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CONSTANCE RANGE IRON DEPOSITS, NORTH-WESTERN QUEENSLAND

by

E. K. Carter and D. O. Zimmerman

PART 1 of 3

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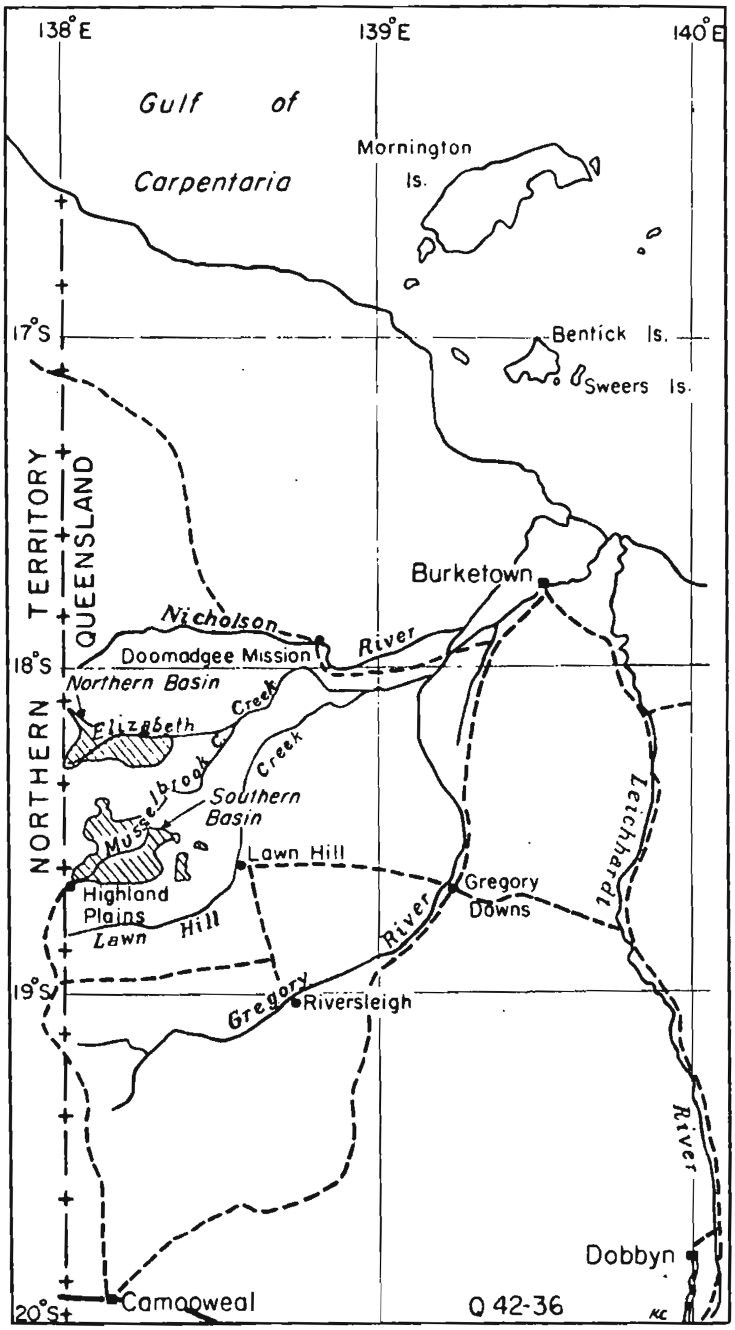
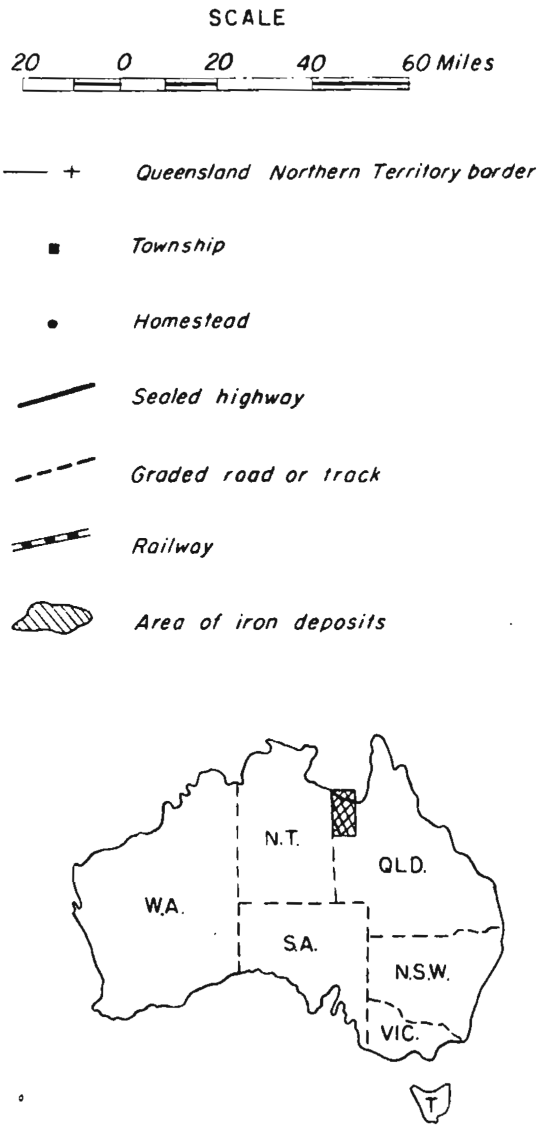
The survey on which this report is based was done jointly by the Bureau and the Geological Survey of Queensland from April to October 1958. Those taking part were: E.K. Carter, D.O. Zimmerman, M.A. Randal, of the Bureau of Mineral Resources, and C.H. Shipway of the Geological Survey of Queensland. Plates 13-28 are copies of field sheets only.

PLATES

LOCALITY MAP
CONSTANCE RANGE IRON DEPOSITS





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SUMMARY

Sedimentary iron-rich, generally oolitic, beds of Upper Proterozoic age crop out over, or underlie, about 250 square miles in the Constance Range area of north-western Queensland. The iron-rich strata are part of the Train Range Iron-bearing Member of the Mullera Formation. They occur in two structural basins, at a maximum depth of probably about 6,000 feet. Although steep dips occur near faults, generally the beds dip at less than 30°. The region is extensively faulted, particularly in anticlinal zones; the rocks have not been metamorphosed.

The important iron-rich beds all occur within a single stratigraphic section from less than 10 to nearly 300 feet thick. Within the section are from one to six iron 'zones', separated from each other by at least 20 feet of sandstone, siltstone and shale. Probably at no point does more than one zone contain iron ore of commercial grade and tonnage, but the highest grade material occurs in different zones and beds in different parts of the region.

Iron minerals recognised are hematite, siderite, chamosite and pyrite. The pyrite is mainly epigenetic and occurs in thin stringers; it does not occur in sufficient quantity to raise the sulphur content of the iron beds unduly. Magnetite has not been recorded. Primary iron ore consists of hematite and siderite, with greater or lesser proportions of sand, silt and clay size sediment, and chamosite. The highest grade material is entirely free of detrital material and was apparently formed by chemical precipitation. Hematite mainly appears in oolites, commonly with sand grain nuclei, but also forms part or all the matrix in places. It occurs in two forms, as red ochreous hematite and as blue-black crystalline hematite. Siderite is the main

cementing material but also forms oolites. Oolites are generally composed of concentric shells of iron minerals or silica. Successive shells may be of different minerals.

In the weathered zone, from 40 to 100 feet thick, the iron minerals are generally oxidized to limonite or goethite, but hematite is commonly unaltered. Silica, of supergene origin, forms a large part of the cement. As a result, material exposed or near-surface generally contains more silica than does the unweathered rock.

Extensive drilling by the Broken Hill Proprietary Co. Ltd. indicates that the most extensive and thickest beds of ironstone, with a high iron and low silica content, occur in Deposit A, in the Southern Basin; they are up to 36 feet thick in Deposit A, but in most deposits rarely exceed 15 feet. Iron content ranges up to 60% Fe but probably only a very small proportion of the iron-rich strata contain enough iron, together with a low silica content, to constitute potential ore at present. The sulphur, phosphorus, titanium and manganese content, and that of other deleterious impurities, is well within acceptable limits. No estimate is available of the possible tonnages of ironstone of various grades and purity in the region.

The iron-beds were formed in an extremely shallow, possibly marine, basin. They are similar to the Wabana iron ore deposits of Newfoundland and have many points of resemblance to the Clinton iron ore of eastern U.S.A.

INTRODUCTION

LOCATION

The Constance Range iron deposits are found in two basins in north-western Queensland, over an area of about 250 square miles, south of the Nicholson River. They are from 5 to 31 miles from the Northern Territory border, 90 to 120 miles north of Camooweal and 85 to 115 miles south-west of Burketown. The nearest outcropping iron is 85 miles from the Gulf of Carpentaria (see Figure 1).

ACCESS

External

The main access route is from Camooweal, on the Barkly Highway, north by graded vehicle track to Gallipoli Homestead, thence to Highland Plains Homestead, near the south-west corner of the deposits. A rough vehicle track continues from Highland Plains to the centre of operations on Stockyard Creek. Total distance by road from Camooweal to the base camp is 124 miles.

Rough tracks also link the base camp with Lawn Hill and Bowthorn Homesteads. These are suitable only for 4-wheel drive or heavy-duty vehicles. All roads and tracks are impassable after heavy rain.

An unsurfaced airfield, suitable for use by light aircraft, has been built near Stockyard Creek, one mile west-north-west of the base camp.

Internal

More than 100 miles of tracks have been constructed to provide access to the various deposits. These tracks deteriorate very rapidly if used by heavy vehicles. Tracks over the Constance Sandstone are generally rough and stony, and those over the Mullera Formation dusty and rutted after use.

TOPOGRAPHY

The area occupied by the Constance Sandstone and the Mullera Formation forms a distinct morphological unit. It is bounded on the east by the Constance Range scarp - a precipitous, almost unbroken, line of cliff which in places is over 300 feet high and which presents a formidable barrier (Pl. 4, Fig. 2).

Below it there is generally a scree slope, up to 200 ft. high, leading down to open plains through which some rough hills of Lawn Hill Formation project. The cliff line is lower in the north of the area than in the south, and is broken by the main water courses of the area - Lawn Hill, Musselbrook, Elizabeth, and Accident Creeks - which drain east and north-east.

A less-persistent scarp line, marking the faulted edge of Little's Range, bounds the area to the south. South of this is a shallow valley, containing mainly Middle Cambrian siltstone, limestone and chert, and the Colless Volcanics. The valley's southern side is formed by highly dissected Camooweal Dolomite.

Within the Constance Range area a large variety of land forms is found, controlled by lithology, attitude of beds, and faulting. The area is being actively eroded.

The Constance Sandstone is almost everywhere exposed in rough, elevated, dissected, plateau-like surfaces. Deep, steep-sided, linear valleys and scarps have formed by erosion along numerous joints and faults. Where the pre-existing (?Early Tertiary) land surface is preserved, with some soil or Mesozoic rubble cover, dissection is generally slight.

The Tidna Sandstone and Middle Creek Sandstone Member (see below) also produce very rough terrain, but, as joints are not well developed and the successions are generally thin, dissection is generally not as pronounced as in the Constance Sandstone and strike ridges are more important.

The siltstones of the Mullera Formation produce sparsely-vegetated rounded to angular hills and valleys, depending on degree of dissection, with relief of 100-300 feet (Pl. 1, Fig. 2). The major streams have alluviated valleys. Subsidiary erosion gullies form a rudimentary dendritic drainage pattern. Although the minor valleys and gullies commonly have steep sides and steeply-graded floors the siltstone areas can be traversed by 4-wheel-drive vehicle, in all but the most strongly dissected parts, by driving along the spurs and ridges. Outcrop is poor, being generally confined to the beds of the small gullies and the watercourses, but the hills are almost everywhere covered by rock rubble. Cliffs with fresh rock exposures, in places more than 100 feet high, are common along watercourses (Pl. 3, Fig. 2).

Strike ridges, with abrupt scarps and scree slopes on one side and dip slopes on the other (hog backs), are the commonest topographic form in the Train Range Iron-bearing Member (Pls. 1, 2, 7 and 8). Relief may exceed 200 feet, as in parts of Deposit I. Deposits H and N form high, almost flat-topped, mesa-like hills, centrally situated in shallow topographic and structural basins; the top of Deposit N is about 600 feet above the floor of Horse Pocket, in which it occurs (Pls. 2 and 7).

The flat-lying Mesozoic sediments form numerous mesas and flat sheets, generally with sharp breakaways, up to 100 feet high, and steep-sided re-entrants (Pl. 3, Fig. 1).

VEGETATION

Large trees are restricted to the water courses, where large ti-trees (paper barks), eucalypts and rare pandanus palms, flank permanent and semi-permanent water. On the alluvial flats river gums, bloodwood, ironwood, bauhinia and other medium-sized trees provide tropical, open-forest, cover. Smaller water courses may be lined by yellow-wood and similar scraggly trees. Low ground may be covered by dense stands of scrub ti-tree, various acacias and silver leaf box. The river flats are well-grassed.

The rocky areas of outcropping sandstone, with scanty soil, grow snappy gum, other scrubby bushes and schrubs, and spinifex. Many gullies have dense scrub growth.

The rubble-covered hills with underlying Mullera siltstone support practically no trees, apart from some snappy gums. Spinifix is the dominant plant, and some patches of light scrub occur.

Breakaways flanking the Mesozoic cappings are commonly covered by dense stands of lancewood.

WATER SUPPLY

Some very large permanent waterholes occur along the major watercourses, notably Musselbrook Creek. The largest occur where the streams cut through resistant strata such as sandstone or the iron-bearing beds. For this reason some of the large waterholes are not readily accessible. Many permanent rockholes lie at the base of scarps of Constance Sandstone. In addition, after rain, and for several months after the Wet Season, springs emerge from very many points along these scarps. Some appear to be permanent. Water also flows from some drill holes in Deposit I. Most of the larger, and many minor watercourses have water-holes along their length which persist for a few weeks or months after substantial rain.

CLIMATE

The climate is the tropical continental type; it is healthy, but warm. Rain falls mainly in the months December to April, usually in heavy storms. The average annual rainfall is 20-25 inches, of which no more than 3 or 4 inches normally falls between May and November.

During summer, the average daily temperature is probably at least 95°F. maximum and 80°F. minimum, with moderate to high humidity. The winter daily average is probably about 80°F. maximum and minimum 55°-60°F. Frosts are almost unknown and humidity is low.

HISTORY

The iron-bearing strata were first recorded by geologists of the Bureau of Mineral Resources and the Geological Survey of Queensland in 1950, and were mapped in reconnaissance in 1954, in the course of regional geological mapping of the Precambrian of north-western Queensland. In December, 1954, the attention of geologists of Broken Hill Proprietary Co. Ltd. was drawn to the presence of the iron-rich sediments, and a photo-geological map showing the distribution of beds was provided in May, 1956.

Mr. G. Cochrane, of B.H.P. Co. Ltd., examined the deposits, and took samples, in August 1956. As a result of the assays obtained a large-scale drilling programme was initiated by the company in 1957 to establish the possible grade and tonnage of ore suitable for open cut mining. Several holes intersected primary ore, which was shown to contain a high proportion of siderite - iron carbonate. This material seems more likely to provide a grade of ore, suitable for shipping without beneficiation than that at the surface. Accordingly, deeper drilling was undertaken in 1958 to test the iron-bearing beds below the weathered zone. To the end of 1958, some 27,000 feet had been drilled.

REGIONAL GEOLOGY

SETTING

The iron-rich beds are part of the Mullera Formation, one of several Upper Proterozoic formations in the region. Table I presents the stratigraphic column and a brief description of the units in N.W. Queensland. The relationships of the units are shown in Figure 2.

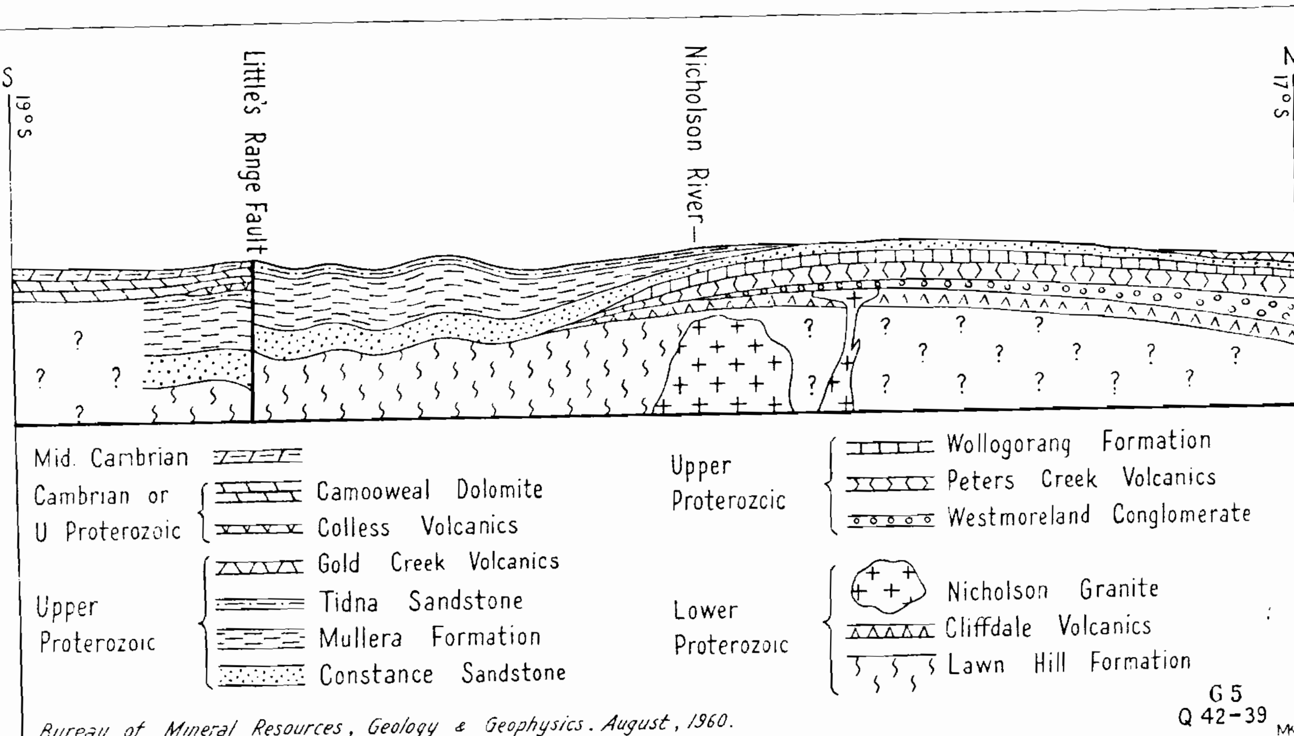

Fig. 2: **Schematic reconstructed cross-section of Lawn Hill and Westmoreland 4-mile Sheets, through Constance Range area, showing relationships of units. Faults, other than Little's Range Fault, omitted. Distance across section about 130 miles.**

GEOLOGICAL HISTORY

The first record of Upper Proterozoic sedimentation in the region is given by the Westmoreland Conglomerate. This lies about a west-trending arch, north of latitude 18°S, in which Cliffdale Volcanics and Nicholson Granite are exposed. The Cliffdale Volcanics Volcanics and Nicholson Granite were previously regarded as Upper Proterozoic (Carter, 1959) but mapping in the Mount Drummond Sheet area in 1959 (see below) indicates that the Cliffdale Volcanics are the same age as, or older than, the Lower Proterozoic Lawn Hill Formation. South of latitude 18°S the Lawn Hill Formation underlies the Upper Proterozoic strata with a major unconformity.

The Westmoreland Conglomerate derived its sediments from the east and from the arch about which it lay. It was succeeded by two periods of vulcanicity, which produced the Peters Creek and Gold Creek Volcanics. Only the earlier of these is well represented in Queensland. Neither the volcanic successions nor the intervening Wollogorang Formation extended far south of latitude 18°S. (if at all).

Arenaceous sedimentation followed the Wollogorang Formation, apparently without a break, but the centre of the basin in which the sediments, the Constance Sandstone, accumulated migrated to the south. The resultant changes in the strandline apparently exposed some of the Wollogorang Formation and the Peters Creek Volcanics, as pebbles from these units appear in a conglomerate in the Constance Sandstone north of the Nicholson River. The Mullera Formation, of siltstone, thin-bedded fine sandstone, shale and ironstone, succeeded the Constance Formation conformably, and was succeeded without interruption by the Tidna Sandstone. Lithology and sedimentary structures show that terriginous material was received mainly from the eastern quarter. In the north of the basin the lower part of the Constance Sandstone also received material from the north but cross-bedding in the upper part of the Constance Sandstone, north of Elizabeth Creek, shows sedimentation from the south, and not the north. Thinning of the Constance Sandstone and Mullera Formation to the north in this area shows that a sub-aqueous ridge persisted.

Mapping by J.W. Smith and H.G. Roberts in the Mount Drummond 4-mile Sheet area, west of the Constance Range area, in 1959, indicated that the Constance Sandstone extends 100 miles into the Northern Territory. The formation there ranges in thickness from 1,700 to 5,500 feet compared with 1,600 to 3,600+ ft. in the Constance Range area and less than 1,000 ft. north of the Nicholson River. The southern limit of deposition of the Constance Sandstone is not known but it probably extended as far as 19°S. in Queensland.

The Mullera Formation and Tidna Sandstone are not definitely known north of latitude 18°S, but a 50 ft. thickness of dolomitic shale in the Upper Settlement Creek Valley, Calvert Hills 4-mile Sheet area, may mark the approximate northern limit of the Mullera Formation. By superposition, the Tidna Sandstone and Masterton Sandstone (Calvert Hills 4-mile Sheet area) could be contemporaneous but the senior author believes that the two units were formed in separate basins, or at least in two lobes of the one basin. The Mullera Formation probably extends at least 80 miles into the Northern Territory, west of the Constance Range area, where it is up to at least 8,000 feet thick.

The variations in thickness of the Mullera Formation within the Constance Range area are discussed below.

Iron-rich beds occur in the Mullera Formation in the Northern Territory but at best, the moderate grade ironstone occurs in beds only a few inches thick. They are both too small and too low grade to be of economic interest.

After the Tidna Sandstone had been laid down the region was moderately folded and extensively faulted to form the two main structural basins, the Northern and Southern, and associated minor basins, in which the iron deposits now crop out. An east-trending high-angle fault, the Little's Range Fault, caused the downthrow of a block south of Deposits A, F and E (see Plate 1). The Lower Cambrian or uppermost Upper Proterozoic Camooweal Dolomite, the Middle Cambrian Border Waterhole Siltstone, and the Thorntonia Limestone later accumulated in a basin that developed south of Little's Range Fault. Basalt was also extruded (the Colless Volcanics), probably along the fault line and before the Camooweal Dolomite was deposited. Further fault movements, involving thrusting from the south-west, produced strong deformation, including high angle reverse faulting, of the Middle Cambrian sediments along the old fault zone (Pl. 11, Fig. 2).

The last sediments to be laid down in the area were Mesozoic freshwater and marine siltstones and sandstones which now form numerous mesas and sheets over the Precambrian strata. In the Constance Range area the Mesozoic sediments are found mainly on the Constance Sandstone, but wide areas of Mullera Formation are covered in the Northern Territory. A thickness of 270 ft. has been measured over the Constance Sandstone between the Northern and Southern Basins, but generally the Mesozoic sediments are less than 100 ft. thick.

STRATIGRAPHY OF THE CONSTANCE RANGE AREA

The lithology, thickness and relationships of the Lawn Hill Formation, and of the ?Upper Proterozoic and Cambrian units south of the Constance Range area are briefly given in Table 1.

TABLE I

REGIONAL STRATIGRAPHY

AGE	UNIT	LITHOLOGY	MAXIMUM THICKNESS	REMARKS
Mesozoic		Sandstone, siltstone, porcellanite.	270' as cappings	May attain thickness of 2,000 ft. below plains of Gulf country. Terrestrial sediments overlain by marine sediments.
		UNCONFORMITY		
Middle Cambrian	Currant Bush Ls.	Limestone, some marly.	500'	Flat-lying except in fault zones.
	Border Waterhole F.	Limestone, chert and siltstone.	150'	Extensively faulted.
	Thorntonia Limestone	Limestone and dolomitic limestone.	150'	
		DISCONFORMITY		
Lower Cambrian or Upper-most Upper Proterozoic	Camooweal Dolomite	Dolomite, chert nodules, some sandy interbeds.	800'	Occurs only S. of Constance Range area. Flat-lying except in fault zone. Relationship to Colless Volcanics not established.
	Colless Volcanics	Basalt.	?200'	Restricted to narrow zone S. of Constance Range area. Flat-lying.
		UNCONFORMITY		
Upper Proterozoic	Gold Creek Volcanics	Porphyritic acid to intermediate lavas, interbedded sediments.	300'+	Occurs in Queensland only 60 miles north of Nicholson River. Overlies Constance Sandstone. Gently folded.
	?	?	?	No contact.
	Tidna Sandstone	Fine to medium-grained quartzitic sandstone, some siltstone.	1,100'	Not recorded N. of Nicholson River. Moderately folded, extensively faulted. Mullera Formation contains several sandstone members and lenses.
	Mullera Formation	Siltstone, shale, sandstone, iron-bearing beds.	6,000'	
	Constance Sandstone	Fine to medium-grained sandstone	?4,000'	Some coarse, impure, strongly-jointed sandstone and conglomerate. Lens of siltstone N. of Elizabeth Creek. Limey greywacke at base in southern Constance Range scarp. Unit best developed S. of Nicholson River but extends 60 miles N. of it. Moderately folded into basins, extensively faulted.
	DISCONFORMITY, PROBABLE SLIGHT UNCONFORMITY			
	Wollogorang Formation	Dolomite, chert breccia, siltstone, sandstone.	?1,000'	Does not crop out in Queensland S. of Nicholson R. Moderately folded.
	Peters Creek Volcanics	Acid to basic, generally intermediate, lavas with interbedded sediments.		As for Wollogorang Formation.
	Westmoreland Conglomerate	Coarse, poorly-cemented sandstone and conglomerate	4,000'	As for Wollogorang Formation. Sediments generally have a clay, ?originally feldspathic, cement and are poorly sorted. The formation lenses sharply.
		UNCONFORMITY		
Lower Proterozoic	Nicholson Granite	Biotite-hornblende granite, adamellite and granophyre.	-	Intrudes Cliffdale Volcanics. Of two distinct petrological types, each overlain by Westmoreland Conglomerate.
	Cliffdale Volcanics	Porphyritic intermediate lavas, tuff, agglomerate.	?	Does not crop out S. of Nicholson R. in Queensland. Believed on evidence in Mt. Drummond 4-mile Sheet area to be contemporaneous with part of the Lower Proterozoic Lawn Hill Formation or to be older.
	Lawn Hill Formation	Sandstone, quartz greywacke, shale, some limey beds.	?5,000'	Does not crop out N. of Accident Creek. Directly underlies Constance Sandstone with major unconformity. Strongly folded.

CONSTANCE SANDSTONE

This unit is defined and described in Carter, Brooks and Walker (in preparation). It consists mainly of white, light brown and red, medium-fine to coarse-grained quartz sandstone (Pl. 4). Beds are massive to flaggy. Surface silicification has produced quartzitic sandstone over wide areas, but some exposed beds are friable. Some conglomeratic beds and lenses occur throughout the formation, and a lens of siltstone, similar to that in the Mullera Formation, and probably a few hundred feet thick, crops out north of Elizabeth Creek.

In addition, a succession of thin-bedded calcareous greywacke, quartz greywacke and quartz sandstone is exposed at the base of the formation in the scarp east of iron deposit E. The calcareous greywacke contains many spherical concretions, up to ten inches in diameter. The succession is included in the Constance Sandstone, but with further mapping should be delineated as a separate unit as it differs lithologically from the bulk of the Constance Sandstone.

The lower part of the Constance Sandstone tends to be red, coarse-grained, conglomeratic, and friable; it is well-exposed in the Constance Range scarp. The upper beds are light brown and medium-fine to medium-grained; they are clearly bedded and are better sorted than the lower beds. White to light grey, highly siliceous, poorly bedded strata are seen only on elevated flat surfaces. Their appearance is the result of supergene silicification, probably related to lateritization.

Cross bedding of various types and ripple marks are common throughout the formation. Mud cracks have also been recorded.

The lithological transition at the Constance Sandstone - Mullera Formation contact is abrupt.

MULLERA FORMATION

The Mullera Formation has been subdivided into five by the creation of two members, as follows:

Siltstone - immediately below the Tidna Sandstone (upper part of the Mullera Formation)

Middle Creek Sandstone Member

Siltstone (Middle part of the formation)

Train Range Iron-bearing Member

Siltstone (Lower part of the formation).

Only the two members are formal stratigraphical units as the three siltstone successions are generally distinguishable only by superposition, not by lithology.

As defined in Carter, et al. (in preparation), the Mullera Formation includes the quartzitic sandstone succession now named the Tidna Sandstone. It is here redefined.

Definition

Derivation of name: Parish of Mullera, in the County of Mueller (see Queensland Department of Public Lands map No. 4M100, 1939).

Map Reference: Lawn Hill 4-mile sheet - E54/9 and Mt. Drummond 4-mile sheet - E53/12.

Distribution: In Queensland the unit is confined to the western portion of the Lawn Hill Sheet, from south of Accident Creek to the latitude of Colless Creek (Lat. 18°40'10"S), a meridional distance of 40 miles. Its eastern limit in Queensland is 32 miles east of the Northern Territory border. The area of outcrop in Queensland is about 340 square miles.

The distribution in the Northern Territory has not been mapped but the unit is believed to be confined to the Mount Drummond Sheet area. It probably crops out over an area of about 700 square miles.

Sub-units: Middle Creek Sandstone Member
Train Range Iron-bearing Member.

Lithology: The dominant lithology is thin-bedded, commonly micaceous, siltstone, siliceous siltstone, shale and fine grained sandstone. At some stratigraphic levels fine to medium-grained quartzitic sandstone forms the main part of the succession but these sandstone beds do not persist throughout the whole area of outcrop of the formation. The thickest and most persistent sandstone sequence is designated the Middle Creek Sandstone Member (see below). From 900 to 2,200 feet above the base of the formation a zone rich in sedimentary iron begins. It consists of quartzitic sandstone, siltstone, shale, oolitic ironstone and chamositic sandstone. It is defined below as the Train Range Iron-bearing Member. Other thin ironstone beds and lenses (generally less than six inches) occur throughout the formation.

Shallow-water sedimentary structures abound throughout the unit; they include ripple-marks, cross-bedding, scour-and-fill features, mud pellet casts, intraformational breccia, mud cracks, and possibly rain prints. Small scale slumping has also been recorded (Pls. 5 and 6). Well-developed cone-in-cone structures occur in the Upper Elizabeth Creek area (lat. 18°18'15"S, long. 138°06'55"E).

Although the upper, middle and lower siltstone successions are generally not readily distinguishable by lithology, the lowermost 500 feet of the formation contains more, and thicker, fine sandstone beds than is generally the case higher in the succession; dolomitic shale, some with cherty lenses and concretions, occurs in the lower siltstone in the upper Elizabeth Creek area, just below the iron-bearing member.

Type Section: From lat. 18°32'15"S, long. 138°06'30"E. on true bearing 128° for a distance of 6¼ miles.

Thickness: ?3,600 to 6,000 ft. The Formation in Queensland varies considerably in thickness from place to place. Thickness in the various iron deposits are given in Table 2: they are approximate.

Age: Upper Proterozoic.

Contacts: Conformably underlain by Constance Sandstone, conformably overlain by Tidna Sandstone. Unconformably overlain by ?Upper Proterozoic Colless Volcanics and Camooweal Dolomite.

Description and Comment

The siltstones of the Mullera Formation are commonly not well exposed, but the siliceous beds form a mantle of rubble over most of the hills. The siliceous siltstone and fine sandstone weathers to light brown or red-brown. Many cliff faces along the water courses expose fresh shale and siltstone. These are generally dark grey, but some are red and others grey-green (Pl. 3, Fig. 2). Magnesite forms nodules and seams along bedding planes and minor cross-fractures throughout most of the formation.

Except where flaggy to massive quartzitic sandstone exists, the beds are thin, ranging from less than one tenth of an inch to several inches thick. Small, but thick, lenses of sandstone, filling contemporaneous channels, are numerous in places.

There are several important quartzitic sandstone lenses in the Mullera Formation, other than those in the two members. The oldest is well-developed in Deposit A, where it lies about 800 ft. stratigraphically below the Train Range Member, and has a maximum thickness of about 150 ft. It lenses out to the north and east of Deposit A, in the same manner as the Middle Creek Member, but is less persistent. A bed of friable red sandstone, generally about 4 ft. thick, forms a useful marker about 300 ft. above the iron zone in Deposit F, but lenses out to the west. Thin quartzitic sandstone beds also occur in the Northern Basin between the Middle Creek Member and the Tidna Sandstone.

The thin ironstone beds, referred to on p.11, occur at several stratigraphic levels. A group of about six beds may be seen about 400 ft. stratigraphically below the Train Range Member west of Deposit A and near Deposit E. Isolated occurrences in about the same position have been recorded in Deposits H, N and north of Deposit K. A thicker bed immediately overlies the Middle Creek Member in Deposit A and lenses and beds occur between the Middle Creek Member and the Tidna Sandstone in Deposit A and in the Northern Basin. In the latter the thin ironstone beds and lenses are 100 to 200 ft. below the Tidna Sandstone. These ironstone beds and lenses are of two types. One is oolitic, though commonly severely altered by weathering; the other is an intraformational breccia with ironstone fragments. Some of the smaller lenses appear to be concretionary, but this may be the result of weathering late in geological time. All outcrops are of hematite, limonite or goethite.

In drill cores many thin beds of chamositic sandstone have been recorded. The green mineral chamosite occurs in oolitic form. At the surface the chamosite is almost invariably oxidized to hematite or limonite to form ferruginous sandstone or quartzitic sandstone spotted with hematite or limonite.

<u>TRAIN RANGE IRON-BEARING MEMBER</u>

<u>Definition</u>

Derivation of name: Train Range (Lat. 18°33'50"S, Long. 138°06'00"E). The member is part of the Mullera Formation.

Map Reference: Lawn Hill 4-mile Sheet - E54/9.

Distribution: Constance Range area. It crops out over, or underlies, about 250 square miles in Queensland. It also occurs in the Northern Territory but is recognisable in only a few places, notably about 9 miles west of Springvale Homestead.

Lithology: Ironstone, including moderate to low grade oolitic iron ore, chamositic sandstone and ferruginous sandstone, with interbedded massive quartzitic sandstone, siliceous siltstone, and shale. Numerous shallow-water structures occur.

Many of the beds are lenticular. Ironstone beds vary in number from one to eight or more, but can be conveniently grouped into one to six groups or zones.

At the surface the richer ironstones consist of hematite oolites set in a matrix of hematite or chalcedonic silica, but in the unweathered zone consist of hematite, hematite-chamosite, or rarely siderite, oolites in a siderite matrix. Finely-divided hematite or quartz grains may also be present. Chamositic oolites of the chamositic sandstone do not appear at the surface, being altered to hematite or limonite to produce ferruginous sandstone.

Considerable redistribution of iron, as hematite, limonite or goethite, has occurred at the surface. The secondary iron oxides commonly form layered polygonal patterns, apparently by precipitation along joints or other planes of weakness (see Pls. 9 and 10).

Thickness: 150 to 600 feet.

Individual ironstone beds rarely exceed 30 feet in thickness and are generally less than 10 feet thick (see Pl. 12 and Table II).

Age: Upper Proterozoic.

Type Section: From the base of the quartzitic sandstone 1300 feet north of the base of the lower iron zone at Lat. 18°33'50"S, Long. 138°06'00"E, S to the top of the quartzitic sandstone associated with the upper iron zone.

Description and Comment

Quartzitic sandstone is an important constituent of the formation in the south-west of the region but diminishes both eastward and northward. The basal quartzitic sandstone in Deposit A is 50 ft. thick and is separated from the lower ironstone by 160 ft. of micaceous siltstone. Thinner beds of quartzitic sandstone overlie both the iron zones; each contain ironstone pebbles. The basal quartzitic sandstone may be traced through Deposits F, E and much of C, but it is thickest in the south and west of Deposit A.

The lower grade iron beds, e.g. west end of Deposit A, Deposit M, and portions of Deposits N and I, are ferruginous quartzitic sandstone, with very little oolitic material apparent at the surface. They are generally coarsely flaggy, with interbedded siltstone and shale, and in places have been heavily iron-stained by vadose iron during weathering (Pl. 9, Fig. 1).

Typical sections of the iron-rich part of the Train Ra Member appear in Pl. 12. The ironstone beds are further discus in "Economic Geology".

In drill cores the strata mapped at the surface as thin-bedded siliceous siltstone and shale are recorded as dark grey shale and light grey fine-grained sandstone, the latter forming 5 to 30% of the whole.

MIDDLE CREEK SANDSTONE MEMBER

Definition

Derivation of name: Middle Creek, a tributary of Elizabeth Creek (lat. 18°15'10"S, long. 138°14'10"E).

Map reference: Lawn Hill 4-mile Sheet - E54/9.

Distribution: Constance Range area, Northern and South- Basins. Probably also occurs in Mt. Drummond Sheet area.

Lithology: White and light brown massive and flaggy, fine to medium-fine quartzitic sandstone, with some interbedded siltstone and shale. Some poorly cemented, cross-bedded, brown sandstone. Cross-bedding, ripple marks, mud cracks, and mud pellet casts are common throughout the member (Pl. 6, Fig. 2).

Thickness: 0 to 480 ft.

Type section: Along the watercourse of Middle Creek at lat. 18°15'10"S, long. 138°14'10"E, for distance of one third of a mile.

Relationship to other units: A member of Mullera Formation.

Description and Comment

The quartzitic sandstone beds in the Northern and Southern Basins which have been mapped as the Middle Creek Sandstone Member are correlated by superposition and similarity of lithology.

The greatest thickness (480 ft.) occurs in the Northern Basin. It is also well developed in Deposits A and F, but is only represented by a few thin sandstone beds near the B.H.P. base camp in Deposit G, and has not been recognised in Deposit M.

TIDNA SANDSTONE

Definition

Derivation of name: Parish of Tidna in the county of Mueller (see Queensland Department of Public Lands map 4M100, 1939).

Map reference: Lawn Hill 4-mile Sheet - E54/9. Probably also on Mt. Drummond 4-mile Sheet - E53/12.

Distribution: Constance Range area, north-western Queensland.-- Probably also occurs to west in Northern Territory, but not mapped. Area of outcrop in Queensland is about 18 square miles.

Lithology: Generally medium to fine-grained quartzitic sandstone, with some interbedded siltstone and shale. In the Southern Basin the base of the succession is marked by a massive, white to light brown, medium to coarse-grained, quartzitic sandstone, but in the Northern Basin the passage from Mullera Formation to Tidna Sandstone is transitional. The base of the formation here is placed at the point where a predominantly arenaceous succession, of thinly flaggy sandstone, begins. It is about 60-160 ft. above the uppermost thin ironstone bed. A thin ferruginous sandstone has been recorded in the Southern Basin, but not in the Northern Basin.

Thickness: Maximum thickness (calculated) is 1,000-1,200 ft. This figure is recorded in both the Northern and Southern Basins.

Type section: From lat. 18°37'35"S, long. 138°14'50"E, north for a distance of 3,000 ft.

Age: Upper Proterozoic.

Contacts: Conformably overlain by the Mullera Formation, unconformably overlain by ?Upper Proterozoic Colless Volcanics and by Mesozoic sediments.

Description and Comment

The Tidna Sandstone is the youngest of the three conformable Upper Proterozoic formations in the Constance Range area. There is no record of later continuing sedimentation. The succession displays many sedimentary structures such as cross-bedding and ripple-marks but little evidence has been obtained of the direction from which sediments were derived.

STRUCTURE

The two major structural basins, with the many minor structures, which are apparent in Plate 13, owe their configurations to both folding and faulting. Only one period of folding is apparent and this took place before the Colless Volcanics were extruded, but subsequent dragging on faults and minor warping has further altered the attitude of the beds.

At least two periods of faulting can be recognised - the earlier did not involve the Colless Volcanics and the later displaced Middle Cambrian strata. Faulting has also affected some of the Mesozoic sediments very slightly. Because of the relationship between many of the faults and the folds, and of the much lower density of faulting in the younger rocks, it is assumed that the main faulting which affected the Constance Sandstone, Mullera Formation, and Tidna Sandstone took place before the Colless Volcanics were extruded - about the same time as the folding. Probably the folding and faulting had a common cause.

FOLDING

Beds generally do not dip more steeply than 30°, except in the vicinity of faults: near major faults the steepening in dip may be of regional extent, e.g. the southern limb of Deposit F.

The Southern Basin has a roughly triangular shape, but this appears to be determined by faulting which has modified a series of basins with major axes trending roughly easterly. The major easterly axial trend is apparent in the Northern Basin.

It is not possible to trace linear fold axes for any distance and it seems likely that the folding is due to vertical crustal adustment rather than to lateral compression.

FAULTING

Practically all faults are high angle faults; most are believed to be tensional faults, but high angle reverse faults and transcurrent faults have been recorded.

The most important faults trend easterly to east-north-easterly, such as those that bound the northern and southern margins of the Northern Basin, several in Deposit N, a fault zone that passes along the N. limb of Deposit M and between Deposits G and H (Pl. 11, Fig. 2), another that forms the contact between the Constance Sandstone and the Mullera Formation north of Deposits B and C and between Deposits A and M, and the

Little's Range Fault zone. The movement on most of these faults was south block down, but the overall result of faulting along the southern edge of the Northern Basin was to lower the north block. Some of these faults appear to be pivotal. Slickensides and displacement of beds show a strong horizontal component in some faults.

The juxtaposition of Constance Sandstone and Tidna Sandstone to the south-west of the Northern Basin requires a vertical movement of at least 4,000 ft. Ironstone has been faulted against Constance Sandstone in Deposit M and north of Deposit B; vertical movement must have exceeded 1,000 ft.

Faulting with the east-north-east to easterly orientation is strikingly concentrated along anticlinal crests, particularly in the Southern Basin. It is therefore reasonable to expect that the iron beds are much less disturbed by faulting in the centres of the basin structures than in the anticlinal areas. Furthermore, faults in the Mullera Formation are not nearly as pronounced as in the Constance Sandstone. Paucity of outcrop in the Mullera Formation could provide one explanation but mapping demonstrated that faults tend to die out in very short distances in the shales and siltstones.

In the Little's Range Fault zone flat-lying Camooweal Dolomite and Cambrian sediments may be seen overlying highly deformed Constance Sandstone or Mullera Formation. Elsewhere intricately crumpled and vertical-dipping Cambrian sediments (Plate 11, Fig. 2) give evidence of post-Middle Cambrian compressional faulting. The thrust is believed to have acted from the south-west. In both Deposits A and F, particularly the latter, steep dips on the southern limbs of the pitching synclines show the effect of the Palaeozoic compression.

The southern beds in Deposit C also dip more steeply than is general elsewhere, and in the Constance Sandstone, east of this area, a high angle north-west striking fault with horizontal slickensides on the fault plane, intensely fractured and slickensided bedding planes in the north-east block, and widespread bowing and dragging of the sediments, show that strong pressure from the south had operated. In addition to the major faults and fault zones the Constance Sandstone has been deformed by innumerable faults, with a wide range of orientations. Many of these faults have little displacement, though movement is shown by slickensides and breccia: possibly many were joints along which

TABLE II

INTERSECTIONS OF IRON-BEARING STRATA, 1958 DRILLING

D.D.H. No.	Thickness of Iron-bearing section, in feet.	No. of Zones *	Distance apart of Zones, in feet.	No. of Ironstone Beds. *	Total thickness of Ironstone, in feet. *	Thickest Ironstone Bed, in feet.	Total Thickness of Siliceous Ironstone & Ferruginous Sandstone, in feet.	REMARKS
DEPOSIT A.								
61	44	1	-	2	24	18	3	
62	37	1	-	2	8	5	2	Two sandstone beds, less than 1 foot each, in main bed. Chamosite 70-85 feet above iron zone.
63	36	1	-	4	12	6½	3	Chamosite 80-94 ft. above iron zone.
64	70	1	-	3	43	36	-	" 74-105 ft. " "
65	56	1	-	4	21	12	4	" 93-99 ft. " "
66	22	1	-	2	12½	9	-	" 84 ft. " "
67	136	2	96	4	23	15½	5	2 feet ironstone only in upper zone.
68	157	2	87	6	25	7	10	No ironstone in upper zone.
69	33	1	-	2	17½	9	7	Chamosite 103-109 feet above iron zone.
70	53	1	-	4	35	13	2	" 90-95 " " "
71	41	1	-	4	23½	15	1	" 84-91 " " "
99	176	2	93	5	36	16½	13	2 feet ironstone only in upper zone.
105	55	1	-	7	26½	14½	5½	Chamosite 89 feet above iron zone.
108	60	1	-	3	24½	20	12	" 87-93 feet " "
109	45	1	-	2	21½	20½	10	" 93-99 feet " "
110	167	2	94	2	19½	12½	30	Ferruginous sandstone only in upper zone.
111	165	2	86	3	26½	13½	21½	No ironstone in upper zone.
112	75	1	-	4	25½	12	8½	Chamosite 90-105 feet above iron zone.
113	168	2	107	4	12	5½	26	Ferruginous sandstone only in upper zone.
114	58	1	-	2	19½	14	20½	Chamosite 90-95 feet above iron zone.
115	35	1	-	3	10	8	20½	" 70 feet " " "
DEPOSIT B.								
92	34	1	-	3	4	2	13	Chamosite 74-103 feet above iron zone.
93	135	2	107	-	-	-	20	Upper zone ferruginous sandstone only.
94	13½	1	-	1	1	1	10	
96	47	1	-	-	-	-	24	Chamosite 101-106 feet above iron zone.
100	20	1	-	-	-	-	3	
DEPOSIT C.								
97	173	2	141	1	5½	5½	21½	Upper zone has 1½ ft. silic-ironstone only; chamosite 52 feet above upper zone.
101	224	2	172	2	20	17	15	Chamosite 3-5 ft. & 17-20 ft. below upper zone and at 34 ft. and 47 ft. above it.
104	219	2	188	2	8½	7	7½	No ironstone in top zone.
DEPOSIT G.								
89	106	2	56	4	21½	12	6	
106	256	3	56 135	4	21	13	17	1½ feet ferruginous sandstone only in lower zone, chamosite(?) 37 ft. below middle zone.
107	180	2	134	-	-	-	18	Chamosite 39-41 feet below upper zone.

TABLE II (CONTD.)

D.D.H. No.	Thickness of Iron-bearing section in feet.	No. of Zones *	Distance apart of Zones, in feet.	No. of Ironstone Beds. *	Total thickness of Iron-stone, in feet. *	Thickest Ironstone Bed, in feet.	Total thickness of Siliceous Ironstone & ferruginous Sandstone, in feet.	REMARKS
DEPOSIT I.								
74	282	5	34 21 90 52	8	29	8	23	Top and second bottom zones of siliceous ironstone only.
75	263	4	26 70 126	4	16½	9	10	Chamosite 99-105 feet above bottom zone.
79	275	3	115 132	2	8½	5	11	Ferruginous sandstone only in top zone; chamosite 17-48 feet below top zone.
83	154	2	120	2	16½	13	13	34 feet of chamositic sandstone immediately above, & 108-110 feet above upper zone. Iron-bearing beds lost 88-95 feet above upper zone.
84	276	5	55 22 57 40	6	24	7	12	Bottom zone of siliceous ironstone only.
86	270	4	103 62 45	8	34	9	10	Ironstone pebbles 80 ft. above top zone, (near surface); two chamosite-bearing zones 21-31 ft. and 56-66 ft. below top iron zone.
DEPOSIT J.								
80	129	1	-	6	43	16	40	Bottom 44 ft. contains siliceous ironstone and ferruginous sandstone only.
81	111	2	38	6	14	4½	13	Bottom zone of siliceous ironstone and ferruginous sandstone only.
82	124	2	36	3	14½	9	21	Bottom zone of siliceous ironstone only.
85	117	1	-	6	20½	5	33	
DEPOSIT K.								
76	41	1	-	2	16	8	1½	Bottom 21 feet contains ½ ft. siliceous ironstone and chamosite sandstone, no ironstone.
77	25	1	-	2	20	17	1	Ironstone low grade.
78	91	2	24	4	9½	5	24	
DEPOSIT M.								
72	154	2	140	4	6	3½	1	
73	155	2	135	2	8½	4	-	
90	36	1	-	2	13	11	9	Chamosite 21-23 feet below iron zone.
102	9	1	-	-	-	-	9	
103	-	-	-	-	-	-	-	1/4 ft. chamosite, with siderite.

TABLE II (CONTD.)

D.D.H. No.	Thickness of Iron-bearing section in feet.	No. of Zones *	Distance apart of Zones, in feet.	No. of Ironstone Beds. *	Total thickness of Iron-stone, in feet. *	Thickest Ironstone Bed, in feet.	Total thickness of Siliceous Ironstone & ferruginous Sandstone, in feet.	REMARKS
DEPOSIT P.								
87	155	2	110	3	21	14	5	Upper zone has only 2 feet of ironstone
88	138	2	95	2	8½	7	5	
91	126	2	88	1	2½	2½	12	Chamosite 22-28 feet below upper iron zone.
95	45	1	-	2	17½	11½	20	Chamosite 98 ft. & 104 ft. above iron zone.
98	19	1	-	2	5½	4	11	Chamosite 78-85 ft. and 110 feet above iron zone.

* These data are based on visual logging only of drill core by C.P. Taylor, geologist, The Broken Hill Proprietary Co. Ltd. and not on assays. It is emphasized that <u>ironstone is not necessarily of ore grade</u>. Ironstone generally contains a high to moderate iron content but may contain too much silica to constitute ore under present conditions. Siliceous ironstone is distinguished from ironstone by having sufficient megascopic silica to render it obviously sub-economic.

Ferruginous sandstone contains some ore minerals - hematite and siderite - in addition to chamosite. It is clearly poor in iron and rich in silica. Sediments containing chamosite as the only iron mineral are not included in ferruginous sandstone, but chamositic sandstone in some cores has been included when measuring the width of the iron zone.

An iron zone is defined as a section of the stratigraphic column, containing iron ore minerals, in which no interval of 20 feet or more, free of iron ore minerals, is included. Adjoining zones are therefore at least 20 feet apart. The zones in this table do not necessarily coincide with those in the maps.

An ironstone bed is defined as a bed, or group of beds, of ironstone which does not include a stratum of other sediments greater than one foot thick. Where information is available in the log the thickness of iron-poor beds within the ironstone is excluded from the quoted thickness of ironstone.

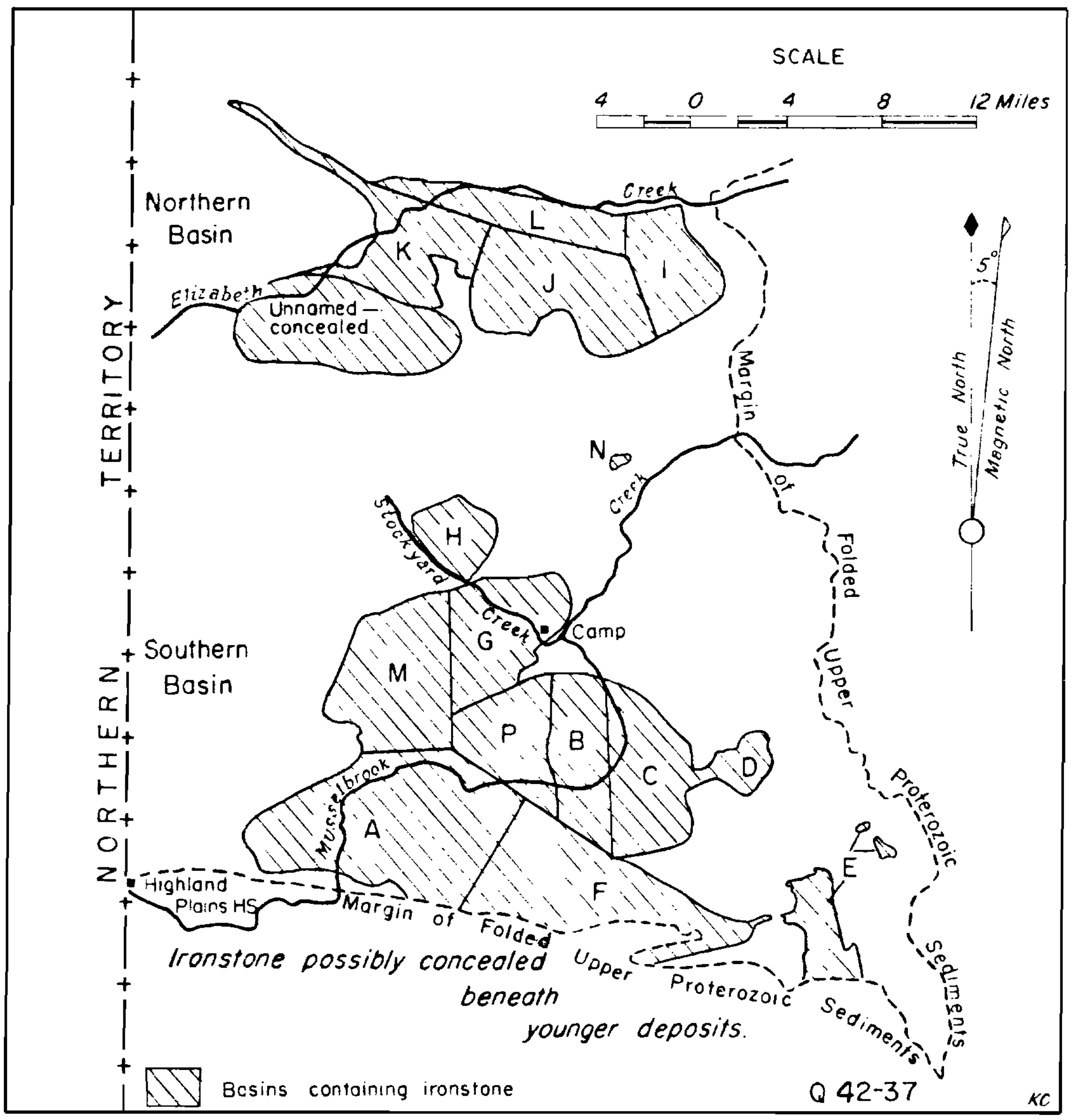

Figure 3: Distribution of named iron deposits.

minor stress adjustments occurred. Others show displacements of several hundred feet. Faults of this type have also affected the iron zone of the Mullera Formation. In some places displacements of 10 to 100 ft. are common. However a great many of those observed in the Constance Sandstone appear to have died out in the siltstones and shales of the lower Mullera Formation.

JOINTING

The Constance Sandstone is very strongly jointed (particularly the lower beds), but no study of the joint directions has been made. The roughness of the Constance Range is largely due to weathering out along joints. Jointing is not conspicuous in the Mullera Formation or the Tidna Sandstone.

ECONOMIC GEOLOGY

DESCRIPTION OF IRON-BEARING SECTION.

The only economically significant iron-rich strata occur in the Train Range Member. Most other iron-rich beds are less than one foot thick. The greatest recorded thickness of ironstone*

* "Ironstone" is used in the text to describe both "siliceous ironstone" and "ironstone" as defined at the foot of Table II, except where the context makes a different usage apparent, e.g., where both siliceous ironstone and ironstone are referred to.

other than in the Train Range Member, is near the top of the Middle Creek Sandstone Member, where a lensing ironstone bed is in places about 10 feet thick; it is very siliceous.

In Table II the thickness and distribution of ironstone, siliceous ironstone and ferruginous sandstone (see notes at foot of table) in 1958 drill-holes are summarized. 1957 drilling results are not used as most holes, being designed to test the near-surface ironstone, did not intersect the whole of the iron-bearing section. During 1958 Deposits D, E, F, H, L and N (see Fig. 3) were not tested by drilling as free-sampling and the 1957 drilling indicated that the deposits were low grade. Deposits N and H form high mesa-like hills and are difficult of access (see Pl. 7, Fig. 1) and have not been drilled. Deposit H contains only low-grade, siliceous ironstone and ferruginous sandstone; Deposit N appears to have some good oolitic hematite ore, but the tonnage available is small.

Generally the zones in Table II correspond to those in the maps except where the number of zones, as defined in Table II, exceeds three. In Deposits I and J the outcrops have been split into three goups of zones, the upper two of which are almost contiguous. In Deposit C four beds or groups of beds have been mapped but only two zones have been established on drill information. Surface mapping indicates three well-defined zones in Deposit D but minor intervening iron-bearing beds might result in only two zones being recognised in a drill-hole. Deposit E has three zones and Deposit F has two. In Deposit H there are three zones but the middle zone is thin and lenses out in places; the bottom zone is the thickest, at least 26 feet in places, but is very siliceous. Only one zone is exposed in Deposit L. Deposit N has three zones. The lowest is more than 100 feet below the middle zone and is very poor; the two upper zones have many ferruginous beds including at least two which could be classified as ironstone.

From the data presented certain regional trends emerge:

1. In both basins the thickness of the iron-bearing section diminishes progressively from east to west, owing to the lensing out of zones and beds.

2. The number of zones and iron-rich beds diminishes from east to west. All iron beds and zones are lenticular to greater or less extent. This can be seen clearly in Deposit G (Plate 19) where the top zone lenses out to south and west, and the bottom zone thins to north and west.

3. In general there are more iron-rich beds in the northern basin than in the southern basin. A fairly uniform progression from south to north is apparent through Deposits F, C, D, N and I. Marked departures from this generalization are apparent in places e.g. the poverty of parts of Deposit B.

4. Optimum development of ironstone, on the regional scale, is governed by two factors. Near the strandline, although iron oxide was apparently abundant, sandy sediment was also plentiful and formed many thin beds and lenses within the iron zones. As a result iron-bearing beds are generally thin, though numerous; further, contamination by detritus produced very siliceous iron-bearing strata. Farther from the strandline the lensing out of many of the sandstone beds gave rise to fewer, but thicker and richer, iron beds. Gravitational concentration of oolites precipitated near the strandline may also have contributed to the

richness and thickness of the iron beds in this favourable area. At greater distances from the strandline the second factor, the availability of iron, became important; strata are progressively poorer in iron with distance from the strandline, beyond the optimum point.

The position of the area of optimum ironstone development relative to the strandline, varied from place to place and from bed to bed.

5. As the accumulation area was clearly extremely shallow, with channels, mud banks, contemporaneous erosion and small-scale slumping (see p. 12) great local variations are superimposed on the regional trends.

6. In general the iron-bearing section has more sandstone associated with it in the Southern Basin than in the Northern Basin. Testing to date indicates that the following deposits are not likely to contain large tonnages of ore grade material, at least near the outcrops: D, E, F, H, K, L, M, and N. Some beds are fairly rich in iron but are siliceous. Description of individual deposits is restricted to Deposits A, B, C, G, I and J.

Deposit A forms a simple east-pitching syncline. The southern limb is slightly steeper than the northern limb; dips generally do not exceed 20^{o}, except near the Little's Range Fault, along the southern margin of the deposit. The outcropping iron section forms an almost continuous high ridge, with a dip slope on one side and a precipitous scarp on the other. The deposit is notably free of faults, except in the south-east. In the deepest part of the basin the ironstone may be nearly 6,000 feet below surface.

The deposit has one persistent iron zone, from 20-75 feet thick, which contains some thick (up to 36 feet) oolitic ironstone beds. Above the persistent iron zone is a thin (generally less than 5 feet) siliceous iron zone which lenses out in the west of the deposit; it is not known to contain any likely ore material. The lower zone also thins in the west. The thickest, richest, ironstone beds of oolitic hematite in a hematitic and sideritic matrix, crop out in the south limb near Musselbrook Creek and in the north limb on about the same meridian of longitude. A belt of high grade material may extend between these two points.

Deposit B crops out in a flat domal structure. It is greatly disturbed by faults, most of which strike roughly east.

The main iron zone is very erratic in both thickness and grade. About 100 feet above the main iron zone is another, very weak, zone, none of which could be called ironstone; it is represented only by chamositic sandstone in many places. The two zones correspond to those in Deposit A.

Deposit C forms the eastern part of a steep faulted basin, and includes a small shallow domal structure to the east. It is faulted against Constance Sandstone in the north. Ironstone crops out along the eastern edge of the basin, at dips up to 60°, and forms broken ridges. The domal section has extensive outcropping ironstone in a high, deeply dissected, hilly area.

The two zones have many iron-rich beds but few of them are of ironstone. The upper zone, 170 to 220 feet above the main zone, is the poorer of the two. The two zones correspond to those in Deposits A and B. Chamositic sandstone about 50 feet above the upper zone may correspond to the lenticular upper zone in Deposit G.

Deposit G also forms the eastern part of a basin, the western part of which constitutes Deposit M. The basin is faulted along its northern and southern sides, but in the central portion seems to be free of faults. The outcropping iron beds form hog-back ridges (Pl. 7, Fig. 2) and generally dip 20° to 25°.

Three iron zones crop out in the north, but only two in the south, as the top zone lenses out. The lensing is clear on air photographs. In DDG89 the bottom zone, which thins and becomes poor from south to north, is absent and only one foot of ironstone has been recorded in the lower (middle) zone. Some of the ironstone in the upper bed in the north-east of the deposit appears to be good grade. The lower and middle iron zones are probably those that appear in Deposits A, B, M and P. The upper zone probably extends into the north-east of Deposit M and weakly into Deposit H.

Deposit I covers the eastern part of the Northern Basin. It contains the thickest iron-bearing section in the region and the most abundant iron-rich beds. The structure is simple, with dips up to 45° in the outcropping iron beds in the south, where several faults have been mapped. The basin is bounded in the north by a major fault zone in which the iron-rich section is faulted against Constance Sandstone. Dips near the northern end of the deposit are up to 35°, but in the centre, which is free

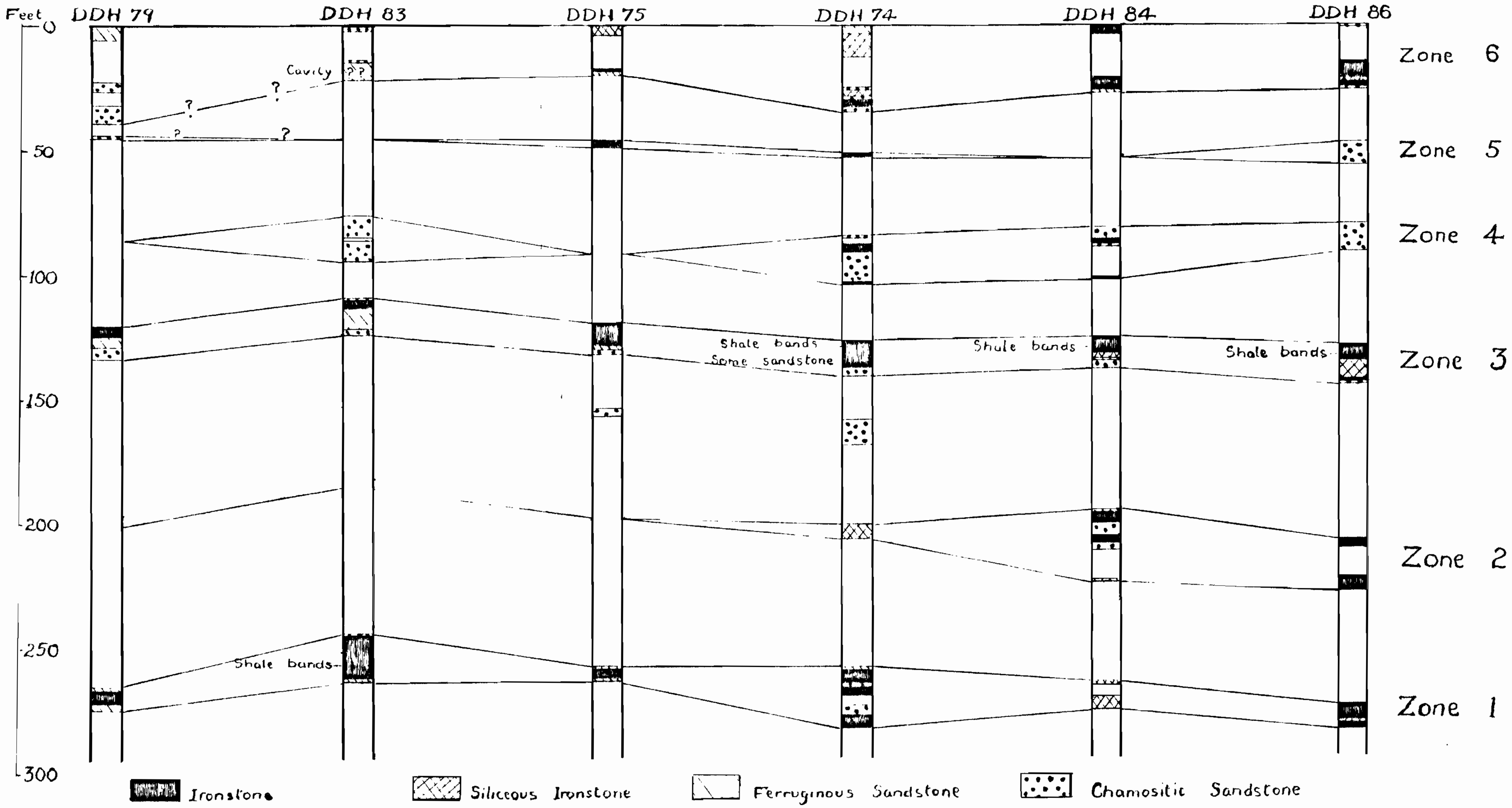

Fig 4 Correlation of iron zones of Deposit I, intersected in 1958 drill-holes.

of large faults, do not exceed 20°.

Deposit I has six iron zones. All appear in DDH74 but the two top zones are less than 20 feet apart and are therefore grouped as one in Table II; in none of the other drill holes are all the iron zones present. Figure 4 shows the variations in thickness and character of the zones. It can be seen that zones 1 and 3 are the most persistent. The top zone is generally of poor grade.

The bottom zone of Deposit I is probably the same as that in Deposit N, and possibly that in Deposit G. Zones 3 to 6 probably correspond with the two upper zones of Deposit N, but correlation with Deposit G is uncertain.

<u>Deposit J</u> includes the south-central part of the Northern Basin, which has three structural basins within it. The outcropping iron beds are extensively faulted; locally they dip steeply but generally dips do not exceed 30°.

The fewer iron zones in Deposit J, relative to I, is due in part to the presence of intervening iron-bearing beds between the zones established in Deposit J, resulting in one thick zone that includes several of those in Deposit I. Correlation of beds or zones between Deposits I and J cannot be made with certainty, although correlation of the four drill cores from Deposit J has been established. Possibly the drill holes did not intersect the bottom zone in Deposit J.

DESCRIPTION OF THE IRON BEDS

The iron-bearing beds range from fairly normal sediments to pure chemical precipitates. A brief account of them is given on p. 14 . The beds at the surface differ from those intersected in the primary zone by drill holes in the replacement of most of the siderite by chalcedonic or finely crystalline silica and ferric oxides, and the oxidation of chamosite and siderite to ferric oxide. Siderite has been recorded at the surface in a few places, but is rare. Iron-poor beds near iron-rich beds are commonly iron-stained at the surface and may give a misleading impression of the size of the iron zone.

Owing to the resistance to erosion of many of the iron-rich beds outcrops are bold and the beds are well-exposed in precipitous scarps. The lower grade siliceous beds are generally the most prominent. The lower beds are commonly largely concealed by scree.

Iron-bearing beds range from massive to laminated; commonly they are flaggy (see Pl. 8, Fig. 2, and Pl. 9, Fig. 1) and are lenticular. Both high-grade and poor beds (ferruginous sandstone) may form thick (three feet or more) beds without partings. Thick iron-rich beds have thin lenses or inclusions of iron-poor sediments in many places; these may develop sharply along the strike at the expense of the iron-rich part. Grade may also change within a bed in a very short distance.

The many shallow-water features observed in the Mullera Formation (see p. 12) occur within the iron-rich section and some appear within the iron-rich beds. Cross-bedding is not very common in iron-bearing beds; and it appears to occur only in low-grade beds.

Ferruginous sandstone in outcrop is generally red-brown; very poor beds may be white or brown and spotted by purple alteration products of chamositic, sideritic or hematitic oolites. It is generally fine to medium grained, but some coarse, gritty beds have been recorded. At the surface silicification has produced quartzite, with a siliceous cement, in many places. In the unweathered zone - generally from 40 to 100 feet below the surface - ferruginous sandstone is light to dark grey. In some beds the iron content is due to scattered oolites of chamosite and hematite, with some sideritic cement; in others iron oxides are finely distributed through the sediment as a cement, and no oolites are apparent.

Ferruginous siltstone and shale are commonly micaceous; some carbon has been recorded.

Siliceous ironstone is defined as a sediment containing abundant iron ore minerals but with a considerable amount of megascopically visible silica. Siliceous ironstone probably contains 40% Fe and at least 20% SiO_2. Beds may be fine-grained and dense and without obvious oolites, or oolitic. Siliceous ironstone is generally hard. Many beds which were logged as ironstone were found, on assay, to be very siliceous; the silica occurs as quartz grains around which the iron-mineral oolites have grown.

Ironstone crops out as hard, massive, dark brown, red-brown or blue-black beds and as soft, commonly oolitic, hematite-red, beds. The former are generally fine-grained and form bold outcrops. The red, hematite-rich beds, being soft, generally are not well exposed. They may contain abundant oolites, up to 3 mm. in diameter, but generally rather smaller, or may consist almost entirely of ochreous hematite. If the original rock contained siderite this is generally oxidized to limonite or goethite and replaced in part, or whole, by silica.

Unweathered rock is described under "Mineralogy".

In general it is clear from the widespread iron-staining and the formation of polygonal patterns of limonite and goethite (see Pl. 9, Fig. 2 and Pl. 10, Fig. 1) that some of the iron has been redistributed at and near the surface. None-the-less, comparison of assays of face samples, drill cores from the weathered zone, and drill cores from the primary zone indicates that weathered iron beds generally retain all, or most, of their iron content, and that soluble products of oxidation are replaced partially or wholly by silica.

MINERALOGY

Edwards (1957 c-e, 1959 a and b) has described the minerals and texture of weathered and unweathered sections of drill core, and has discussed the significance of these features.

The following iron-bearing minerals have been recorded:

Chamosite - 15 (Fe, Mg) O. $5Al_2O_3$. $11SiO_2$. $16H_2O$
(Dana's Textbook of Mineralogy) - Iron content 30%.
Siderite - $FeCO_3$ - Iron content 48.2%.
Hematite - Fe_2O_3 - Iron content 70%.
Pyrite - FeS_2 (approx).

Magnetite, which is found in some sedimentary iron deposits, has not been recorded.

A green mineral in one drill core has been logged as possibly glauconite. Chamosite generally occurs in oolitic form. It ranges in colour from light green and blue-green to almost black and probably has a range of chemical composition about that given above. The mineral in the Constance Range area has been identified by optical methods only. It occurs as sparse to densely packed oolites, in chamositic sandstone and in association with other iron minerals. It does not occur in the best ore. Where it occurs in association with siderite or hematite it is generally partially replaced (see below).

Siderite occurs mainly as a finely to coarsely crystalline cement but also occurs in places as oolites; it commonly replaces other minerals. It is brown or red to colourless and where it forms the main mineral gives a brown, lustrous appearance to the rock.

Hematite mainly occurs as oolites, but may be set in either a hematitic or a sideritic matrix. In the matrix the hematite is a finely-divided ochre, producing a soft red rock, or crystalline, when it is generally a steely blue-black. Hematite oolites have cores of rounded quartz grains or of crystalline hematite. Rare pebbles of pyrite, of sedimentary origin, have been recorded but most of the pyrite is epigenetic and occurs in veinlets less than 1 mm. wide. The epigenetic pyrite is not confined to the iron-rich section.

Oolites range in size from 0.1 to 3 mm. They are generally round but some are flattened. They may be massive, and composed of one mineral only, or made up of concentric layers, or shells. Some of the shells are only 0.001 mm. thick. Layered oolites may consist of the one mineral only or may contain several: chamosite and hematite for example, have been found to form composite oolites. Quartz also, forms thin shells between iron-mineral shells in some oolites; in some cases the quartz is of replacement origin, in others it is apparently primary. The cores of oolites are commonly of rounded quartz grains but may be of massive or crystalline iron minerals; some rounded rock fragments have been observed.

The matrix of the iron-rich rocks is generally siderite but may also be either red ochreous, or blue-black crystalline, hematite. In weathered rocks the matrix, or cement, may be wholly or partially replaced by limonite or silica. Some clay minerals and carbon occur. The siderite is crystalline and a single crystal may enclose many oolites or quartz grains. Commonly the siderite has partly or wholly replaced the oolites, or filled cracks within them. The blue-black crystalline hematite also forms large crystals and, where crystallization is well-developed, has partially or wholly replaced oolites, destroying them in the process.

Siliceous cement is generally the product of supergene alteration but silica has replaced some iron minerals at depths of over 100 feet; replacement probably took place in a late stage of diagenesis.

ECONOMIC CONSIDERATIONS FOR ORE

The following factors determine what might constitute ore:

Iron content
Silica content
Content of deleterious impurities
Amenability to beneficiation (for ore not suitable for direct shipment).

As Australia at present has adequate supplies of high grade iron ore (65% Fe) only the best grade of material from the Constance Range is likely to be considered for mining for some time, particularly in view of the remoteness of the deposits and the large capital that would be needed to develop them. Assays of ironstone beds range up to 60% Fe, but no estimate is available at present of likely tonnage of the various grades of ore.

Silica content of the ironstone is a more critical factor in the Constance Range deposits than iron content. The present maximum allowable contained silica for Australian blast furnaces is 7%. Probably only a very small percentage of the moderate and high grade iron beds contain less than 10% SiO_2. A mineable width of iron beds may contain silica in several forms:

1) as thin beds and lenses within the iron section mined.
2) as quartz grains intermingled with the oolites and set in a matrix composed largely of iron minerals.
3) As quartz grain nuclei and silica shells within the oolites.
4) As chalcedonic or microcrystalline silica replacing the iron minerals. Silica in this form is found mainly in the weathered zone.

Tests have been made on material from Deposit A and from Roper Bar, N.T. (which is similar to the Constance Range secondary material, see Edwards 1956a-d, 1957 a and b) by the Ore Dressing Section of C.S.I.R.O. (Blaskett, 1957 a and b, 1958 and 1959). They show that sink-float methods of separation alone are unlikely to produce acceptable furnace feed. Fine grinding, probably to 200 mesh, followed by magnetic roasting, wet magnetic concentration and classification, of composite samples from 11 drill holes on the south side of Deposit A gave satisfactory recovery and grade of iron and silica. The material tested came from both the weathered and primary zones. Possibly preliminary sink-float separation to eliminate low-grade material from included beds and lenses would result in a better end product.

However at present it is most likely that the only acceptable ore would be low-silica direct-shipping ore from the primary zone. This could be used as blast furnace feed without preliminary processing other than sintering, in the course of which the carbonate would be oxidized and any other volatiles would be removed. Underground mining would be necessary to obtain this material.

The Constance Range iron beds are fairly free of deleterious constituents, all analysed samples being well within acceptable limits. Sulphur is generally very low; assays of cores from Deposit A drill holes showed a maximum of 0.66%S and many samples contained less than 0.1%S. Local concentrations of pyrite veinlets might possibly raise the sulphur content but if the ore were sintered, the sulphur would be eliminated before feeding into the blast furnace. Phosphorus content of analysed specimens was below 0.1%. Calcium and magnesium oxides are present in small quantities only and clay content is within acceptable limits. Few assays have been made for titanium or manganese but minerals containing these elements have not been recognised in any specimens that have been examined optically. Edwards (1959b) includes an analysis of a specimen of iron ore from DDH42B. It contained 0.04% Ti and 0.94% MnO. The ores should therefore prove to be suitably low in these two elements. No other metallic elements have been recognised in any of the ore. Sections of drill core 10A were analysed and found to contain no copper.

POSSIBLE EXTENSIONS OF IRON DEPOSITS

As the southern limit of the outcropping Mullera Formation and Constance Sandstone is a fault, with down-throw to the south, the Train Range Iron-bearing Member may extend some distance to the south below the Camooweal Dolomite and Thorntonia Limestone. The combined thickness of the two formations, together with other Middle Cambrian units, is not known; it may exceed 1,000 feet. As some of the ironstone in Deposit A is of good grade some good grade ore may be expected to lie to the south of the Little's Range Fault.

The Mullera Formation extends west into the Northern Territory about 100 miles but mapping during 1959 by J.W. Smith and H.G. Roberts, of the Bureau, showed that although some iron-rich beds crop out none are of ore grade.

The Mullera Formation has not been recorded to the north-west and north of the Constance Range area. Known deposits at, and within 50 miles of, Roper Bar (at the south-west corner of the Gulf of Carpentaria) may lie at about the same stratigraphic position as those in the Mullera Formation, but a reconstruction of the palaeogeography of the region by the senior author indicates that the two deposits formed in separate depositional basins and were not continuous.

To the east of the Constance Range scarp, the only Precambrian rocks preserved are Lower Proterozoic.

OTHER MINERALIZATION IN THE CONSTANCE RANGE AREA

Thin veins of galena occur in the upper Elizabeth Creek area, as recorded on map Sheet 10 (Plate 23), but they are not of economic size.

Production of 27 tons of ore, containing 12% copper, has been recorded from the Ridgepole copper deposit, in the Colless Volcanics (Plate 26). The deposit is small and probably much of the ore was hand-picked.

Manganese minerals occur in marked superficial concentrations in cappings east of the Ridgepole copper deposit. The cappings are of Middle Cambrian sediments, breccia in part, and manganese concentrations were probably formed by weathering in Tertiary time. The manganese does not occur in economic grade or quantity, particularly when the remoteness of the locality is taken into account.

ORIGIN OF THE DEPOSITS

DEPOSITIONAL ENVIRONMENT OF THE MULLERA FORMATION

It has been mentioned above that features indicative of shallow water deposition are numerous throughout the Mullera Formation. The shallowness of the water in which the sediments accumulated is shown by the abundance of mudcracks and contemporaneous breaks in sedimentation. For example, in drill hole DDC101 six erosional breaks are recorded between 220 and 320 ft. depth in and near the iron zone.

Little evidence of direction of sedimentation within the siltstones has been recorded. The cross-bedding generally reflects only local currents of no regional significance. A systematic study of scour-and-fill features would doubtless supply the necessary information, but this has not been done. However cross-bedding in the Middle Creek Sandstone Member in the eastern part of the Northern Basin indicates sedimentation from the east and north-east. The variations in thickness from deposit to deposit of the five subdivisions of the Mullera Formation and the direction of lensing of some beds are consistent with deposition of sediments derived from the east, and possibly south-east, in a basin of the same general configuration as that postulated for the upper Constance Sandstone (see p. 8) and with an axis roughly through Deposits H and N.

No evidence has been obtained whether the sediments were laid down in the sea or in fresh water but similar types of deposit in other parts of the world have fragments of marine fossils as nucleii of the hematite and chamosite oolites, and must therefore be marine.

If the sediments and ironstone were formed in a marine environment the area was probably a barred bay with only slight tidal influences, or at least subject to fluctuations of greater magnitude than that of the tide as mud cracks would not normally form in the interval between tides. James (1954) has examined the environment necessary for the formation of the Lake Superior iron deposits and has also come to the conclusion that a shallow marine basin with restricted circulation is necessary.

SOURCE OF THE IRON

For bedded iron deposits in other parts of the world two main hypotheses have been brought forward to account for the presence of large quantities of iron to form deposits which contain little clastic sediment. They are:

1. Normal erosional processes operating on an iron-rich terrain, either one with abundant basic igneous rocks or a lateritic surface.
2. Submarine emanations of iron-rich solutions of magmatic origin.

Much support has come for the second hypothesis because of the difficulty in accounting for the transport of ferric iron in the neutral or very weakly acid waters to be found in streams. Tropical streams rich in organic material are known to carry up to 7 parts per million of ferric oxide and stagnant marshes up to 61 parts per million (Gruner, 1922), but it is doubtful whether humic acid was present in Precambrian waters to raise the acidity to the level found in present-day sluggish tropical streams. Experiments, e.g. Castano and Garrels (1950) have failed to show whether transported iron is in the colloidal or solute form. It has also not been established whether organic matter plays a more direct part than merely influencing the acidity of the water. An attempt to overcome the problem of the transport of iron has been made by Borchert (1960). He postulates the existance of a zone in the ocean, at moderate depths, which is rich in carbon dioxide and therefore has abundant dissolved ferrous iron. Upwellings of deep ocean waters are considered to sweep the iron-rich waters into the oxygenated shallow coastal waters where the ferrous iron is oxidized and precipitated. The difficulty with this hypothesis is the constant association of oolitic iron deposits with extremely shallow water sedimentary structures. Not only would the ocean waters have difficulty in reaching the areas where such features as mudcracks form but with a deep sea source for the iron, deposits should have formed in many coastal areas from which they are absent.

In the case of the Constance Range deposits the possibility of contemporaneous vulcanicity cannot be excluded.

The Gold Creek Volcanics, which are rich in finely divided hematite, and occur mainly in the Calvert Hills 4-mile sheet area, directly overlie the Constance Sandstone. By superposition they therefore occupy the same stratigraphic position as the Mullera Formation. The dolomitic shale in the upper Settlement Creek Valley (see p. 8) is overlain by the Gold Creek Volcanics, but this does not exclude contemporaneity of the lavas and the Train Range Iron-bearing Member. However, there would need to be a source of iron-rich solutions closer to the site of accumulation than the Gold Creek Volcanics.

On the other hand it is most likely that an iron-rich terrain was being eroded to the east of the present iron deposits, as the vast Eastern Creek Volcanics, of metabasalt and interbedded metasediments, were probably exposed in the deeply eroded Lower Proterozoic orogenic belt. Easterly extensions from the present outcrop area of the hematite-rich Cliffdale Volcanics and Peters Creek Volcanics may also have been subject to erosion.

DEPOSITION OF THE IRON

Experimental work by Krumbein and Garrels (1952) and others, and a theoretical treatment, based on thermo-dynamic data, by Huber (1958), to determine the stability fields for the minerals hematite, siderite, pyrite and others, in terms of acidity (pH) and oxidation-reduction potential (Eh) have produced different results, particularly in the stability field for siderite and the presence or absence of magnetite.

Krumbein and Garrels demonstrated that siderite will form in moderately oxidizing to weakly reducing conditions, the environment required for stability being more highly reducing in alkaline solution (e.g. seawater) than in acid solution. Their experiments apparently did not produce magnetite.

Huber shows a much smaller range of pH and Eh for the formation of siderite, restricted to an acid, oxidizing environment. In the neutral to slightly reducing alkaline zone, magnetite is shown as the stable mineral. Variations in the partial pressure of carbon dioxide, temperature, salinity, sulphur content and the proportions of manganese, magnesium and calcium, of the orders to be expected in nature throughout geological history would vary the range, and to some extent, the position of the various stability fields, but not to such an extent as to invalidate general conclusions reached. Sulphate-reducing bacteria could reduce the oxidation potential and increase the acidity. However the most important departure from theory may result from the slowness of formation of magnetite, as a consequence of which reactions may not attain equilibrium, and very little magnetite may form.

Specimens of drill core from the iron-bearing zone in the ConstanceRange have been mineragraphically examined by Edwards - see above - and he concludes that the oolites underwent local transport at the site of deposition and that the red ochreous hematite was formed at the time of deposition of the beds.

The scarcity of detrital material in the higher grade iron beds, the abundance of oolites, and the widespread crystalline siderite matrix, appear to require the formation of the deposits by chemical precipitation. The hematitic oolites were possibly formed early, in an oxidizing environment, and accumulated in a siderite mud, formed under oxygen-poor, relatively acid conditions.

During diagenesis, in an oxygen-poor environment, the siderite was recrystallized and, in some cases, formed at the expense of the hematite.

Where silt was abundant, chamosite oolites, or chamositic layers on hematite oolites, formed. The chamositic sandstone demonstrates this point. Conclusions reached by Huber lead one to expect the presence of magnetite, particularly as, by analogy with Wabana and Clinton ores, the environment of deposition is believed to have been marine. However, to date no magnetite has been recorded.

On the data available no conclusion can be reached on the role played by colloids or by bacteria. The dearth of detrital material in the higher grade beds suggests that the iron-rich solutions from which the iron minerals were precipitated were either magmatic in origin or were from sluggish, practically silt-free streams. The authors favour the latter view. Accumulation must have been fairly rapid, probably with optimum accumulation in a zone roughly parallel to the strand-line. The widespread distribution of the iron-rich beds, however, appears to exclude the possibility of instantaneous precipitation of iron minerals at the point of mixing of magmatic or river water with seawater.

The presence of poor, thin oolitic ironstone beds at other stratigraphic levels in the Mullera Formation indicates that conditions necessary for the precipitation of iron were attained at more than one period during the deposition of the formation but only at the one period were all conditions met for large scale formation of oolitic iron beds.

COMPARISON WITH OTHER SEDIMENTARY IRON DEPOSITS

There are three main types of sedimentary iron deposit:

1. Banded iron deposits, e.g. Lake Superior iron formations. These generally consist of thinly alternating hematite-magnetite rich bands and chert bands. The rocks are known variously as taconite (North America), itabarite (Brazil) and calico rock (South Africa). Deposits may contain tens of thousands of millions of tons of iron-rich strata but the high grade iron ore, the main source of iron for industry in the past, has been formed by epigenetic processes, generally supergene desilicification and concentration of iron by weathering processes. This type of deposit is restricted to the Precambrian.

2. Oolitic hematite-siderite-chamosite iron deposits of the Constance Range type. In the absence of supergene concentration these form medium to low grade iron ores. Deposits of this type occur at many periods in geological time but are believed not to be forming at the present time. Major deposits include the Wabana, Newfoundland, deposits (Ordovician), the Clinton ores of Alabama, Pennsylvania and New York (Silurian); and the Jurassic iron ores of Great Britain and Western Europe.

3. Bog iron ore; these generally form relatively small deposits and rarely contain more than 50% iron.

The Wabana deposits (Hayes, 1915) most closely resemble the Constance Range deposits. They are Ordovician in age. The ore is oolitic and is of hematite and chamosite, with locally-abundant siderite in the upper bed. Quartz and shell fragments are important constituents of the ore beds. Ripple-marking, cross-bedding and fossil algae are common. The strata adjoining the ore beds are non-oolitic ferruginous sandstone and shale; some contain chamosite.

Hematite is the chief iron-bearing mineral; it occurs mainly in spherules, in many cases laminated with chamosite. The siderite is of later origin than the other iron minerals and commonly has partially replaced oolites, including quartz or shell nuclei. Silica occurs as detrital quartz, fine-grained siliceous material which commonly cements oolites and which was probably derived from a siliceous mud, and introduced quartz. In places phosphorus content exceeds 1% because of the high proportion of organic detritus. It averages about 0.9% P.

There are five iron rich zones, three of which contain ore; one is a pebbly bed rich in pyrite. The thickest ore beds are 30 ft. thick (though not mined over that thickness) and ore beds possibly extend over 70 square miles. Minimum grade of ore shipped is 48% iron and 13.75% silica.

Ores of the Silurian Clinton Formation in eastern U.S.A. extend discontinuously over a distance of nearly 1,000 miles from Alabama through Tennessee, Virginia, Pennsylvania to New York State. Only locally do they form ore beds. One or two beds, up to about 20 feet thick, are mined. The greatest development is in the Birmingham district of Alabama. The Clinton Formation consists of thin beds of ferruginous sandstone (some richly fossiliferous), shale, limestone and oolitic hematite, with abundant cross bedding and some conglomerate (Lindgren, 1933). According to Alling (1947) all the ore beds are calcareous, some being lenses in limestone, formed by diagenetic replacement of limestone.

The main iron minerals are hematite and chamosite. Other iron chlorites, sulphides and oxides are present. Siderite is rare, but calcite, in various forms, is common. Oolites form a large proportion of hematite ore; they commonly consist of interlayered hematite and chamosite with fossil fragments or quartz grains as nuclei.

The primary ores average 39% iron, 11% silica, less than 1% phosphorus, 0.2% sulphur, and 16% calcium oxide. At the surface, leaching of calcium carbonate and silica has resulted in pockets of higher grade "soft" ore.

The Jurassic ores of Great Britain contain no hematite; they are generally of chamositic mudstone or chamositic siderite mudstone. They contain oolites of chamosite set in a matrix of fine-grained chamosite and may also have rhombs and grains of crystalline siderite. A typical section in the Cleveland Hills of Yorkshire contains three ore zones, separated by a few feet of shale, and underlain by sandy sediments. The middle ore zone is the thickest, and is up to 16 feet thick.

The Jurassic ores of Lorraine, France, contain siderite, iron chlorite, hematite and limonite; in places magnetite is also present. The ores occur in a succession of shales, sandstones and marls in a zone 75 to 175 feet thick within which up to eight beds of ironstone may occur. Productive beds occur over an area of about 500 square miles.

Oolites are generally of hematite, with some siderite, set in a calcareous, argillaceous or siliceous matrix. Iron content varies from less than 30% to 40%, silica from 7-20%, calcium oxide from 5-12%, and phosphorus from 1.6 to 1.8%.

ACKNOWLEDGEMENTS

The regional mapping of the Constance Range iron deposits was done during 1958 concurrently with the testing, by systematic drilling, of the deposits by the Broken Hill Proprietary Co. Ltd. and was intended to provide the basis and framework for the more detailed investigation by the Company.

In the course of the work the Company and its officers made available many of the requisites for the project - air photographs, base maps, camping and messing facilities and many of the ancillary services and amenities available in the Company's base camp. Frequent consultation took place between the technical officers of the Company and the Bureau, and the company subsequently made available all drill logs.

Thanks are due, and are freely given to the Company and to those of its officers who helped in this way. The permission to incorporate data from Company records in this report is also acknowledged.

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Plate I

Fig. I. Iron-bearing beds of Deposit C, south-east Constance Range area. The dark beds in the middle foreground and the dark top of the scarp in the left back-ground are iron-bearing beds of the Train Range Iron-bearing Member.

Fig. 2. Looking south-east from the mesa-like Deposit H over typical terrain produced by siltstone, fine sandstone and shale of the Mullera Formation.

Plate 2

Fig. 1. Looking west from Constance Sandstone over Deposit C iron-bearing beds, which dip west at about 30°. Tidna Sandstone in the background.

Fig. 2. Mesa-like Deposit N from ironbeds of Deposit J. Strongly jointed Constance Sandstone appears in the right-hand middle distance and left background.

Plate 3

Fig. 1. Small capping of flat-lying Mesozoic sediments overlying ironstone of Deposit J.

Fig. 2. Exposure in creek bank of soft red shale near the top of the Mullera Formation. The light band is grey-green shale. Photo looking south-east with Tidna Sandstone at east end of Deposit A in the background.

Plate 4

Fig. 1. Flaggy Constance Sandstone in gorge of Musselbrook Creek between Deposits G and N.

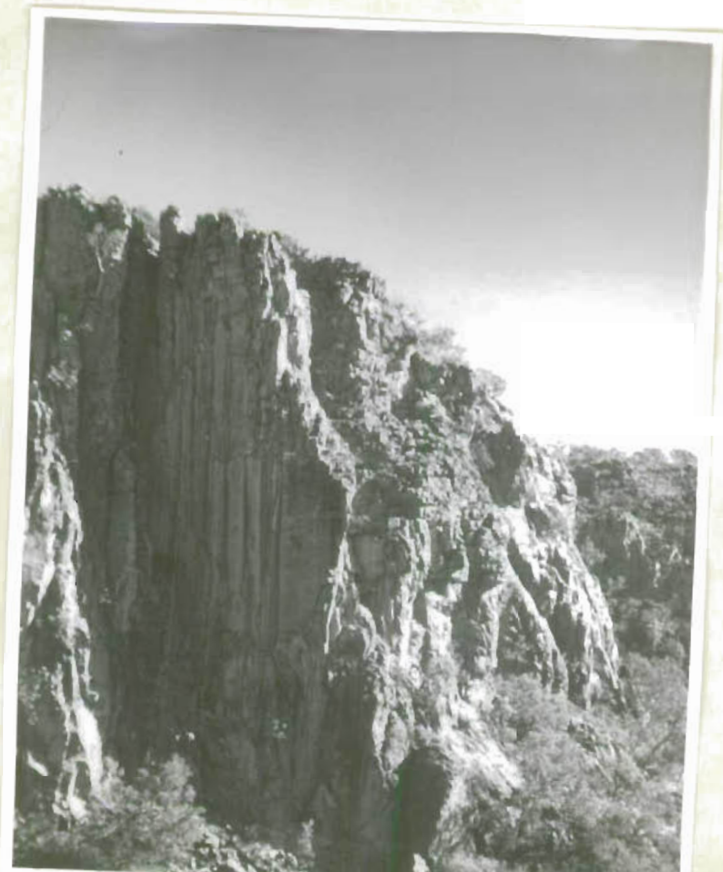


Fig. 2. Close view of portion of Constance Range scarp, north-east of Deposit D.

Plate 5

Fig. 1. Sandstone lenses, probably filling scour channels, in the Mullera Formation on Stockyard Creek, north-west of Deposit H.

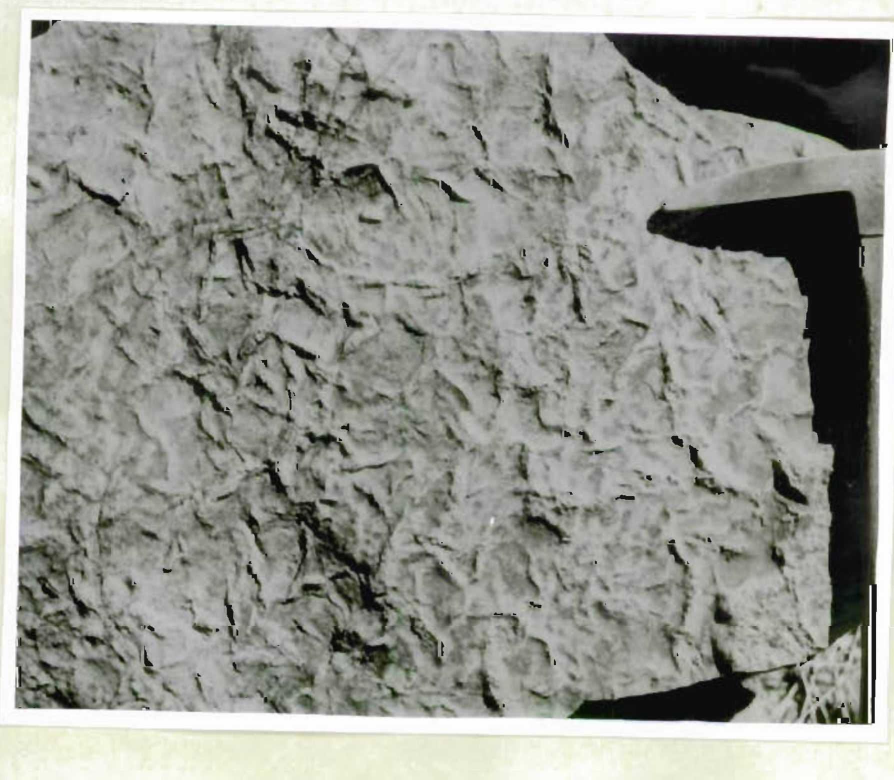


Fig. 2. Mudcracks, lower surface of bed. Deposit E.

Plate 6

Fig. 1. Slump or flow structure at base of sandy bed, and scour-and-fill at top of bed. Middle siltstone, Mullera Formation, Deposit A.

Fig. 2. Cross-bedding in Middle Creek Sandstone Member, in the most north-westerly occurrence of the member.

Plate 7

Fig. 1. Near view of Deposit N, a shallow-dipping mesa-like deposit from the north-west. Very poor siliceous ironstone and ferruginous sandstone crop out in the middle and upper [illegible] of the scarp. The lower iron zone (see p. 23) lies within the [illegible] area below the scarp.

Fig. 2. Deposit G, on the south side of Stockyard Creek - a typical strike ridge, or hog back, type of exposure. This is the most common mode of outcrop of the iron-bearing beds.

Plate 8

Fig. 1. Deposit J, another typical hog-back type of outcrop. The beds in the foreground dip 20° to the north-east. The outcrop continues to the right then swings to the left to form the scarp in the background.

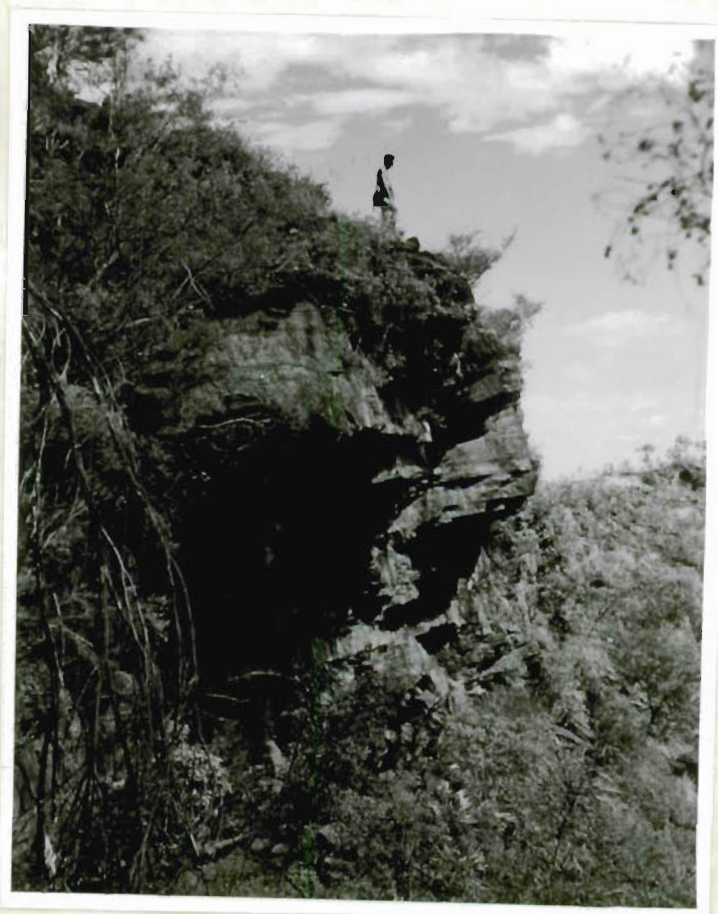


Fig. 2. Close view of iron beds in Deposit E - a typical exposure

Plate 9

Fig. 1. Low-grade iron beds, mainly ferruginous sandstone, underlain by siltstone, Deposit M.

Fig. 2. Concentric iron-rich laminae produced by the weathering of siliceous ironstone, Deposit E.

Plate 10

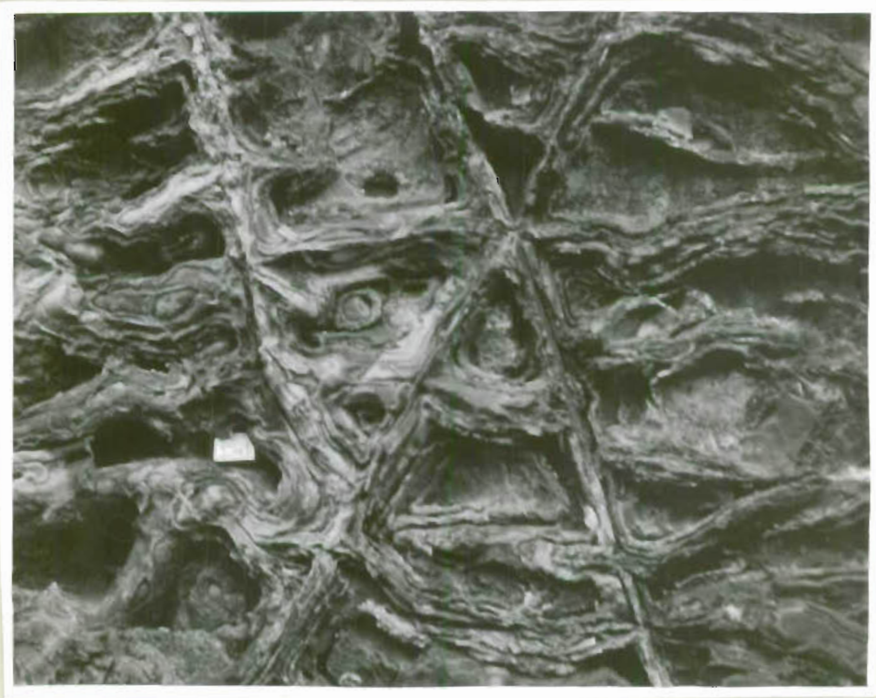


Fig. 1. Limonite concentrated along joints in the roof of a shallow cave, or overhang, in the scarp of Deposit I. A matchbox indicates scale.

Fig. 2. Shale upturned by drag on a fault between Deposits J and N. Iron beds of Deposit J dip shallowly in the left background.

Plate 11

Fig. 1. Iron beds downfaulted against the Constance Sandstone, northern part of Deposit M. The stratigraphic displacement exceeds 1,000 ft.

Fig. 2. Deformation of Middle Cambrian siltstone by reverse faulting in the Little's Range fault zone.

GRAPHIC LOGS OF IRON-BEARING SECTIONS OF SELECTED DRILL CORES.

PLATE 12

ADAPTED FROM LOGS BY C. P. TAYLOR, THE BROKEN HILL PROPRIETARY CO. LTD.

The logs are based on visual inspection only. Silt-size sediments have been logged as either shale or fine-grained sandstone.

REFERENCE

- Soil and alluvium
- Sandstone
- Shale
- Interbedded shale and sandstone
- Erosional breccia
- Conglomerate
- Chamosite
- Contemporaneous erosional break
- Ironstone
- Siliceous ironstone
- Ferruginous sandstone

ABBREVIATIONS

Hem.	-	Hematite
Sid.	-	Siderite
Cham.	-	Chamosite
Pyr.	-	Pyrite
Ss.	-	Sandstone
Qte	-	Quartzite
Sh.	-	Shale
Mic.	-	Micaceous
V.	-	Veinlets
Contemp.	-	Contemporaneous

PLATE 13

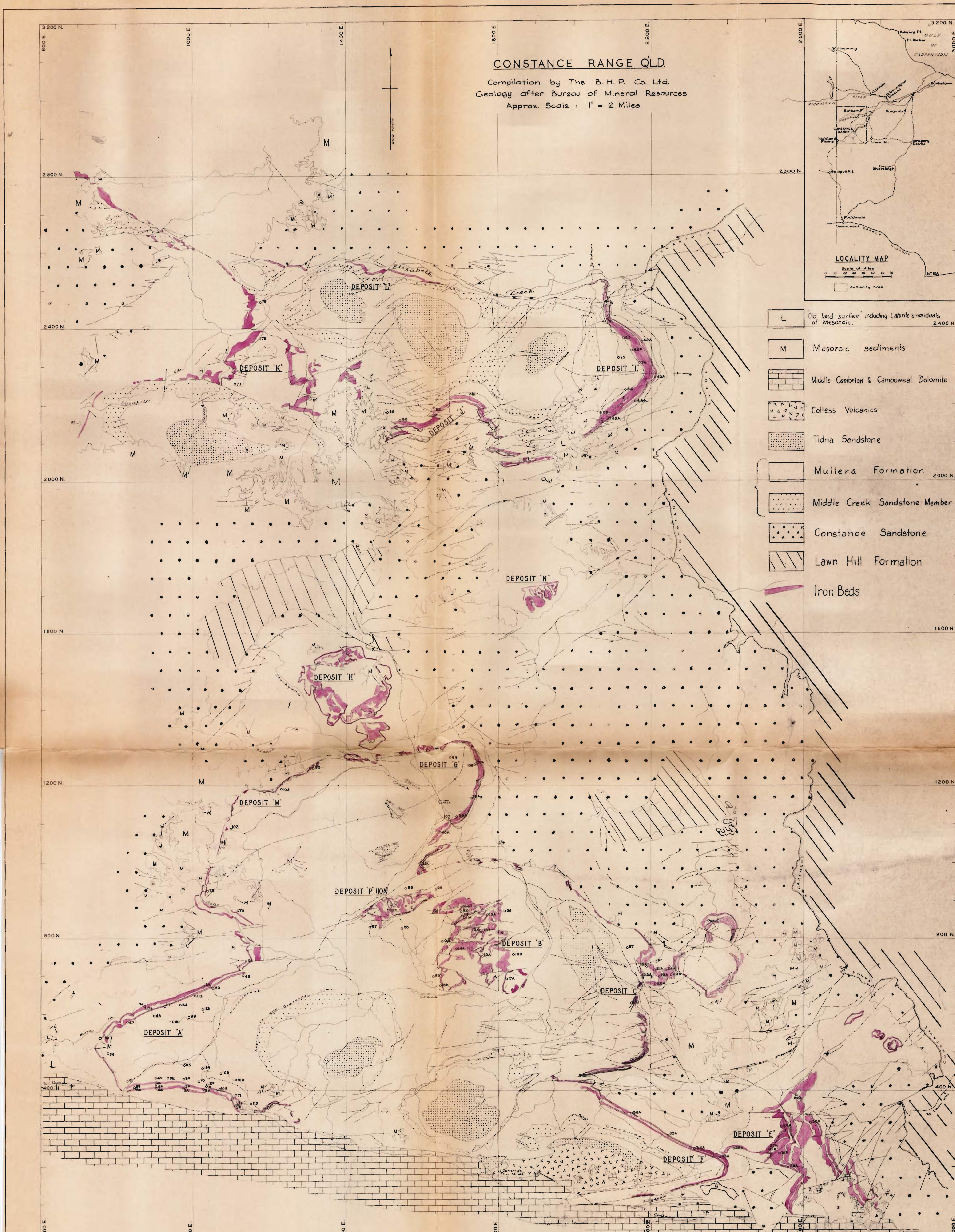

CONSTANCE RANGE Q'LD.
Compilation by The B.H.P. Co. Ltd.
Geology after Bureau of Mineral Resources
Approx. Scale : 1" = 2 Miles
LOCALITY MAP
L Old land surface including Laterite & residuals of Mesozoic.
M Mesozoic sediments
Middle Cambrian & Camooweal Dolomite
Colless Volcanics
Tidna Sandstone
Mullera Formation
Middle Creek Sandstone Member
Constance Sandstone
Lawn Hill Formation
Iron Beds
DEPOSIT 'L'
DEPOSIT 'K'
DEPOSIT 'J'
DEPOSIT 'I'
DEPOSIT 'N'
DEPOSIT 'H'
DEPOSIT 'G'
DEPOSIT 'M'
DEPOSIT 'P' (10A)
DEPOSIT 'B'
DEPOSIT 'C'
DEPOSIT 'A'
DEPOSIT 'E'
DEPOSIT 'F'
Elizabeth
Creek
3200 N.
2800 N.
2400 N.
2000 N.
1600 N.
1200 N.
800 N.
400 N.
600 E
1000 E
1400 E
1800 E
2200 E
2600 E
3000 E
5th. March 1959

PLATE 14

800 N
400 N
80 E
Constance Sandstone
Soil Cover with Rubble of Constance and Mullera
Alluvium
C3 and Rubble
Iron Bed
Dip Slope
Viro Range
Dip Slope
Rubble
Alluvium
Lateritic Crust with Mesozoic and Quartzite projecting through
Fault Rubble
Cambrian Limestone
Flat Lying Camooweal Dolomite
Little's Range Fault
Scree Slope
DDH 4A
DDA 63
DDA 64
DDH 3A
DDH 7B
DDA 67
DDH 6A
DDA 66
DDA 65
DDA 61
DDA 62
DDH 4
DDH 3
DDH 5
DDA 68
A
A'
B
B'
D
Scale 1 inch = 1700 feet approx.
Approximate Stratigraphic Section — To Date
M
Mesozoic and Laterite
Cambrian — fossiliferous Siltstones and Limestones
Camooweal Dolomite
Tidna Sandstone — includes sandy siltstones
Thin bedded Shales and Siltstones distinctly purple towards the top — micaceous
Sandstone Member — Thin Iron beds on top
Thin bedded Shales and Siltstones — micaceous
Siliceous — dominantly grey green — magnesite interbedded becoming sandy towards top
See Enlargement
Siltstones and Shales with magnesite and Sandstones and Sandy Silts from the middle down
Mullera Formation
Constance Sandstone
Alluvium boundary
Geological boundary
Roads
Fault — position approximate
Fault — inferred or indefinite
Shear Zone with breccia
High grade Iron
Low grade Iron
Enlarged Iron Section (idealised)
Scale 1" — 100 feet.
Siltstones
Quartzites with Iron Pebbles overlying low grade Iron Bed — oolitic — ferruginous quartzite or silts
Reddish Siltstones
Quartzite with Iron pebbles at base
Iron bed — oolitic — quartzite and siltstones higher grade
Siltstones — micaceous
Quartzite
Siltstones
A DEPOSIT SHEET 1
FIELD SHEET ONLY
Photoscale 1 inch — 1700 feet approximately
Sheet 2 Joins

PLATE 15

A DEPOSIT SHEET 2

For legend see Sheet 1


PLATE 16
M DEPOSIT
FIELD SHEET ONLY
CONSTANCE RANGE AREA SHEET 3
Scale 1 inch = 1700 feet approximately
Trend lines - generalised
Fold Axis - approximate
O.L.S. Old Land Surface
M Mesozoic
Tidna Sandstone
Mullera Formation
Constance Sandstone
Low Dip - showing direction
Shear Zone - with breccia
Fault - definite {position approximate / where line broken}
Fault - indefinite or inferred
Iron Bed - {position approximate / where line broken}
Minor Fold - showing plunge
Alluvium Boundary
Formation Boundary - position approximate
IRON BEDS
Upper
Lower (main)
Undifferentiated
SHEET 5 JOINS
SHEET 4 JOINS
SHEETS 1 and 2 JOIN
Mesozoic
1200 N
DDM 103
DDM 102
D.D.M.72
D.D.M.73
D.D.H.104
Main Iron
Upper
Rubble
dip variable & disturbed??

DEPOSITS B & 10A (P)
CONSTANCE RANGE
SHEET 4
PLATE 17
Sheet Key
SCALE 1 inch = 1700 feet (approx)
Map prepared from uncontrolled mosaics (same scale)
Sheet 6 Overlaps
Sheet 13 Overlaps
Reference
Old Land Surface Caps
Tidna Sandstone Member
Mullera Formation
Iron Bed - undifferentiated
Upper Iron Bed - and associated quartzites - < 20' thick
Lower Iron Bed - Main Iron ± 35' thick
Mullera Formation showing quartzite bed
Constance Sandstone
Mullera Formation
Geological Boundary - position approximate
Geological Boundary - inferred or indefinite
Alluvium Boundary
Fault - position approximate
Fault - indefinite or inferred
Fault - throw less than 20 feet
Shear Zone with breccia
Strike and dip of inclined strata
Horizontal Strata
Near flat strata - showing dip direction
Minor Fold - showing plunge
Track
Level Peg - surveyed height above base
Drill Hole or Proposed Site
Drill Site 10A.4
Drill Site 10A.3
Drill Site 10A.2
Drill Site 10A.1
Drill Site B2
Drill Site B3
Drill Site B4
DDH.10A
DDH.11A
DDH.15A
DDH.13B
DDH.14A
DDH.12A
DDH.17A
DDH.16A
Lateritic Rubble
Quartzites in part Fe rich
Collapsed blocks of Iron here
Rubble Cover
Misery Creek
To Deposit A Camooweal
800 N
1600 E
C3

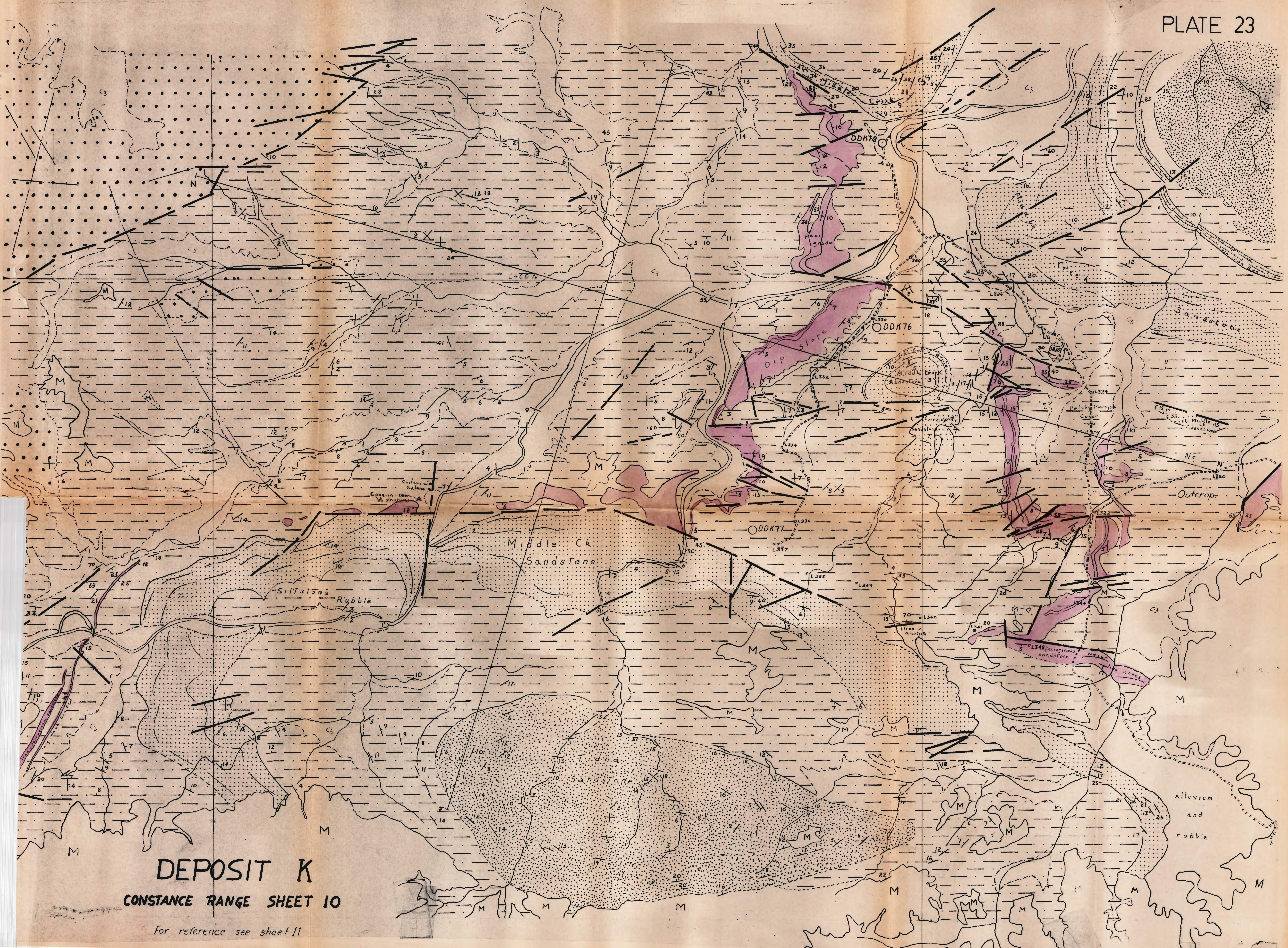
PLATE 18
Sheet 5

PLATE 19
DEPOSIT G
CONSTANCE RANGE
SHEET 6
SCALE (Photoscale) 1 inch = 1700 feet
Map prepared from uncontrolled mosaics
Sheet Key
1
2
3
4
5
6
7
8
Reference
O.L.S. Old Land Surface or Laterite
Mesozoic
Tidna Sandstone Member
Mullera Formation - with quartzite bed
Upper Iron Lens
Middle Iron Bed =?? upper iron-qtzite of Deposits A, B, 10A.
Lower Iron Bed (main iron)
Iron Bed - undifferentiated
Mullera Formation
Constance Sandstone
Trend Line
Alluvium Boundary
Geological Boundary - approximate
Geological Boundary - indefinite
Fault - position approximate
Fault - inferred or indefinite
Fault - throw less than 20 feet
Shear Zone
Fold Axis - showing
Fold Axis - inferred
Strike and Dip - inclined strata
Horizontal Strata
Near Flat Strata - showing dip
Minor Fold - showing plunge
Drill Hole or Proposed Site
Track
Alluvium
Cz
Drill Site G3
DDH 37A
Drill Site G2
DDH 38A
DDH 39A
Drill Site G1
DDH 40A
DDH 41A
Drill Site 10A
Drill Site B1
Drill Site B2
DDH 11B
DDH 11A
DDH 15A
Fault Zone
Rubble Cover
1000 E
2000 E
True N
Grid

DEPOSIT N
CONSTANCE RANGE SHEET 7
Approximate Scale in Feet
0 500 1000 1500 2000 4000 6000 8000 10,000
Reference
O.L.S
M
Soil and Alluvium
Old Land Surface or Laterite
Mesozoic
Mullera Formation
Constance Sandstone
Upper Proterozoic
Iron Beds within the Mullera Formation
Upper Beds – generally high grade
Middle Group of Beds – generally low grade
Lower Bed
Fe
Thin Iron Bed – no economic interest
Symbols
Geological Boundary – position approximate where line broken
Alluvium or Laterite Boundary
Fault, position accurate, showing dip
Fault, position accurate vertical dip
Fault, probable or inferred (photo-interpreted)
Shear Zone
Minor Fold, showing pitch
Bedding, strike and dip, inclined strata
Bedding, strike and dip, vertical strata
Bedding, flat lying strata.
Bedding, almost flat lying – less than 3°
Bedding, strike and dip, photo-interpreted
Edge of escarpment
Watercourse, channel ill defined
Waterhole
Spring
Road
Geological Trend Lines
PLATE 20
Sheet Key
1
2
3
4
5
6
7
True
Grid
N
? Laterite
2000 N
1600 N
1600 E
2000 E
Fe Rubble
W.H.
Spr


DEPOSIT I
CONSTANCE RANGE SHEET 8
SCALE
0 1000 2000 4000 6000 8000 10000'
Distance in feet approximately
Map prepared from uncontrolled mosaics - same scale
Sheet Key
9 8 7 5 3 6 4 1 2
Reference
PLATE 21
Alluvium - soil and rubble
Old Land Surface - includes laterite
Mesozoic Caps
Tidna Sandstone
Sandstone Beds - persistent
Mullera Formation
Constance Sandstone
Upper Proterozoic
Mullera Formn
Lawn Hill Formation - Lower Proterozoic
Iron Zones within Mullera Formation
Upper Iron Zone - includes 2 or more thin beds
Middle Iron Zone - generally 2 thin (<10') beds sandy
Lower Iron Zone - 1-2 beds ± 10' each
Geological Boundary - approx. where broken
Geological Boundary - indefinite or inferred
Alluvium Boundary
Trend Line
Fault - position definite
Fault - position approximate
Fault - position indefinite or inferred
Shear or Strain Zone
Synclinal Axis - approximate
Bedding - strike and dip
Bedding - horizontal
Bedding - slightly inclined <2°
Bedding - photo interpreted
D.D.I. 79 Drill Hole
L.450 Survey Peg
Road
Watercourse - channel ill defined
Escarpment
N
True
Grid
Fault Zone
Alluvium and Rubble
Alluvium and Rubble with scattered Outcrops
Elizabeth Creek
Fault
Alluvium
Scree Slope
Dip Slope
DDI 73
DDI 83
DDH 42A
DDH 42B
DDI 75
DDI 74
DDI 43A
DDI 84
DDH 43
DDI 86
DDH 45A
Laterite Rubble
Constance Range Escarpment
Much Faulting
PART 3 of 3

DEPOSITS J & L
CONSTANCE RANGE SHEET 9
SCALE
2000 1000 0 2000 4000 6000 8000 feet
Map prepared from uncontrolled mosaics - same scale
Sheet Key
N
True
Grid
Reference
PLATE 22
Old Land Surface
Mesozoic and Laterite Caps
Tidna Sandstone
Sandstone Beds - persistent
Mullera Formation
Constance Sandstone
Mullera Formation
Iron Zones within Mullera Formation
Upper Iron Zone
Middle Iron Zone
Lower Iron Zone
Undifferentiated Iron Zone
Geological Boundary - approximate where line broken
Alluvium Boundary
Trend Line
Fault - position approximate where line broken
Fault - position indefinite or inferred
Zone of Shearing or Strain
Bedding - Strike and Dip - inclined strata
Bedding - horizontal strata
Bedding - gently dipping - 2° or less
Bedding - attitude photo interpreted
Drill Hole
Survey Peg
Road
Watercourse ill-defined
Faulted Area
Sand and Alluvium
Elizabeth Ck
Alluvium and Rubble with small scattered outcrops
Tidna Sandstone
Alluvium and Rubble
Middle Creek
Mesozoic and Laterite
ODDJ81
ODDJ82
ODDJ85
ODDJ80



DEPOSIT K

CONSTANCE RANGE SHEET 10

For reference see sheet II


DEPOSIT K
CONSTANCE RANGE SHEET 11
PLATE 24
SCALE
0
1000
2000
4000
6000
8000
10000
Distance in feet
Map prepared from uncontrolled mosaics same scale
Sheet Key
11
10
9
8
7
5
6
3
4
1
2
Grid North
Reference
Alluvium - soil and rubble
Old Land Surface - includes laterite
Mesozoic Caps
Tidna Sandstone
Sandstone Beds - persistent
Iron Zones
Mullera Formation
Constance Sandstone
Mullera Form.
Upper Proterozoic
Geological Boundary - approx. where broken
Geological Boundary - indefinite or inferred
Alluvium Boundary
Trend Line
Trend Line - Significance Unknown
Fault - position definite
Fault - position approximate
Fault position indefinite or inferred
Fault position concealed
Bedding - strike and dip
Bedding - horizontal
Bedding - photo interpreted
DDK76
Drill Hole
BL32A
Survey Peg
Road
No Outcrop
No Outcrop
3800 N
Ironstone rubble in creek
Thin patchy Mesozoic over Mullera
Thin Iron Bed flat-lying
Middle Ck Sandstone
Zone of slight dislocation No fault movement observed
Middle Creek Sandstone
Siltstone rubble
Creek
Sandstone
8OOE
12OOE
M

Reduce AB (20") to AC (3") to give Scale 1 Inch = 2 Miles

CONSTANCE RANGE
IRON DEPOSITS.

NORTH-WESTERN QUEENSLAND.

DEPOSIT D
and portion of
DEPOSIT C.

approximate scale – feet.
0 2000 4000 6000

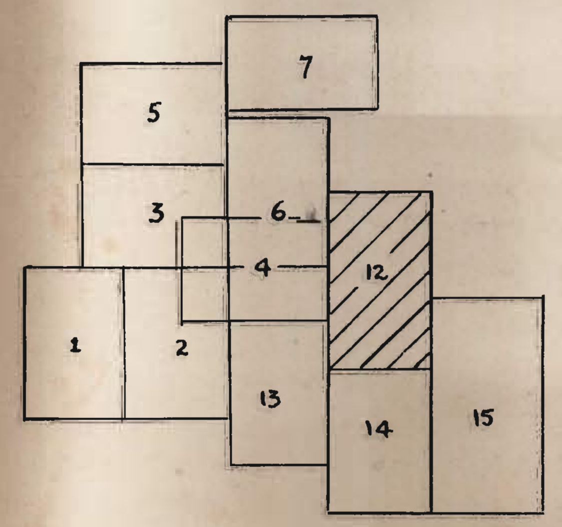
Geology by M. A. Randal, E. K. Carter, C. H. Shipway } Sept. – Oct. 1958

Compiled Jan. 1959.

Reference.

C3	Soil and Alluvium.
M	Mesozoic.
	Tidna Sandstone.
	Mullera Formation.
	Constance Sandstone.
Plf	Lawn Hill Formation.
	Iron beds.
	Sandstone in Mullera Formation.
L	Laterite.
	Geological boundary, position accurate.
	Alluvium boundary.
	Established fault, position accurate.
?	Probable or inferred fault, position accurate.
	Shear zone.
10	Bedding dip and strike, measured.
	Bedding dip and strike, photo-interpreted.
+	Horizontal strata.
	Trend line.
D.D.C.104, D.D.H 25A	Diamond drill holes.
L104	Survey Peg.
	Vehicle track.
W.H.	Water Hole.

Sheet Key.



SHEET 13.
PLATE 26

Constance Range Iron Deposits.

North-western Queensland.

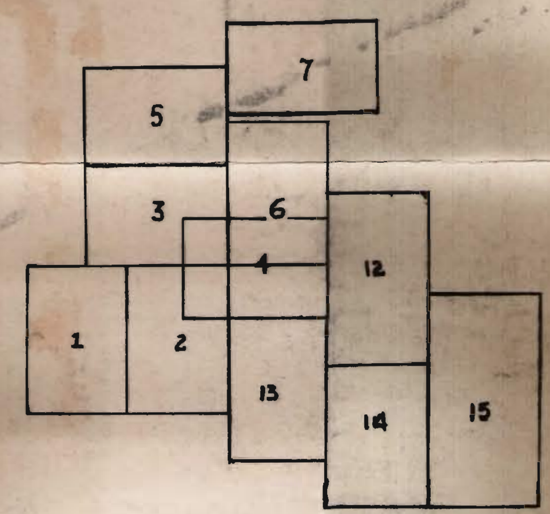
Approximate Scale — Feet.

0 2,000 4,000 6,000 8,000 10,000

Geology by C.H. Shipway. October 1958.
Compiled by E.K. Carter.

Map based on uncontrolled photo-mosaic.

Sheet key.



Cz Soil and Alluvium.

M Mesozoic — sandstone and siltstone.

Єm Middle Cambrian — breccia, siltstone and limestone.

Puc Camooweal Dolomite.

Єo Colless Volcanics — basalt.

Tidna Sandstone.

Mullera Formation — siltstone, shale, sandstone, iron beds.

Iron beds undifferentiated.

Fe Sub-economic sedimentary iron bed. (in Tidna Sandstone).

Geological boundary, position accurate.

Geological boundary, indefinite or position approximate.

Alluvium boundary.

Established fault, position accurate.

Probable or inferred fault, position accurate.

10 Bedding dip and strike, measured.

Bedding dip and strike, photo-interpreted.

Trend-line.

L180 Survey peg.

Vehicle Track.

W.H. Waterhole.

Cu Copper workings.

Sandstone beds, generally quartzitic.

Breccia.

A C Reduce AB (20") to AC (3") to give Scale 1 Inch ≡ 2 Miles B

SHEET 14.

PLATE 27

Constance Range Iron Deposits —— Deposit F and portion of Deposit C.

North-Western Queensland.

Geology by C. H. Shipway, M. A. Randal, E. K. Carter — Oct. 1958.

Compiled by E. K. Carter Jan. 1959.

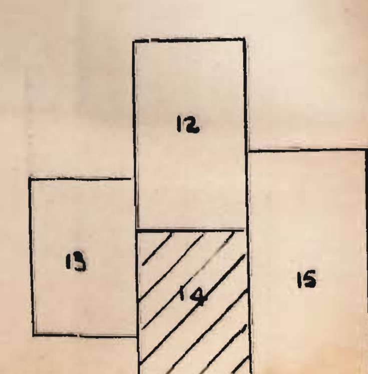
- C3 — Soil and Alluvium.
- M — Mesozoic. — sandstone and siltstone.
- Єm — Middle Cambrian — breccia, siltstone and limestone.
- Єo — Colless Volcanics — basalt.
- Єuc — Camooweal Dolomite.
- Tidna Sandstone.
- Mullera Formation. — siltstone, sandstone, shale, iron beds.
- Constance Sandstone.
- Iron beds.
- Sandstone in Mullera Formation.
- Breccia — ? Middle Cambrian.

Approximate Scale – Feet.

0 2000 4000 6000 8000 10,000

- Geological boundary, position accurate.
- Geological boundary, indefinite or position approximate.
- Alluvium boundary.
- Established fault, position accurate.
- Established fault, position approximate.
- Probable or inferred fault, position accurate.
- Bedding dip and strike, measured.
- Bedding dip and strike, photo-interpreted.
- Horizontal strata.
- Trend line.
- DDC 104, DDH 36A — Diamond Drill Holes.
- L201 — Survey Peg.
- Vehicle track.

Sheet Key.



SHEET 15.

PLATE 28

Constance Range Iron Deposits

North - Western Queensland.

Deposit E.

Approximate scale - Feet

0 2000 4000 6000 8000 10,000

Geology by E.K. Carter, M.A. Randal } October 1958

Compiled by E.K. Carter January 1959.

Reduce AB (3½") to AC (4.5") to give Scale 1 Inch = 2 Miles

Reference.

Cz	Soil and Alluvium.
M	Mesozoic - sandstone and shale.
Cm	Middle Cambrian - chert.
? Pℓc	Camooweal Dolomite.
? Co	Colless Volcanics - basalt.
	Mullera Formation - siltstone, sandstone, shale and iron beds.
	Constance Sandstone.
Pℓf	Lawn Hill Formation. - lower Proterozoic.
	Iron beds.
	Sandstone in Mullera Formation.
	Geological boundary, position accurate.
	Geological boundary, indefinite or position approximate.
	Alluvium boundary.
	Established fault, position accurate.
?	Probable or inferred fault, position accurate.
10	Bedding dip and strike, measured.
	Bedding dip and strike, photo-interpreted.
+	Horizontal strata.
	Trend line.
	Escarpment.
DDH 36A	Diamond Drill hole.
L218	Survey Peg.
	Vehicle track.
W.H.	Water hole.
Spr.	Spring.
Fe	Ironstone.

Upper Proterozoic (bracketing Camooweal Dolomite to Constance Sandstone)

Sheet Key.