COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

RECORDS:

1965/81

GEOLOGY OF THE AREA AROUND DUGALD RIVER LEAD-ZINC PROSPECT, CLONCURRY DISTRICT, QUEENSLAND.

by

F. de Keyser

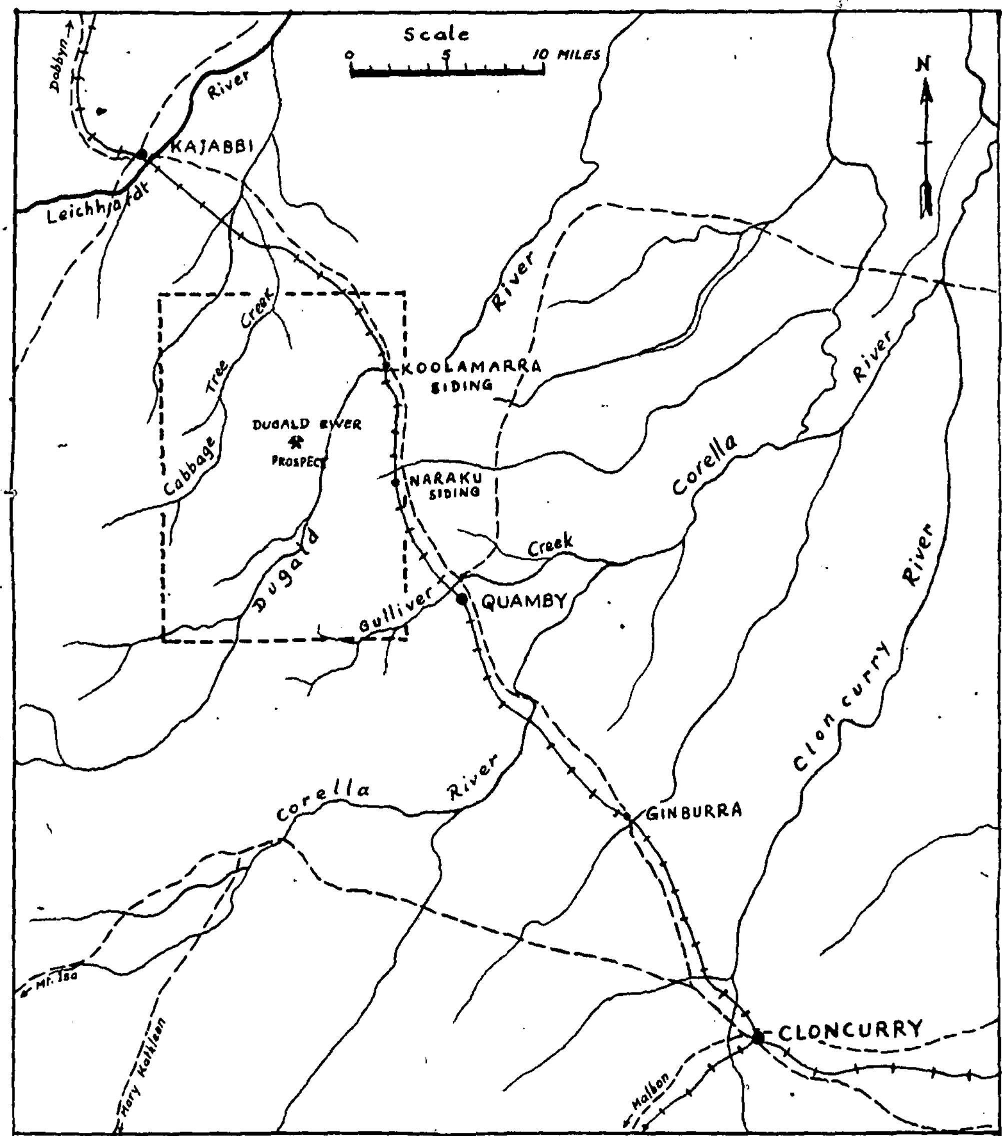


FIGURE 1 — *Locality diagram of Dugald River lead-zinc prospect and surrounding area.*

- - - *main road or track*
-+-+- *railway line*
[- - -] *boundary of area mapped in 1956*

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

F54/A2/2

GEOLOGY OF THE AREA AROUND DUGALD RIVER LEAD-ZINC PROSPECT, CLONCURRY DISTRICT, QUEENSLAND

by

F. de Keyser

RECORDS 1965/81

CONTENTS

FIGURES

PLATES

GEOLOGY OF THE AREA AROUND DUGALD RIVER LEAD-ZINC PROSPECT, CLONCURRY DISTRICT, QUEENSLAND

by

F. de Keyser

RECORDS 1965/81

SUMMARY

In September, 1956, a geological party of the Bureau of Mineral Resources, assisted by a geologist of Mount Isa Mines Limited, mapped an area of about 100 square miles around the Dugald River lead-silver-zinc prospect, 45 miles north-west of Cloncurry, north-western Queensland. A limited geochemical survey was also carried out to determine the extent of possible mineralization in the black slate zone, which is the locus of the lead lode.

Folded Lower Proterozoic rocks with steep regional dips underlie the greater part of the area. They are mostly metamorphosed calcareous sediments and limestone of the Corella Formation, containing some quartzites and schists. The central part of the area is dominated by a quartzite ridge (Knapdale Quartzite), the stratigraphical position of which is not clear. Intruding the Proterozoic rocks in the east, in places with an ill-defined boundary, is the Naraku Granite. Remnants of Mesozoic sandstone occur as flat-topped residuals in the west.

Faulting is intense and predominantly north-south, forming, for example, the narrow graben now filled with the (?) Upper Proterozoic Quamby Conglomerate.

A large number of old abandoned prospects and small mines are evidence of widespread but scattered and mostly unimpressive copper mineralization. The lead-silver-zinc mineralization is restricted to a narrow zone of black calcareous and carbonaceous slate, and has been tested by geophysical work and drilling; tonnage and grades indicated were not high enough to warrant mining. Gold was mined from the conglomerates of Mount Quamby in the early days.

INTRODUCTION

Location and access.

The Dugald River lead-zinc prospect is situated 45 miles north-west of Cloncurry on the west bank of the Dugald River in north-western Queensland (Fig. 1). The Cloncurry-Kajabbi road (unsealed) and railway line cross the area in the east, and dirt tracks connect several of the mineral prospects with Koolamarra and Naraku (or Narraku) railway sidings. These tracks are usually impassable during the wet season. A small grazing property is situated on the eastern bank of the Dugald River, 4½ miles west-south-west of Naraku siding.

Climate and topography.

The area lies in a semi-arid belt with wet summers and dry winters, and with mean annual temperatures between 75° and 80° in the shade. Rainfall figures show a maximum in January and February, and a minimum in July and August. The following statistics, though referring to the Cloncurry recording station, illustrate the climate of the area:

Average annual rainfall (over the period 1948-55): 22.2 inches, with a recorded minimum of 14.7 inches, a maximum of 37.1 inches;

Mean average maximum temperature for January: 95^{o}

Mean average minimum temperature for January: 74^{o}

Mean average maximum temperature for July: 75^{o}

Mean average minimum temperature for July: 50^{o}

There are no permanent streams, and potable water during the dry season can be obtained only from bores and rare waterholes.

The area is part of the divide between the Leichhardt and Flinders River systems. In the west, the area is drained by Cabbage Tree Creek, a tributary of the Leichhardt River. The central and eastern parts of the area are drained by the Dugald River and Gulliver Creek, both of which are branches of the Flinders-Cloncurry river system.

The relief is low, and much of the country consists of alluvial plains (especially in the north and west) in which no outcrops are found. Elsewhere the topography is gently undulating, and there outcrops are numerous, though small, scattered, and rubbly. The best exposures are found in deeply incised secondary creeks, and in the few high ridges. The highest points are the range composed of Knapdale Quartzite, Mount Quamby (250 feet above the surrounding plain), and a small area occupied by granite dykes and sills intersecting metamorphosed sediments, east of the Dugald River. The relief is controlled by structure as well as by lithology: the Quamby Conglomerate, for example, although occupying a down-faulted, narrow rift-valley, stands out topographically because of its resistance to erosion.

Purpose of the survey.

This report presents the results of restricted geological-geochemical investigations carried out in September 1956 by F. de Keyser and D.O. Zimmerman (B.M.R. Geologists), A. Debnam (Geochemist), and J. Neale (Geologist from Mount Isa Mines Limited), under the supervision of W.C. White.

The main purpose was to geochemically test the zone of black slates in which the lead mineralization is localized; the surrounding country was mapped in as much detail as possible within the allotted time, in the hope of locating extensions of structural repetitions of the black slate zone.

The mapping was done with the aid of vertical air photographs, taken in 1950 by the Royal Australian Air Force at 1:50,000 scale (Cloncurry, Survey 886, Runs 3 to 6). Data were plotted on an uncontrolled planimetric base prepared from the air photographs.

PREVIOUS INVESTIGATIONS AND PROSPECTING HISTORY.

Most references known deal with the mineral prospects of the area, and geological observations were only incidental initially.

The first comments were probably made by Jack (1898), who during a visit to the area in 1881 noticed the presence of two shallow shafts and a trench, dug in '...foliated and contorted graphitic shales, more or less impregnated with yellow lead ochre and peroxide of iron; some red oxide of lead also occurs in places'. He also mentioned the striking absence of trees and spinifex along the line of mineralization.

Although the large extent of the lode left a favourable impression, no further interest was shown until 1937, when combined geological and geophysical investigations were carried out by the North Australia Survey and the Queensland Department of Mines (Honman, 1937; Ball, 1937, 1939; Rayner and Nye, 1937). The lode exposed at the surface was found to be unpayable, but it was hoped that this would improve with depth, and the conclusion was reached that the deposit was '...a potential source of a considerable tonnage of silver-lead ore which has very good prospects of being profitably exploited'. Apart from some drilling tests (Ball, 1939), nothing was done until after the second World War, when Zinc Corporation Ltd. obtained the Dugald River freehold, and started a program of diamond-drilling and geological investigation of the surrounding area. It soon became apparent that the lead and silver values decreased in depth, where the mineralization consists mainly of sphalerite, and that, notwithstanding the ready access and the proximity of a railway connection with Cloncurry, a payable development could not be undertaken (Knight, 1953).

Little is known about the history of the many scattered copper prospects. Some of them were worked as early as 1893 (Rayner, 1938), but production figures are incomplete. The production in the Cloncurry Field as a whole reached a peak during the first World War, when the price of copper on the London market rose to about £150 per ton. When the price dropped to around £70 per ton after the war, many mines closed down, and at present no copper ore is being produced from the Dugald River area.

A little native gold was found in the Quamby Conglomerate in 1908, but hopes of finding a rich reef were never fulfilled. The grade is low, and the total output was not more than a few hundred ounces when production ceased (Ball, 1921, 1922).

Some cobalt was first mentioned in 1923 from the Godkin copper shafts, and two years later from the Coocerina copper zone along the south-western margin of the Knapdale Quartzite, but there was no production.

Geological mapping was done several years after the second World War by Sturmfels (1952) for Enterprise Exploration Co. Pty Ltd., and the area was also included in a regional geological survey carried out from 1950 to 1958 by joint field parties of the Bureau of Mineral Resources and the Geological Survey of Queensland (Carter, Brooks, and Walker, 1961). The petrology of the Cloncurry Mineral Field in general was described by Joplin (1955), and the widespread scapolitization, an unusual form of metasomatism, was discussed more specifically by Edwards and Baker (1954).

STRATIGRAPHY

Three (or perhaps four) Proterozoic sedimentary formations are intruded by the Naraku Granite. The Corella and Knapdale Formations, of Lower Proterozoic age, are tightly folded and are unconformably overlain by the (?) Upper Proterozoic Quamby Conglomerate. Remnants of a Mesozoic sandstone cover are preserved in the west.

Corella Formation. (Previously known, since 1928, as 'Corella Limestone' and 'Corella Series', but name amended to 'Corella Formation' by Carter in 1961. Name presumably derived from Corella River).

The Corella Formation, which crops out over a considerable part of the metamorphic belt of north-western Queensland, is the main unit found in the Dugald River area, where it consists of calc-silicate rocks (including quartz-feldspar granulites), calc-silicate breccias, limestones, black calcareous slate, micaceous schist, quartzite, and amphibolite. The rocks are rather varied, and transitions between the rock types are common. An interesting feature is the regional occurrence of scapolite in most of the calc-silicate rocks and in many of the limestones and schists (Edwards and Baker, 1954). Current-bedding, reported to be rare in the

Corella Formation (Carter et al.,1961), is not uncommon in the Dugald River area, where it is observed mostly in well-bedded limestone. Graded bedding is also present in a few places. These sedimentary structures usually show that the beds face west; east-facing beds are rare. It appears therefore that in general the formation becomes younger towards the west.

Owing to the tight folding and intense faulting, any estimate of the total thickness of the formation is unreliable. Carter et al. (1961) and Sturmfels (1952) both suggest a thickness of between 5,000 and 10,000 feet.

The limestones of the Corella Formation are widely exposed west and south of the ridge of Knapdale Quartzite in the centre of the area; they also occur along the black slate zone which contains the lead-zinc prospect, and form intercalations in the calc-silicate rocks east of the Knapdale Quartzite. Most limestones are dark grey or black, carbonaceous, argillaceous, and well bedded. Both thin-bedded and thick-bedded members are present. Scapolite marbles, calc-silicate limestones, and micaceous limestones are the products of metamorphism of more impure carbonate rocks. Some hard, dense, fine-grained rocks resembling black limestone are probably silicified silty limestone or calcareous slate, or else fine-grained carbonaceous calc-silicate rock. A few limestones contain clastic quartz grains, and the most western beds exposed are light grey, and contain pebbles of the normal dark grey limestone. Cross-bedding is common, and ripple marks were noticed in one outcrop of calc-silicate limestone. The darker limestone members commonly contain pyrite and pyrrhotite.

The calc-silicate rocks, mostly regularly and thinly-bedded rocks of varied composition, occupy most of the area between the Knapdale Quartzite and the Naraku Granite, and are interspersed with beds of limestone and schist and, in the east, with amphibolite. Because their texture is granular they have commonly been referred to as 'granulites' and 'scapolite granulites', but it should be stressed that their grade of metamorphism is generally far below the level of the granulite facies of metamorphism. They are commonly mottled pink, grey, red, mauve, and green.

The calc-silicate rocks are composed of green monoclinic pyroxene, quartz, albite, epidote, calcite, sphene, and scapolite in various combinations. Biotite, muscovite, amphibole, apatite, ilmenite, plagioclase, tourmaline, magnetite, and chlorite, are accessory and secondary minerals, or are less common constituents. Microcline is not uncommon in places, and generally shows irregular outlines and sieve-structure. Some thick-bedded grey calc-silicate rocks are mottled with rounded white, greenish, or (where altered) red spots 3 to 5 mm. across, which according to Joplin (1955) are prophyroblasts of scapolite with marked sieve-structure.

Many of the calc-silicate rocks are stained brick red by fine hematite dust. Such rocks are generally much altered, and their bedding is usually obscured. They were described as 'red rocks' by Edwards and Baker (1954), who considered that the hematite was derived from the leaching and alteration of the mafic minerals. In the few thin sections made of 'red rock' sampled during 1956, however, the mafic minerals appear to be quite unaltered, and a different source of the hematite therefore seems possible. Most of the 'red rocks' are concentrated along the large fault-zone extending northwards from Mount Quamby, with which are also associated hydrothermal magnetite-hematite bodies.

The calc-silicate breccias (in the literature usually referred to as 'agglomerate', 'breccia-conglomerate', 'calc-silicate breccia', or simply 'breccia') consist of unsorted, non-directed, sub-angular fragments up to 10 inches across, or more. Smaller fragments are better rounded than the larger ones. The breccias do not appear to form continuous beds, but occur as lenses or in repeatedly interrupted zones. The various theories put forward to explain their origin have been summarized by Carter et al. (1961, pp.89,90), who conclude that the majority of them were formed by slumping and density-current action at or near the foot of a slope below wave-base; others may be reef breccias and fault breccias. In the Dugald River area the percentage of fault breccias among these rocks is probably fairly high: the breccias are commonly best developed along major fault zones. A cross-fault in the central-eastern part of the Knapdale Quartzite is lined by a breccia which resembles a calc-silicate breccia, but is more probably an altered quartzite breccia in view of its stratigraphical position; indeed it is a quartzite breccia in some places. Where the adjoining unaltered and unbroken quartzite is calcareous, the 'calc-silicate breccia' is also calcareous. Another point suggesting that many of the calc-silicate breccias may be due to faulting is the fact that they are not the only type of rock brecciated: pure quartzite breccias occur in places along the eastern edge of the Knapdale Quartzite, and limestone breccias are also found. Finally, some fragments in the calc-silicate breccias indicate brecciation after complete lithification, showing small clean-cut faults. Possibly the calc-silicate breccias originated as submarine rock slides, triggered off by faulting.

Of special economic importance are the b l a c k s l a t e s, the main zone of which, about 800 feet wide, is exposed over a length of five miles, east of the Knapdale Quartzite, and contains the Dugald River lead silver-zinc prospect. Another, thinner, band is present west of the Knapdale Quartzite, and continues, much broken up, southwards to the Dugald River. The slates are calcareous, though at the surface much of the carbonate has been leached out. They commonly lack a definite slaty cleavage, and are more truly carbonaceous shales or argillites. They contain a few zones of fine-grained dark graphitic schist, and in places grade into black carbonaceous, argillaceous limestone.

Micaceous s c h i s t s and q u a r t z i t e s are the main rock types in the extreme eastern parts ofthe outcrop area of the Corella Formation. The schists are mostly biotite (-muscovite)-quartz schists generally also containing plagioclase (including albite) and porphyroblasts of microcline and scapolite, commonly with pronounced sieve-structure. Chlorite and epidote are secondary products, and apatite, tourmaline, and ilmenite the common accessory minerals. Some schists contain hornblende porphyroblasts. In places, especially where they are intruded by granite, the schists grade into gneiss. Elsewhere along granite contacts they are more appropriately called foliated biotite hornfels. Some mica schists, between the Knapdale Quartzite and the Dugald River prospect, are more strongly schistose, and contain more muscovite, so that they are brighter and have a more silvery sheen.

The quartzites are dense, mostly fine-grained rocks (increasingly coarse-grained towards the east), which are in places lineated and foliated, and grade into quartz-rich calc-silicate rocks towards the west.

The a m p h i b o l i t e s appear as lenses intercalated in the calc-silicate rocks and micaceous schists and hornfelses in the eastern part of the area. They are fine-grained to coarse-grained rocks composed of plagioclase, green hornblende, some quartz and potash feldspar, albite, carbonate, secondary epidote, sericite, kaolin, and chlorite, and accessory apatite and altered biotite. A few of the amphibolites have a sub-ophitic texture, indicating an igneous origin. Most amphibolites are banded and lineated, and may be metamorphosed dolomitic sediments, as suggested by Edwards and Baker (1954), especially where they contain appreciable amounts of quartz. Walker, Joplin, Lovering and Green (1960) have studied the amphibolites of north-western Queensland in detail, and decided that, in the absence of relict structures, it is extremely difficult to distinguish between amphibolites of igneous and those of sedimentary origin. However, in the Dugald River area a sedimentary origin for most of the amphibolites would seem to be more likely in view of the regional distribution of sedimentary facies types, which suggests the presence of land to the east, where there is a predominance of quartzite. Pettijohn (1957, page 421) stated that '... it appears that dolomite is more commonly a near-shore facies, and limestone is the product of off-shore and deeper-water sedimentation'. To consider the amphibolites as metamorphosed dolomitic sediments satisfies not only the probable palageographic distribution of sedimentary environments, but also the textural, structural, and compositional fabric of the amphibolites, and their relationship to the other sediments of the Corella Formation, as demonstrated by Edwards and Baker (1954).

Finally, along Cabbage Tree Creek, near the western edge of the outcrop area, a quartzite or sandstone is exposed which may represent a different stratigraphic unit, younger than the Corella Formation. Sturmfels (1952) suggested that this rock might be of the same age as the Upper Proterozoic Quamby Conglomerate. Evidence, however, is slight, and in this report the sandstone has been included with the Corella Formation.

The rock is a white, coarsely cross-bedded sandstone with kaolinitic matrix. Its quartz grains are well-rounded and are in places fairly coarse. The sandstone dips at angles of less than 45° to the west, whereas the limestones to the east are tilted at more than 60°. The limestone adjoining the sandstone is massive, white to grey, and fine-grained, and contains a few pebbles of dark banded limestone of the kind normally occurring farther east. A possible unconformity between sandstone and limestone is suggested by the difference in their bedding dip values, as well as by a zone of ferruginous rubble separating the sandstone from the limestone; it cannot be proved, however, because of the scarcity of sandstone outcrops. Another possibility is that the sandstone is faulted against the limestone; evidence for faulting might be represented by the band of ferruginous rubble, and by the shearing and slickensided surfaces locally found in the sandstone.

It appears from the nature of the Corella Formation that its sediments were probably laid down in a fairly shallow, near-shore marine environment. Edwards and Baker (1954) convincingly demonstrated that the formation is built up of various shaly to sandy sediments that were calcareous and dolomitic to a greater or lesser degree, and which became recrystallized or metamorphosed to the complex of calc-silicate rocks, scapolite marbles and schists, limestone, amphibolite, and quartzite. The distribution of the sediment types - limestones in the west, impure calcareous sands, silts, and shales in the centre, and slightly calcareous and dolomitic sediments followed by fine and coarse sands in the east - seems to suggest that the Lower Proterozoic shore line was located not far beyond the eastern boundary of the Dugald River area.

Knapdale Quartzite (named by Carter et al., 1961, after the Parish of Knapdale).

The Knapdale Quartzite forms a low ridge or narrow plateau, 200 feet high, almost 9 miles long, and 1½ miles wide, which is the topographic backbone of the area. Lithologically the Knapdale Quartzite may be divided across its width into four zones, each with somewhat different characteristics. They will be described in order from east to west.

In the east, the sediments of the Corella Formation appear to grade rapidly into thick but well-bedded quartzites still containing interbeds of dense, fine-grained, calcareous quartzite or quartzitic calc-silicate rock, and a few thin beds of impure limestone. Grain-sizes are generally 1 mm. or less, but thin seams or lenses of fine conglomerate occur locally, and contain pebbles of quartz and weathered siltstone up to ½ inch across. Cross-bedding, ripple-marks, and mud-cracks are very common, and leave no doubt as to the right-way up position of the steeply westerly dipping beds. Both current ripples and wave ripples are represented.

The central zone of the ridge is occupied by massive white non-calcareous quartzites with indistinct bedding and very few bedding structures. The matrix is kaolinitic. Recrystallization or silicification is pronounced, and shearing and brecciation are common.

This spinal zone is followed to the west by a zone, 1000 feet to 1500 feet wide, of quartzites with intercalated micaceous quartz schist or siltstone.

The most westerly zone is composed of bedded pink quartzites with some ripple-marks (generally wave ripples), cross-bedding, and slump structures.

All quartzites dip steeply west, generally between 60° and 80°, and are right-way up apparently over the whole width of the ridge.

The relationship of the Knapdale Quartzite to the all-surrounding Corella sediments is an unsolved problem. A previously held theory that the quartzite ridge is an overturned anticline plunging north and south is obviously untenable because of the constant westerly facings of the beds across the whole ridge, and because the quartzites are seen to overlie the Corella Formation in the east. An overturned syncline is also out of the question for much the same reason.

There remains the possibilities that either the quartzites form a huge sandy wedge within the Corella Formation, or that they are younger than that formation and are preserved in a fault block. That the eastern part of the quartzites overlies the Corella Formation can hardly be doubted. The northern and southern ends of the Knapdale Quartzite, however, terminate most abruptly against the Corella sediments, and, at least in the south, the junction area is very much broken up and shattered by numerous faults and shears. The same probably also applies to the northern termination, but lack of outcrops there masks the faulted nature of the boundary. The western edge of the Knapdale quartzite range is probably also faulted: though evidence is scarce (a common feature of strike faults), the presence of some mineralization, silicification, and quartz veining along the western base of the ridge possibly indicates the reality of this faulting.

The Knapdale Quartzite is therefore younger than at least part of the Corella Formation, is possibly incorporated within that formation, but is separated from it by faults on at least three sides.

Current-bedding directions indicate an easterly provenance for the Knapdale Quartzite.

Quamby Conglomerate (first named 'Quamby Conglomerates' by Ball in 1921, after Mount Quamby, a hill 250 feet high, 6 miles south-west of Naraku siding. Later known as 'Mount Quamby Series' in AGGSNA half-yearly reports. Carter in 1961 retained the original name but used the singular form).

The Quamby Conglomerate, occupying roughly 2 square miles in a narrow north-south graben, consists of coarse conglomerate with intercalated finer pebbly beds. At the base of Mount Quamby the fragments are angular, and comprise mostly black carbonaceous slate and calc-silicate rock clearly derived from the Corella Formation. Higher up in the succession the pebbles and boulders are well-rounded and water-worn, and consist mainly of vein-quartz, sandstone, and quartzite, embedded in a sandy to silty matrix which is quite rich in feldspar, and also contains grains of hematite. Carter et al. (1961) also mention the occurrence of red jasper and rare pebbles of rhyolite in the conglomerate. The pebbles and boulders are most commonly between 2 inches and 3 inches across, and are rarely larger than 6 inches, although in the northern outcrops some boulders attain a diameter of up to 3 feet. Economically the conglomerate is of some interest because of its gold content.

The beds are gently folded, and dips do not exceed 40°, so that there is a marked unconformity with the underlying, steeply dipping calc-silicate rocks of the Corella Formation (Fig. 2). The age of the conglomerate is doubtful. As pointed out by Carter (Carter et al., 1961), the inclusion of fragments of metamorphic rocks in an unmetamorphosed matrix indicates that the conglomerate is much younger than the fragments, which are derived from the Lower Proterozoic Corella Formation; the Quamby Conglomerate is therefore tentatively placed in the Upper Proterozoic.

On the western side of the Quamby Conglomerate are steeply tilted quartzites which were included by Carter et al. (1961) in the Quamby Conglomerate. However, they are associated with calc-silicate rock and some limestone, and their dips are much steeper than those shown by the Quamby Conglomerate proper. They have, therefore, in this report, been included in the Corella Formation (Plate 1.) It is possible that they may be correlated with the Knapdale Quartzite, which they resemble very much.

Naraku Granite (name introduced by Carter in 1961, after Naraku railway siding), and other igneous rocks.

The Naraku Granite, which, in the Dugald River area, crops out along the railway line in the east, has been described by Joplin (1955) as a fine-grained massive or slightly foliated biotite adamellite in which the proportions of plagioclase, potash feldspar, and quartz vary in different parts of the batholith. Plagioclase (30 to 45 per cent) is generally much more abundant than microcline (15 to 30 per cent), quartz forms 30 to 40 per cent, biotite 4 to 6 per cent, and accessory minerals less than 1 per cent. The mapping done in 1956 furthermore disclosed hornblende-rich varieties of Naraku Granite in the Dugald River area, and many aplitic and micrographic, pegmatitic granite dykes. The grain-size of the granite tends to increase towards the east, away from the contact.

The granite intrudes the sediments of the Corella Formation irregularly, leaving many rafts and roof-pendants of biotite schist and hornfels, amphibolite, and quartzite. Pegmatitic and granitic dykes and sills are abundant in the central part of the area. The boundary between granite and intruded rock is commonly not sharp, but transitional, the sediments being granitized. In other places the contact is sharp, but increased mobility of the invaded rock is demonstrated by its plastic folding. Contamination and assimilation, probably of amphibolite or calc-silicate rock, appear to have produced the more basic and hornblende-rich varieties of the Naraku Granite.

It is to be noted that the granite is restricted to the region east of the great quartz-filled fault that forms part of the Mount Quamby graben system.

An outcrop of a red quartz-feldspar porphyry is located on the western side of the great quartz-filled fault mentioned above. The rock contains phenocrysts of quartz and pink feldspar in an aphanitic red groundmass.

A few outcrops of meta-dolerite of unknown age are scattered over the area, for example, south of the Knapdale quartzite ridge. Their sub-ophitic texture is still recognizable, and distinguishes them from the banded and lineated amphibolites which are probably of sedimentary origin.

Metamorphism and metasomatism.

The originally more or less calcareous sediments of the Corella Formation were converted by regional metamorphism to calc-silicate rocks, marbles, schists, amphibolite, and quartzite. The most interesting feature is the widespread scapolitization, which Edwards and Baker (1954) have shown to be the result of a soda-chlorine metasomatism of the finely interbedded calcareous, less calcareous, and non-calcareous beds. Scapolite, albite, and sphene were thereby formed. Potash may also have been introduced, as many of the sediments contain a fair number of irregularly-shaped microcline porphyroblasts with sieve-structure.

Scapolite, which here is a soda-rich variety (about $Ma_{70}Me_{30}$), was formed in the calcareous beds, albite in the non-calcareous beds, and there is an association of both minerals in transitional sediments. According to Edwards and Baker, pyroxene tends to be associated with the scapolite-rich rocks, biotite with the non-calcareous members, and hornblende occurs mainly in the transitional rocks; this distribution was considered to be a result of differences in chemical composition rather than of different degrees of metamorphism. A study of thin sections made in 1956 does not fully support this conclusion, as many pyroxene-rich calc-silicate rocks appeared to lack scapolite.

The grade of metamorphism decreases from east to west. This may be the result partly of the large amount of graphitic or carbonaceous impurities in the western limestones and slates (cf. Harker, 1950, page 224) but is more probably due mainly to increasing distance from the axis of metamorphism and granitization. Thewestern rocks fall in the greenschist facies of metamorphism, whereas the eastern rocks belong to the amphibolite facies. The metamorphism is probably regional rather than thermal (co-existence of calcite and quartz), though foliated biotite hornfels locally appears to indicate thermal effects along the granite margin.

The metamorphic rocks of the Corella Formation and other Precambrian units in north-western Queensland have been described by Joplin (1955) and by Walker (in Carter et al., 1961).

Mesozoic.

Remnants of horizontal deposits of Mesozoic age occur as low flat-topped mesas in the western part of the area. They consist of shallow-water sediments, mainly conglomerate, grit, sandstone, pebbly sandstone, and ferruginous shale. In places the base is a ferruginous, silicified pebbly sandstone grading upwards into kaolinitic quartz sandstone and mudstone.

Below the Mesozoic capping, the calcareous sediments of the Corella Formation are leached of most of their carbonate content, and are deeply weathered to micaceous sandy or earthy rocks.

The age of the Mesozoic in the Dugald River area is uncertain. The Geological Map of Queensland (1953) includes the outcrops in the Lower Cretaceous Tambo Formation. Plant fossils from south of Cloncurry are reported to indicate a Triassic to Jurassic age for the Mesozoic there, whereas in other places, also south of Cloncurry, a Jurassic to Lower Cretaceous age was determined (see Carter et al., 1961, p. 126).

A small, 20-foot thick, cap of possibly Mesozoic conglomerate and inter-bedded mudstone, siltstone, and pebbly sandstone covers the top of Mount Quamby. A difference with the underlying Proterozoic conglomerates is that the latter are commonly jointed, fractured, and in places somewhat sheared, whereas the (?) Mesozoic conglomerate is unaffected.

STRUCTURE

The Corella Formation and Knapdale Quartzite are steeply folded, their beds dipping at angles generally between 60° and 90°, mostly to the west. The regional strike is north-south. Shearing is nearly everywhere evident to a greater or lesser degree, as may be expected in tightly folded beds, especially in the vicinity of the axial planes. Somewhat more open and larger-scale folds can be recognised by mapping and by air-photo interpretation, e.g., at the Godkin shafts, and in the limestone country along the Dugald River south of the Lady Clayre workings. At the Godkin shafts the black slates appear to be folded-out in tight synclines with northerly plunges.

To the east of the great quartz-filled fault that forms part of the Mount Quamby graben fault system, two large-scale and steeply plunging folds can be recognized in the calc-silicate rocks and schists.

Folding is less intense in the Quamby Conglomerate, where dips do not exceed 40°, and are generally much lower. The synclinal structure of the conglomerates is almost certainly due to drag effects along the down-faulted narrow Quamby rift block (Fig. 2).

Faulting, most commonly strike-faulting, is very common in the Dugald River area, and several large meridional faults have been mapped, and can be easily traced on the surface. One of the results of faulting was the formation of the narrow Mount Quamby rift valley or graben; this structure tapers out northwards into a spectacular large fault, represented at the surface by a series of huge quartz veins that stand out above the surrounding flat country as high, vertical, narrow hogback ridges. Farther north the fault feathers out into several quartz-filled branches.

The Quamby Conglomerate does not seem to contain granite pebbles, and the faulting may, therefore, have been pre-granite. However, the pebbles of Corella sediments being metamorphosed rocks, and metamorphism and intrusion of granite presumably being associated in time, the faulting is believed to be post-granitic, and to have taken place at a time when the granite was not yet exposed. Movement along the great quartz-filled fault which crosses the map area from south to north was probably east-block up, in view of the restriction of the (presumably deep-seated) granite to the area east of the fault.

Another large fault probably runs along the western margin of the Knapdale Quartzite, but is only slightly expressed in the field by some silification, mineralization, and slight brecciation. Judging from fracture-cleavage orientations, the direction of movement of the Knapdale Quartzite block must have been upwards and to the north, relative to the Corella sediments in the west.

As discussed on page 7, the Knapdale Quartzite represents a fault-block of quartzites that are either incorporated within the Corella Formation, or are younger than the latter, and the concept of an over-turned anticline or syncline must, therefore, be rejected. Yet, when taking notice of the repeated but mirrored sequence of Corella sediments on either side of the Knapdale range, one must seriously consider the possibility of a major overturned fold structure within the Corella Formation, for the quartzite range is flanked on either side, first by a zone of calc-silicate rocks, then, farther out, by a narrow succession of mica schist and black slate, and finally by black, carbonaceous limestone. This symmetrical disposition relative to the Knapdale Quartzite suggests, at least for the Corella sediments, the presence of a large fold. The two calc-silicate rock- mica schist- black slate- and limestone zones have similar lithology; both black slate bands carry some lead mineralization (though admittedly very little in the western band); and the slate furthermore appears to curve around the northern end of the Knapdale range, where a slate outcrop shows east-west cleavage. There is the difficulty that the limestones occupy a much larger area in the west than in the east. This might be explained by one or more of the following possibilities: 1. the eastern limestones are largely cut off by a north-south fault of hitherto unrecognized magnitude; 2. the eastern limestones were more impure than the western, and were converted to calc-silicate rocks by the higher degree of metamorphism; 3. the western limestones were thickened by structural repetition or by lateral stratigraphical thickening. On the other hand, however, the apparent disappearance of the eastern black slates towards the south through the effect of folds with northerly plunges militates against the concept of a major overturned syncline (with the Knapdale Quartzite as a faulted block in the axial region).

Hence, notwithstanding the superficial though attractive evidence for a large fold structure, the difficulties encountered in the reconstruction of such a fold seem to leave only one other alternative: that is, to regard the repetition of certain rock-types as simply reflecting a recurrence of certain depositional environments.

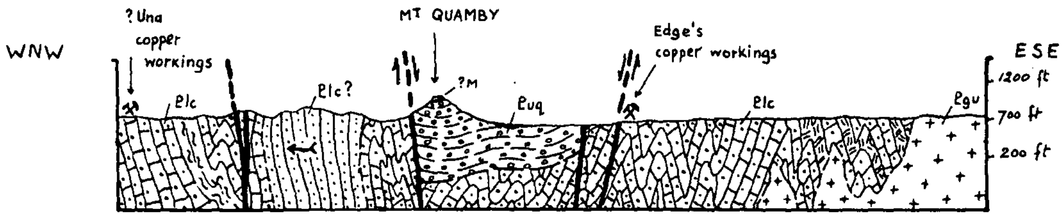


FIGURE 2 - *Diagrammatic cross-section, Mount Quamby area.*

Horizontal scale:

0 — 1 MILE

Vertical exaggeration = 2× (approximately)

F54/A2/3

MINERALIZATION

Although mineralization is widespread in the Dugald River area, the known deposits are small and scattered, good gossans are rare, and the existence of large, payable ore-bodies has yet to be proved. Copper, lead-silver-zinc, gold, and cobalt mineralization is known to be present, and some mining of copper ore was done in the past, especially during the peak period of the first World War.

The main interest was shown in the Dugald River Lead-silver-zinc prospect, which has been geologically mapped and tested by drilling and geophysical methods (Honman, 1937; Rayner and Nye, 1937; Ball, 1937, 1939; Knight, 1953). The mineralization is confined to a belt of black carbonaceous, calcareous shales or slates on the eastern side of the Knapdale Quartzite range, which are sheared and contorted, and apparently bounded by faults. A strong lithological control is indicated. The mineralization extends for more than a mile along the strike of the slates, but the main shoot is about 700 feet long and 40 feet wide at the surface. The oxidized zone extends to a depth of less than 125 feet, and contains cerussite, massicot, and a little minium, which impregnate the broken and sheared slates. Surface sampling in 1937 showed average assay results of 4.95 percent lead and 3.6 oz. of silver per ton over the richest part of the lode. In the primary zone the lead and silver values deteriorate, and the proportion of zinc (as sphalerite) increases. Drilling by Enterprise Exploration Co. Pty Ltd indicated some 1,280,000 tons of ore containing 1.6 percent lead, 11.6 percent zinc, and 1.2 oz. of silver per ton, to a depth of 500 feet in the main shoot. The deepest hole drilled intersected the main shoot at a depth of 800 feet. The primary ore-minerals are pyrite, arsenopyrite, sphalerite (variety marmetite,) galena, tetrahedrite, pyrrhotite, and a few specks of pyrargyrite (Stillwell and Edwards, 1947).

During the geochemical testing carried out by A. Debnam in 1956, 181 samples were collected, of which 90 were taken from the eastern zone of black slates. The samples were collected at 200-foot intervals along traverse lines extending 6000 feet north and 4000 feet south from the prospecting shafts. The results suggested that no significant lead mineralization can be expected apart from that already known at the site of the prospect, where values up to 35,000 ppm. were obtained from gossan samples. Samples taken 50 feet east and west of theprospect gave values of less than 50 ppm.

The remaining 91 samples were taken from the black slates west and south of the Knapdale Quartzite range. The general background was less than 25 ppm., and in only one place rose to 500 ppm. A little galena was found in small trenches north-west of the Knapdale quartzite range.

Copper deposits are widely scattered, and have been tested by a large number of shallow shafts and trenches. Mineralization occurs throughout the Corella Formation, though it is concentrated along the Quamby fault system (sensu lato) and in shatter-zones south of the Knapdale quartzite range. The total output of ore from the area, distributed over about 20 mines and prospects, was about 7,500 tons, of which 6,784 tons, or roughly 90 percent, was from the Magnet Mine along. Table 1 shows the output figures as given by Nye and Rayner (1940), with that of the Magnet Mine modified after Carter et al. (1961). The average copper content was usually between 10 and 20 percent.

Table 1.

Production of Copper ore, Dugald River Area

Magnet	6,784 tons of copper ore	
Dugald	117	(a number of scattered small workings)
Tin Lizzie	80	
Godkin	?	
Little Eva	53	
Cabbage Tree	14	
Lady Clayre	21	
Una	223)	(These three mines, west and north of Mount Quamby, were not located with certainty in 1956).
Eureka	46)	
Moonlight	11)	
Red Indian	?	
Mavis	25)	(The Mavis and the Gem are between the Magnet mine and Naraku siding, but were not located in 1956)
Gem	5)	
Gidgy Park	7	
Longamundi	2	
Two Sports	15	
Bradford	?	
	7,465 tons	

It appears that the copper mineralization is mainly, if not exclusively, controlled by faulting and shearing, which is expressed at the surface by silicified, gossanous, or quartz-veined shear-zones, breccias, and altered sediments. Lithology has little influence; it seems, however, that limestones do not contain workable ore deposits, notwithstanding their very common and widespread copper staining.

The ore minerals are malachite and azurite, copper silicates, chalcocite, cuprite, chalcopyrite, and bornite. Gangue minerals include calcite and other carbonates, quartz, biotite, tremolite-actinolite, kaolin, and hematite. A little molybdenite is found in some of the shafts near the granite, as in the Magnet and the Red Indian. Erythrite and asbolite (an earthy, cobaltiferous manganese oxide) are associated with the copper ore in the Godkin and Coocerina copper zones, and ore from the Tin Lizzie is locally reported to contain some nickel. Samples of chalcopyrite picked up from the dumps occasionally show successive phases of replacement, first by a black submetallic oxide (chalcocite?), then by cuprite, and finally by malachite.

The Magnet mine is about 3 miles west-north-west of Naraku railway siding. Mineralization occurs along an east-west shear-zone dipping steeply to the north, in a roof-pendant of biotite and muscovite schist near the margin of the Naraku Granite. The secondary ore consists of copper carbonates and chalcocite in a quartz gangue, whereas the primary ore, which appears at a depth of 230 feet, consists of pyrite and chalcopyrite with a little molybdenite. The lode is 500 feet long and up to 15 feet wide, but rich ore was restricted to small lenticular shoots 5 foot wide at the most (Carter et al., 1961, page 217).

G o l d was first discovered in 1908 in the gullies down Mount Quamby. It was traced upwards to the crest of the conglomerate ridge, where the best gold values were discovered. However, the grades were low, even at the slightly enriched surface (Ball, 1921). The output of gold up to 1921 was officially given as 318 oz., but private estimates by prospectors went much higher.

The gold occurs as minute flakes in the matrix of the conglomerate. Its mode of deposition seems uncertain. According to Carter et al. (1961, pp. 124,234) the gold may be of hydrothermal origin because of its association with hematite and its occurrence at all levels in the succession. However, as the hematite is present in distinct grains and hence may be detrital, the first argument is not convincing; nor is the distribution of gold throughout the succession a strong indication for a hydrothermal origin. Enrichment at thesurface could be the result of the mineral being re-concentrated during the (pre-) Mesozoic period of peneplanation. The source of the gold may perhaps be sought in the copper ore bodies in the surrounding area, which are reported to have a rather high gold-copper ratio (Nye and Rayner, 1940).

C o b a l t is present as erythrite and asbolite in the Godkin and Coocerina copper workings, but was never mined for itself. It was first noticed in 1923 in the old Godkin shafts which had been worked for copper about 30 years previously, and it was subsequently traced north and south of the shafts for a total distance of 2½ miles.

In the Coocerina mineralized zone, along the south-western margin of the Knapdale Quartzite, dark brown cobaltiferous sandstone can be traced for several miles north and south of the main shaft; and 2 miles south of the Coocerina shafts a little erythrite was found in some small copper workings (Rayner, 1938).

I r o n mineralization is common along the eastern margin of the Mount Quamby rift block. It occurs in the form of small hematite - magnetite - quartz bodies apparently of hydrothermal origin, and controlled by faulting and shearing. Grades are unknown, but the bodies are, in any case, too small to be considered for economic exploitation.

REFERENCES

BALL, L.C., 1921 - Gold at Mount Quamby, North Queensland. Qld Govt Min.J.,22, 8-10.

BALL, L.C., 1922 - Mount Quamby. Geol.Surv.Qld (unpubl.rep.)

BALL, L.C., 1937 - Dugald River silver-lead freeholds. Ibid.

BALL, L.C., 1939 - Dugald River borehole No.1 cores. Ibid.

BALL, L.C., 1939 - Dugald River borehold No.2 cores. Ibid.

CARTER,E.K., BROOKS, J.H., and WALKER, K.R., 1961 - The Precambrian mineral belt of north-western Queensland. Bur.Min.Resour.Aust.Bull. 51, pp.85,94,123,148,217,226.

EDWARDS,A.B., & BAKER,G., 1954 - Scapolitization in the Cloncurry district of north-western Queensland. J.geol.Soc.Aust., 1,1-33.

HARKER, A., 1950 - Metamorphism. Methuen, London.

HONMAN, C.S., 1937 - The Dugald River silver-lead lodes, Cloncurry district. Aer.Surv.N.Aust., Qld Rep. 8

JACK, R.L., 1898 - Report on the geological features of part of the district to be traversed by the proposed trans-continental railway. Publ.geol.Surv.Qld,136.

JOPLIN, G.A., 1955 - A preliminary account of the petrology of the Cloncurry Mineral Field. Proc.Roy.Soc.Qld,66(4), 33-67.

KNIGHT, C.L., and ZACHENKO,V., 1948 - Dugald River Prospect. Enterprise Exploration Co. Pty Ltd (unpubl.rep.)

KNIGHT, C.L., 1953 - The Dugald River Prospect. Ibid.

NYE, P.B., and RAYNER, E.O., 1940 - The Cloncurry copper deposits, with special reference to the gold-copper ratios of the ores. Aer.Surv.N.Aust., Qld Rep. 35.

PETTIJOHN, F.J., 1957 - Sedimentary rocks. Harper & Brothers, New York.

RAYNER, E.O., 1938 - Cobalt deposits of the Cloncurry district. Aer.Surv.N.Aust.,Qld Rep.34

RAYNER, J.M., and NYE, P.B., 1937 - Geophysical report on the Dugald River silver-lead lodes, Cloncurry district. Ibid., 7

STILLWELL, F.L., and EDWARDS, A.B., 1947 - Zinc-lead ore from Dugald River, North Queensland. Sci.ind.Res.Org.Aust., mineragr.Inv.Rep. 375.

STURMFELS, E.K., 1952 - Geology of the surroundings of the Dugald River lead-zinc prospect. Preliminary report. Enterprise Exploration Co. Pty Ltd. (unpubl. rep.)

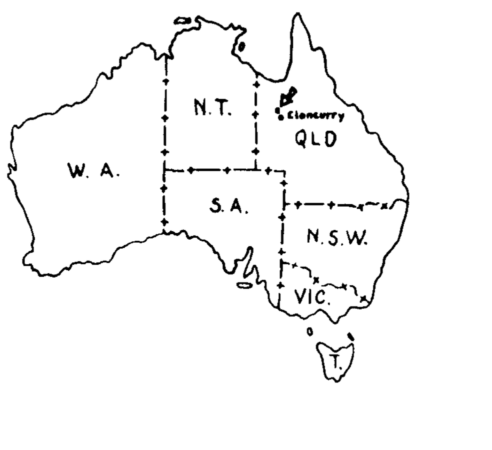
WALKER, K.R., JOPLIN, G.A., LOVERING, J.F., and GREEN, R., 1960 - Metamorphic and metasomatic convergence of basic igneous rocks and lime-magnesia sediments of the Precambrian of North-western Queensland. J.geol.Soc.Aust., 6 (2), 149-177.

GEOLOGICAL MAP
SURROUNDINGS DUGALD RIVER PROSPECT, QUEENSLAND

APPROX. SCALE: 1½ INCHES TO 1 MILE

0 1 2 3 4 5 MILES

Compiled by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Aerial photography by the Royal Australian Air Force. Complete vertical coverage at 1:50,000 scale.



REFERENCE

MESOZOIC		M	Sandstone, conglomerate
UPPER PROTEROZOIC	Naraku Granite	Egu	Biotite granite and adamellite; hornblende adamellite in places
	Quamby Conglomerate	Euq	Conglomerate
LOWER PROTEROZOIC	Knapdale Quartzite	Elk	Quartzite; some intercalations of conglomerate, calc-silicate rock, and limestone
	Corella Formation	Elc	Quartzite
			Limestone (generally darkgrey or black, pyritiferous), silicified limestone, black siliceous slate
			Black slate
			Calc-silicate rock, commonly scapolite-bearing, and including quartz-feldspar granulite
			Calc-silicate breccia
			Biotite schist, biotite hornfels
			Amphibolite, dolerite

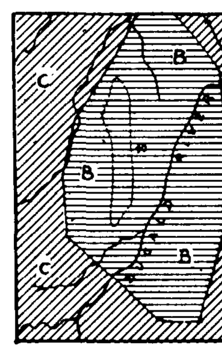
- Trend of bedding
- Strike and dip of bedding
- Vertical beds
- Overturned beds
- Generalized strike and dip of deformed strata
- Plunge of folds
- Strike and dip of metamorphic foliation
- Top of bed
- Jointing
- Fault; where broken, position is approximate; where questioned, fault is inferred
- Breccia
- Quartz vein
- Mine, prospect, group of workings
- Minor mineral occurrence
- Railway
- Main (dirt) road
- Vehicle track, impass
- Fence
- Water bore

Co = Cobalt
Cu = Copper
Fe = Iron (magnetite, hematite)
Pb = Lead
Zn = Zinc

Geology, 1956, by: F. de Keyser, D.O. Zimmerman, W.C. White (B.M.R.); J. Neale (Mt Isa Mines Ltd).

Compiled & drawn, Sept. 1964, by: F. de Keyser.

GEOLOGICAL RELIABILITY DIAGRAM



B - Detailed reconnaissance — numerous cross-traverses and air-photo interpretation

C - Sketchy — air-photo interpretation only, some old notes.

Bureau of Mineral Resources, Geology and Geophysics. To accompany Record 1965/81

F54/A2/1