estuarine	Lamosite
Nagoorin South	1.1	0.4	Tertiary	Lacustrine to estuarine	Lamosite
Rundle	5.0	2.6	Tertiary	Lacustrine to estuarine	Lamosite
Stuart Oil Shale	5.6	2.6	Tertiary	Lacustrine to estuarine	Lamosite
Yaamba Oil Shale	6.4	2.8	Tertiary	Lacustrine to estuarine	Lamosite
Total	**51.46**	**22.96**			

The Nagoorin and Nagoorin South oil shale deposits occur in the Boyne River valley, 75 km southwest of Gladstone in central Queensland. These deposits are Tertiary sediments in the narrow, north-northwest-trending Nagoorin Graben, which is ~40 km long and up to 5 km wide. The Nagoorin Beds were deposited in a freshwater environment and consist of sandstone, siltstone, conglomerate, carbonaceous shale, oil shale, mudstone and low rank coal.

The Yaamba oil shale deposit is 30 km north of Rockhampton in central Queensland and occurs in the western two-thirds of the Yaamba basin. The oil shale sequence is >500 m thick in the centre of the basin but thins towards the margins. Further to the north, east of Marlborough, the Block Creek and Boundary Flats Lagoons oil shale deposits occur as two distinct stratigraphic units in the Herbert Creek Basin.

The McFarlane deposit near Proserpine is the largest known Tertiary oil shale deposit in Australia. A massive oil shale section ranges in thickness from 220–407 m and contains a resource of 4.8 billion barrels of oil.

Photograph 230: Lowmead oil shale open pit.

Photograph 231: Stage one of QER Pty Ltd's Stuart Oil Shale project (image courtesy QER Pty Ltd, Queensland Mineral and Petroleum Review, 2003).

The Stuart and Rundle deposits lie within the 30 km long by up to 6.5 km wide Narrows Graben, which is adjacent to the coastline northwest of Gladstone. Oil shale is hosted by the Tertiary Rundle Formation, which consists mainly of oil shale and barren claystone, with minor siltstone and impure dolomite.

The Stuart Oil Shale Project, which was initially funded by a joint venture between Southern Pacific Petroleum NL, Central Pacific Minerals and Suncor (Canada), commissioned an oil shale plant (Photograph 231) using the Alberta-Taciuk Processor (ATP) retort technology for oil extraction in 1999. The steps in this process are:

- pre-heating to 125–250°C
- retorting at 500°C to break down the kerogen to lighter hydrocarbons
- recovery of hydrocarbon vapours
- combustion, where remnant carbon is burned to provide energy for the pre-heating and retorting stages.

Approximately one-third of the spent shale is recycled through the retort section and contributes thermal energy to the system, raising the overall efficiency of the retorting process. Spent shale was cooled with water and returned to out-of-pit dumps at the mine site for rehabilitation.

The Stage 1 pilot plant was commissioned using ore from the Kerosene Creek Member, a particularly high-grade seam (approximately 130 LT0M) that is the uppermost member of the Rundle Formation (Photograph 232). Target production for the Stage 1 Plant was 4500bpd. Numerous difficulties with the retorting process resulted in repeated plant shutdowns. The companies went into administration in December 2003 and were bought by Queensland Energy Resources Ltd in February 2004. Queensland Energy Resources Limited continued to operate the plant until October 2004. The Stage 1 plant operated for a total of 750 days during which it treated 2.5 Mt of oil shale to produce 1.54 million barrels oil.

Demolition of the ATP plant was commenced in May 2009 and completed in November 2009. These works prepared the site for construction by Queensland Energy Resources Limited of a significantly smaller 2.5 tonnes per hour 'technology demonstration plant' (TDP) using a different processing technology known as the Paraho II™.

This processing method has been successfully demonstrated at a smaller 'pilot plant' in Colorado, USA. The Paraho II™ process uses a single retort chamber that operates by gravity feed with a lower temperature requirement processing a lump feed material (rather than fines) and produces fewer waste streams. The TDP is intended to demonstrate, over a period of at least 2 years, the efficiency, reliability, safety and sound environmental performance of the retorting technology, in the context of a Queensland-based mine using shale from the Stuart resource. Construction of the TDP was commenced in May 2010 with commissioning commenced in mid-2011 and completed mid-2012 (Photograph 233). The staged commissioning process allowed first oil production to occur on 6 October 2011. The TDP has also demonstrated what is believed to be the first 'end to end' processing in a single oil shale plant with the production of ultra-low sulphur diesel in July 2013. The plant was put into care and maintenance mode in March 2014 pending further commercial development. Production of 35,000 litres ULSD(Ultra Low Sulphur Diesel) is being used in ongoing truck fleet testing. A visitor centre at the New Fuels Development Centre, with displays on the geology of the oil shale deposit and the processing method, was opened in 2011 and continues with public access during business hours.

The Julia Creek oil shale is a major Cretaceous oil shale deposit northeast of Julia Creek in northwest Queensland. It occurs within the shallow-water marine sediments of the Toolebuc Formation in the Eromanga Basin. The oil shale is interbedded with and underlies the uppermost section of limestone in the Toolebuc Formation. Significant, potentially commercial grades of vanadium

Photograph 232: Stage one Stuart Oil Shale plant; rotary dryer and processor (image courtesy QER Pty Ltd, Queensland Mineral and Petroleum Review, 2002)

Photograph 233: The Stuart oil shale plant, 2013 (image courtesy QER Pty Ltd)

and molybdenum are associated with the oil shale. The bulk of the oil-shale resource sits within the unweathered Toolebuc Formation, whereas the vanadium and molybdenum enrichment resides in the near-surface oxidised oil shales.

A resource of 2.18 Billion barrels of shale oil at an average grade of 61 litres per ton at zero moisture (LT0M) has been reported by Global Oil Shale Group PLC (GOS Dec 2012 release). Intermin Resources Ltd, the holder of the tenements, is investigating the associated vanadium–molybdenum-nickel resource potential (see ‘vanadium’ section). Blue Ensign Technologies Ltd (through its subsidiary Queensland Oil Shale Ltd) also reports a shale oil resource of 895 million barrels in the Julia Creek area.

On the 24th August 2008, the Queensland Government announced plans to restrict the development of oil shale in the state of Queensland. This involved a 20-year moratorium in respect of development of oil shale within the Proserpine area, but explicitly provided scope for the continued exploration elsewhere with development depending on a Government review of oil shale within the State. On the 14 February 2013 the Queensland Government released the Queensland Oil Shale policy as the final outcome of the review. Under the policy, development of an oil shale deposit by a ‘proposed oil shale technology unproven in Queensland, will be assessed through a trial phase to ascertain whether the technology is meeting environmental standards. If this trial is successful, a staged approach towards commercialisation will be adopted.’ The normal project EIS process will still be required where an oil shale technology has been proven in Queensland. The oil shale deposits in the Proserpine area remain under the 20-year development moratorium.