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THE GEOLOGY AND MINERAL DEPOSITS OF THE MUNGANA, CHILLAGOE, AND ALMADEN 1-MILE SHEETS, NORTH QUEENSLAND

(PART I)

by

F. de Keyser, M. B. Bayly & K. Wolff.

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FOREWORD : USE OF TERMS

Granite - where no specification is needed, includes all acid igneous rocks with grains over 1 mm. - adamellite, granodiorite, syenite and monzonite compositions and textural modifications such as granophyre; its use does not exclude origins such as refusion and metasomatism.

Granulite - implies a rock composed mainly of equidimensional grains, whose texture is attributed to metamorphism, not to first consolidation.

Greywacke and quartz greywacke - imply sediments texturally and mineralogically immature, with moderate to poor sorting and rounding, containing considerable feldspar, mica and rock fragments, and a varying amount of a siliceous or micaceous, more rarely clayey matrix. The quartz greywackes contain a higher proportion of quartz and commonly a more siliceous matrix; the greywackes are richer in feldspar, mica, and sericitic clayey matrix.

SUMMARY

This report contains the results of five months field work carried out by a joint geological party from the Bureau of Mineral Resources and the Queensland Geological Survey, between April and October, 1958. The area investigated is within the Atherton 4-mile sheet boundaries in North Queensland.

Metamorphosed and migmatized pre-Silurian schist, gneiss and muscovite granite are overlain by folded Palaeozoic limestones, cherts, clastic sediments and tuffs, with a few basaltic flows. Age of the sediments ranges from Silurian in the west to Devonian or later in the east. Several formations are distinguished, some of which have similar lithologies though geographically separated. The above-mentioned units are all intruded by a batholith composed mainly of hornblende-biotite granodiorite. Acid and intermediate porphyries were emplaced in several phases, intrusive and extrusive and outlasted the intrusion of the granite.

Associated with the granite is a widespread mineralization, which has given rise to numerous deposits of copper, lead, zinc,

silver, gold, tungsten, molybdenum, bismuth, tin, fluorspar, iron and mica, all of which have been mined intermittently though no mining of importance was being carried on at the time of the survey. Most deposits are of contact-metasomatic or pneumatolytic to hydrothermal type.

INTRODUCTION

A. GENERAL

Situation and Access

An area of about 2,000 square miles is covered by the Mungana, Chillagoe and Almaden 1-mile sheets, between longitudes 144° and 145°E. and latitudes 17° and 17°30'S. (Fig. 1). The small towns of Chillagoe, Almaden and Petford are connected by railway and by road with Cairns which is 145 road miles east of Chillagoe. Airstrips suitable for small aircraft are maintained at Chillagoe and at the Sunnymount battery.

Climate

The area has a dry winter and a wet summer season, and lies just within the semi-arid belt west of the Queensland coastal rain forest. The average annual rainfall is between 30 and 40 inches, with a strong concentration during the summer months and a monthly average of about one inch during the winter season. The mean daily temperature ranges from 60° in the winter season to 80° during the summer.

Purpose of the Survey

The survey was undertaken:

(a) as part of the regional geological mapping of the Atherton 4-mile sheet;

(b) to locate and investigate the mineral deposits; and

(c) to remap in detail the Chillagoe Formation.

Fieldwork

The mapping was carried out between April and October 1958 by a party comprising two geologists from the Bureau of Mineral Resources (F. de Keyser and M. B. Bayly) and a geologist from the

Queensland Geological Survey (K. Wolff). Aerial photographs taken by R.A.A.F. on a scale of approximately 1:47,000 were used in the field and for compilation of the results, and A.G.G.S.N.A. photographs on a scale of 1:12,000 were available for the detailed work in the environs of Mungana and Chillagoe. Plotting of this detailed mapping was carried out on enlargements to 1:12,000 of the R.A.A.F. photographs.

B. PREVIOUS INVESTIGATIONS

Since 1887, much has been published on the mineral deposits in the area, whereas comparatively little attention has been given to the regional geology. The most comprehensive studies were made by Jensen (1923, 1941) and, in the more restricted area between Mungana and Chillagoe, by Broadhurst (1952, 1953). An account of the Dargalong Metamorphics was given in a report by Ball (1918).

After 1946, several mining companies took renewed interest in the area and Authorities to Prospect were given, among others, to Broken Hill South Ltd. (Mungana-Redcap area, 1947); to Clutha Development Ltd. (1956, 1957); to Metals Exploration Ltd (1956); and to New Consolidated Gold Fields Ltd. (1957, 1958) for the eastern part of the area. In the course of these activities, diamond-drilling was carried out at Redcap, on the Cambourne lode, and in the Mungana group of leases. In 1954, the Bureau of Mineral Resources carried out an airborne scintillometer survey which included the Chillagoe area (Parkinson & Mulder, 1956). This was followed up by a closer-spaced, combined magnetometer and scintillometer survey of the Chillagoe area in 1958, the results of which have not been published yet. In 1956, systematic reconnaissance mapping by a joint survey of the Bureau of Mineral Resources and the Queensland Geological Survey included most parts of the present area (White and Hughes, 1957).

C. PHYSIOGRAPHY

Moderate altitude and moderate relief characterize the area, which is part of a topographical system that slopes gently down from the Atherton Tablelands in the east (over 2,000 ft.), to the low sandy plains and alluvium of the Gulf Coast in the west. This tilt to the west is noticeable within the area mapped in the altitudes of places between Batcha (1,971 ft.) and the Cardross area (c. 600 ft.). The maximum elevations are found in the Featherbed Range, where the highest tops are an estimated 2,500 ft. above sea level.

The form of the landscape is controlled to a marked extent by lithology. Gently undulating country is characteristic of the Dargalong Metamorphics in the west, though the gneisses and granulites form rough surfaces in places; the porphyries form rough uninhabited ranges commonly with strong relief; the Chillagoe sediments and the granite areas are the site of moderately flat country, in which the limestones crop out as jagged bluffs and ridges about 150 ft. high. The chert ridges, in contrast, are characterized by rounding and smoothness. Finally, in the west, erosion of the Mesozoic sandstone cover has results in the formation of typical mesas.

The area is drained by the Walsh River system, which flows into the Gulf of Carpentaria via the Mitchell River. The creeks are consequents, with a valley morphology that is generally mature. In the Featherbed Range however, the valleys have a youthful aspect: they are deeply incised and contain many waterfalls. The rectilinear valley pattern in the Featherbed Range is to a large extent controlled by the joints in the porphyries.

Most streams flow only intermittently. The larger ones, such as the Walsh River, Emu Creek and Crooked Creek, retain a string of disconnected waterholes during the dry season. In the limestone country there are many springs, some of which have enough discharge to maintain a permanent waterflow; Chillagoe Creek is a good example.

REGIONAL GEOLOGY

The following geological units are distinguished:

1. The Pre-Silurian gneisses, schists and granulites of the Dargalong Metamorphics, which occupy most of the Mungana 1-mile sheet.

2. The Silurian limestones and cherts of the Chillagoe Formation.
3. Clastic Siluro-Devonian sediments of the Herberton Beds and Hodgkinson Formation. These occur in several areas separated from each other by igneous rocks.
4. Acid plutonic rocks of post-sedimentation age, which occupy large tracts of the Chillagoe and Almaden sheets.
5. Porphyries of acid and intermediate composition. As well as dykes, sills and isolated flows, these form large masses of lava and tuff, ejection of which took place in several phases and outlasted the period of granite intrusion.
6. Flat-lying Mesozoic sandstone, which unconformably overlies the schists in the extreme western portion of the Mungana sheet.

The folded Palaeozoic and pre-Silurian rocks are probably separated by an unconformity. They are both intruded by the granites.

A. STRATIGRAPHY

Pre-Silurian

(a) The Dargalong Metamorphics

These rocks, first named by Skertchly (1899), and described by Ball (1918), crop out over most of the area covered by the Mungana 1-mile sheet. They are overlain by a blanket of Mesozoic sandstone in the west, by porphyritic volcanics in the north and by the Chillagoe Formation in the east; to the south they extend beyond the limit of the Mungana Sheet. The grade of metamorphism has not yet been studied, but the presence of garnet amphibolite and of albite (Jensen, 1941) suggest the albite-epidote amphibolite facies. The rocks consist of mica schist, gneiss, granulite, muscovite pegmatite, granitic rocks, quartzite and amphibolite. Between these varieties, transitions are widespread: with decreasing mica content, the schist grades into gneiss or granulite; some of the granulite strongly resembles muscovite granite; and the muscovite granite occasionally becomes gneissic by development of biotite-rich bands, or pegmatitic by uneven crystal growth.

The schists are commonly folded and crenulated, with amplitudes from a few millimetres to several feet. Mica is nearly always present, with muscovite generally more abundant than biotite, though some biotite rich muscovite-poor rocks occur.

With decreasing mica content in the schist, the highly schistose character is lost, and this leads finally to gneissic and granulitic rock types. Some gneiss has conspicuous augen structure, with large feldspar porphyroblasts of eyes of quartzo-feldspathic material. A few gneisses may have originally been conglomeratic or pebbly sediments, in which the original pebbles became drawn out. Where foliation is weak, the gneiss grades into granulite.

Granulite with the righ mineralogical composition strongly resembles muscovite granite, and it is often not possible to distinguish them in the field. The granite is not obviously intrusive and contacts seem vague and gradational.

Quartz-feldspar-muscovite pegmatites are abundant in many areas, particularly where granitic and granulitic rock varieties predominate. The veins are generally parallel to bedding or foliation but cross-cutting veins are not uncommon. The components are quartz, feldspar and muscovite in grains several inches across.

The quartzite, which has its greatest extent in the north-west section, is generally a slabby, thoroughly recrystallized, white to grey, or more rarely, dark rock. Ripple-marks have been preserved in rare cases.

Amphibolite bodies occur in great numbers in certain areas but are uncommon in others. They are particularly abundant in the eastern exposures of the formation where they form uniform sheets intercalated with the schist and gneiss as well as irregular masses. Garnetiferous members are occasionally found. The degree of foliation is rather variable: the texture ranges from highly schistose to practically non-schistose. Evidence of origin is lacking except for the irregular bodies, whose shapes point to igneous intrusion.

In parts of the area, metamorphism has been accompanied by migmatization or granitization: quartzo-feldspathic material has impregnated country rock, or has penetrated as lenses, tongues and seams along and across foliation planes (fig. 2); irregular plastic folding is common, and strongly porphyroblastic gneisses abound. Gneiss is seen to grade into granite with loss of foliation. In one place, changes probably due to migmatization could be followed along the strike of a biotite schist; they included an increase in grain size, an increase in size and quantity of muscovite, development of feldspar porphyroblasts and quartz-feldspar lenses, and veins which commonly have a biotite-rich margin.

The Dargalong Metamorphics were probably derived from aluminous and siliceous sediments relatively rich in potassium, which were metamorphosed and granitized presumably at medium to great depths. Their age cannot at present be established more precisely than pre-Silurian.

(b) The Boundary with the Palaeozoic

The Chillagoe Formation, which bounds the Dargalong Metamorphics on their north-east edge, contains conspicuous conglomerate lenses of sedimentary origin (p. 11). The pebbles include many metamorphosed rock type that were derived from the Dargalong massif; it is therefore concluded that an episode of erosion separates the two formations.

Observations made along the actual boundary are less conclusive than the above. Jack (1891) found the boundary "intergrading" and Ball (1918) found it "abrupt". The present survey found that in most places the boundary is sharply defined, but a gradation seems to exist in a few places where a wide zone of "phyllite" is present. This "phyllite" is a greenish rock outcropping in a band varying from a few feet to hundreds of feet in width. It is seen to alternate at one point with quartzite and at one point with mica schist. One thin section, not necessarily typical, shows a highly altered rock whose main constituent is probable dolomite. Feldspar, calcite, chlorite and quartz follow in order of decreasing abundance. Some chlorite is closely associated with the dolomite as if they were a replacement aggregate, most probably after an amphibole, and this aggregate composes about 55% of the rock.

It is not certain whether the "phyllite" should be grouped with the Chillagoe Formation or with the Dargalong Metamorphics, and its origin is also unknown.

Particularly where the sequence is Chillagoe shale - "phyllite" - Dargalong schist and gneiss, neither lithological nor metamorphic boundaries seem very sharp.

The conclusion is that an erosional break exists though it cannot at present be traced along all its length. This is perhaps due to faulting and shearing along the boundary, with accompanying imbrication and a fading out of strong metamorphic contrasts owing to phyllonitisation on one hand and retrograde metamorphism on the other hand.

Palaeozoic

Chillagoe Formation

(i) General. This formation, first named by Jack and Etheridge (1892), forms a belt striking south-east from the Walsh River north of Rookwood to the environs of Almaden, with an enclave in the granite near Ootann. Its western limit is the boundary with the Dargalong Metamorphics. In the east the sediments are overlain by the wholly detrital Herberton Beds, or are truncated by granite which also forms the boundary to the south. The formation includes the chert and limestone of the Chillagoe-Mungana area, with minor sandy and silty members and rare acid and basic volcanic rocks. The attitude of the beds is difficult to ascertain; where observed, it appears to be steep or vertical.

The base of the formation (the green phyllites being excluded on grounds already discussed) is formed by a bed, 500 to 1,000 feet thick, of sericitic and feldspathic sandstone;

this is yellow to grey in colour and distinguished from all other members in the formation by its appearance; in places it passes into chert and contains chert lenses, while in others it is interrupted by limestone pockets. The sandstone is overlain by a zone approximately one mile wide of quartz greywacke, shaly siltstone and chert, with some quartz sandstone and small lenses of limestone. The shaly beds are poorly preserved, so that outcrops are small and inconspicuous, but a considerable part of the soil cover is interpreted as overlying shale. Green and brown varieties are common and a black and highly siliceous variety also occurs. Where they are more massive than shaly the siltstone and mudstone are sometimes strongly cross-bedded. The sandy members vary in coarseness; they are commonly poorly sorted and composed of angular and sub-rounded grains of chert, quartz, feldspar and siltstone; they include pockets of fine conglomerate.

East of these clastic sediments, a series of chert and limestone beds appears, with intercalations of quartz greywacke and siltstone comparable with the ones just described. The chert ranges from light grey to black and from creamy through yellow to pink and red; it usually shows regular rhombohedral joints. In spite of fracture, jointing and brecciation, the cherts are generally regularly bedded, with beds 1 to 3 inches thick and separated from each other by silty partings. Broadhurst (1952) distinguishes two classes, massive and bedded, but the distinction is difficult to maintain because a unit which appears thinly bedded in a creek exposure often seems massive where exposed on a ridge; the massive character of the lumps of rubble on the chert ridges is probably attributable to their being derived from the thicker beds which are occasionally found in the thin-bedded cherts. Besides forming independent ridges, the chert also interfingers with the limestone, narrowing, from massive bodies to nodular bands and branching tongues. In places it also includes limestone lenses and commonly weathers in the same manner as limestone. Some of the chert, particularly the dark grey variety, contains silicified fossils including Heliolites species and, in one place, remants of a sponge with well-preserved inner structure (ident. F. de K.).

(The origin of some of the brecciated chert members is discussed on p.15).

Limestone is interbedded with the chert in about equal amount. The limestone is massive, dark grey when fresh and usually compact, though in a few places the rock is more porous i.e. a carbonate sandstone, with the calcite in well sorted grains and with a strong foetid smell when knocked. Outcrops are commonly in conspicuous jagged bluffs with karren-erosion and many caves. This habit is strongly contrasted with the smooth rubble-covered chert ridges, though low lying smoothly worn limestone pavements are exposed in a few valleys. Bedding is usually, but not always, absent or hardly perceptible; thus it could happen that Skertchly (1899), in the belief that the limestones are essentially horizontal, arrived at the conclusion that the Chillagoe limestone lies "as a much denuded cake" unconformably over the cherts and the sediments of the Chillagoe Formation. Cherty members occur in the limestone in which the chert forms branching layers and swells locally into chert lenses. Calci-rudites mixed with arenite material are also found in a few localities mingled with lenses of limestone and chert. Fossils are locally abundant in the limestone but their preservation is not very good (list on p.12). The fauna includes corals, which indicate a reef environment, but the outlines of the present-day bluffs do not coincide with original reef boundaries and much of the limestone is only detritus, not solid reef. In some horizons there is ample evidence for an origin by deposition rather than by organic construction, for instance in the pebbly limestone, which consists of well-rounded quartzite, quartz schist and other siliceous rock types embedded in a limestone matrix.

A striking feature of the limestone sequence is the abundance of a rock termed "breccia-conglomerate". The fragment fraction is dominated either by limestone or by chert but other rock types such as the Dargalong granite and gneiss are incorporated occasionally. Broadhurst (1952) regarded these as volcanic breccias, a view which is not accepted in this report. It is seen in places that these breccia-conglomerates form basal beds above local unconformities and it is believed that they are sedimentary wave-platform breccias, locally contaminated with allocthonous pebbles.

Subordinate to the chert and limestone are purely detrital beds of quartz greywacke, shaly siltstone, sandstone and conglomerates. These rocks are lithologically identical with the Herberton Beds of the Redcap Creek area farther to the east, which are separated from the Chillagoe Formation by an arbitrary boundary only. The quartz greywackes and quartz sandstones vary in textural and mineralogical maturity: some are coarse and poorly sorted, contain much feldspar and rock fragments, and grade locally into fine conglomerate, but a few are even-grained. The siltstones are as a rule easily eroded and consequently poorly exposed. Grey or greenish when fresh, they change to yellow or brown on weathering. Consequently hillside rubble is usually yellowish whereas creek-bed rocks are grey-green. It is also noticed that the hillside rock tends to be more indurated than its creek bed counterpart. Most of the siltstone is finely sericitic and some is cherty or silica-indurated, in which condition it is generally dark in colour. The conglomerate members of the detrital group are coarse and polymict, occurring as strips and lenses particularly in the lower part of the limestone-chert succession. They consist of boulders and pebbles, well water-worn and rounded, of chert, amphibolite, muscovite granite, granulite, gneiss, quartzite and other rock types, with diameters in a wide range from gravel size up to 10" set in a quartz greywacke or sandstone matrix; even larger boulders are known, one measuring 2 ft. by 1 ft. on its exposed surface being exceptional. A well-known exposure of this rock type is the "Conglomerate Hill" of Broadhurst (1952) about half a mile south of Mount Redcap. The sedimentary origin of these conglomerates is apparent from the well-rounded, water worn pebbles and the occurrence of rare seams and lenses of sandy material which is cross-bedded at one locality.

Finally in the limestone succession there are some acid and basic volcanics. The acid volcanics are porphyries closely resembling the younger porphyry dykes (p.24) but there is evidence that they are extrusive. Jensen (1941) reported one outcrop as having tuffaceous nature, and another contains a spectacular volcanic bomb (see fig. 3). Beside porphyries, unmetamorphosed rhyolite has been found as fragments in a pebbly quartz greywacke. The emplacement of acid volcanic rocks during the Chillagoe sedimentary episode is thus certain. Basaltic lavas, and perhaps sills, also occur in the succession. The extrusive nature of one basalt layer is indicated by the presence in a conglomerate just above it of pebbles of this basalt (the identification of the pebbles with this basalt is made on grounds of their distinctive green cherty appearance). One of the most extensive basalts occurs one mile south-west of Mount Redcap. In places its feldspar network can just be seen with a pocket lens, but toward the south-east it becomes finer and more chert-like and is easily mistaken for a chert.

(ii) Fossils. Fossils are almost entirely confined to the limestone. They are abundant only locally and often segregated in layers. The state of preservation is not very good and species determinations are difficult on account of silicification. Types so far identified are:

In limestone:

Corals: 1. tabulata - *Favosites*, *Heliolites*, *Halysites*, (common), *Cladopora*, *Propora* (less common); ident. D. Hill.

2. rugosa - Tryplasma, Kyphophyllum, ?Fasciphyllum, ident. D. Hill; Cyathophyllum, Spongophyllum, (Etheridge, 1911); Cystiphyllum (Jensen, 1941); Xstriphyllum, Pseudamplexus, Grypophyllum (Bryan and Jones, 1945).

The corals are the most abundant of all fossils in the region.

Crinoids: Very abundant, in parts constituting crinoid limestone.

Brachiopods: Less common than crinoids, except in local concentrations. No specimens are yet determined; in places there is abundance of a big, stout-shelled variety 8 cm. across, probably Stringocephalus, ident. D. Hill (see discussion below).

Gastropods: Rare; species are high-coned.

In chert:

Radiolaria: Reported by C.S.I.R.O. (1950).

Corals: Heliolites sp., a few highly silicified fragments.

Sponges: A Demospongea, probably of the sub-order Eutaxicladina. This single example appears to be spheroidal and is internally well preserved; elsewhere rare spicules are identified with uncertainty.

The fossil assemblage has Silurian affinities but the possibility is not excluded that sedimentation has extended into Devonian time. A single specimen from 2 miles east of Rookwood, recorded by D. A. White (White & Hughes, 1957) carries a doubtful Stringocephalus and also a new genus of lamellibranch; the same lammelibranch is found with Stringocephalus at a Clarke River locality where a Middle Devonian age is diagnosed. However, similar successions to the Chillagoe Formation in the Einasleigh region are cut off by an unconformity before the Middle Devonian, so that there is some conflict between the fragments of evidence available relating to the close of the Chillagoe sedimentation.

(iii) Depositional Environment. Much evidence points to an off-shore, shallow-water, reef environment, with a rapidly shifting shoreline and entry of clastic material from the west. The evidence is:

(a) the coralogene fauna;

(b) the interfingering and intergrading of chert and limestone, chert and siltstone, sandstone and siltstone, limestone and sandstone, etc.;

(c) the presence of local unconformities, for example between Chillagoe and Almaden where limestone, chert and basalt bands are overlapped by a breccia-conglomerate. Smaller unconformities are also found which are interpreted as erosion channels (fig. 4);

(d) scour-and-fill surfaces, on siltstone bands in sand and silt successions (fig. 5a);

(e) cross-bedding, on a small scale, in fine-grained sandstone (fig. 5b);

(f) the breccia horizons in the limestone-chert succession which have been mentioned (p.11); those which are believed sedimentary contribute to the picture of an off-shore environment.

(iv) Origin of some of the sediments. The origin of some of the sediments in the Chillagoe Formation is a matter of debate. Jensen (1941) believes for example that the chert is silicified calcareous shale, whereas Broadhurst (1952) regards it as silicified tuff. The latter idea is based on microscope identification of partly or completely replaced feldspar crystals (C.S.I.R.O., 1950); feldspar however is known to be an authigenic mineral (Pettijohn, 1957) and one expects in a tuff other fragments such as hornblende, quartz or glass whose absence throws doubt on

Broadhurst's suggestion. Another obstacle is the presence of corals and sponges in the chert. These are due, according to Broadhurst, to the sudden character of the eruptions, which allowed the corals "just above coral reefs" to be suffocated and incorporated in the tuff. The corals are however often fourd away from limestone reefs in the middle of chert ridges, so that this explanation is not acceptable. It is believed that the cherts are more probably either siliceous bioliths (sponges and radiolaria) or primary precipitates of silica. In the second case the bifurcations and the rhythmic banding in the chert beds may, as Broadhurst has suggested, be attributed to diagenetic differentiation, in accordance with Davis' theory (Broadhurst, 1952).

We turn now to rudaceous rocks. A distinction has already been drawn between the conglomerates (p.11) and the breccia-conglomerates (p.11). The breccia-conglomerate is interpreted as a wave-platform breccia and the conglomerate, on account of the rounding of the pebbles and their composition, is regarded as a simple sediment (Broadhurst's contention that they are volcanic is weakened by his quoting the same origin for "Conglomerate Hill" and for the breccia of very different character on Mount Redcap, discussed below). Besides the conglomerates and breccia-conglomerates, there are frequent breccia horizons. The possibility that some of these are fault breccias was raised on p. but most are considered sedimentary. There is however a noticeable exception exposed on Mount Redcap, which is unlikely to be either sedimentary or tectonic because there is no sign of rounding, bedding, milling or preferred orientation. The breccia is simply an aggregate of angular chert fragments in a red matrix. Broadhurst (1952), following Jack (1891), explains the Redcap breccia as volcanic. However, no volcanic fragments could be recognized, nor is it agreed that the chert is silicified tuff; moreover, a volcanic breccia should contain fragments of other rocks beside chert; and pairs of fragments were seen whose matching profiles showed negligible movement since fracture, which is more compatible with brecciation in situ than with vulcanism. There is another possibility however, suggested by W.C. White, of a collapse or shrinkage breccia. Such a breccia is formed by collapse of rock into a cavity left by solution of a limestone or oxidation of an ore. Either alternative is possible at Mount Redcap where lead-zinc mineralization occurs in limestone country; should the breccia be shown to be due to the oxidation of an ore body localised along the south-westerly dipping Redcap Fault, this would have interesting economic consequences (Text Fig. 6).

The Girofla breccia pipes may be other examples of collapse breccias; both the pipe shape and the great depth may be readily explained by such a theory (Douglas, 1957).

"Herberton Beds"

Several areas of sandy and silty sediments are grouped by Skertchly (1899) as the Herberton Beds, the type locality of which is the region around Herberton. Lithologically they have many points in common with each other and with the Hodgkinson Formation, but their isolation and the absence of fossils make firm correlation impossible. The dip is generally steep, more rarely low, and generally to the north-east, except for south and south-west dips in the Koorboora outcrop. For further description the areas will be treated separately, thus: the Redcap Creek area; the Koorboora areas; and the Petford-Emuford area.

(i) The Redcap Creek area. The sediments in the Redcap Creek area consist of quartz greywacke and quartzite, sericite siltstone, quartz siltstone, shale and conglomerate with some bands of chert and intercalations of acid porphyry. Composition and texture of the sediments are much the same as for the detrital members in the Chillagoe Formation. Bedding characteristics vary: the well-bedded members are generally dark quartz siltstone and pepper-coloured fine-grained sandstone often with cross-bedding, small slump structures or graded bedding. The thickness of the beds is fairly regular, between ½" and 2". The darker of the siltstones is more resistant to erosion. Of the quartz greywackes some are massive and structureless with no visible bedding, while in other exposures, very regular thin beds are prevalent. Throughout the succession, massive and well-bedded horizons alternate, and the quartz greywackes also occur as lenses in the siltstone.

The massive quartz greywackes are composed of grains of quartz, feldspar, mica etc., and fragments of chert and many other rock types; specimen 4248 for example from 4½ miles north-west of Rookwood contains porphyry, limestone, sandstone, phyllite, schist, granite, quartzite, basalt and garnet and ilmenite grains (ident. W.B. Dallwitz). Some of the greywackes have a calcareous matrix but most specimens are not yet determined.

The quartz greywacke grades into fine conglomeratic rocks without sharp boundaries. The pebbles consist of quartz, chert, black siltstone, mudstone and rarer lithological types. There are also many cavities in which the relics of eroded limestone fragments can be found. Beside the conglomeratic variants, the greywacke also includes lenses of pure quartz sandstone. The few chert beds are identical with those occurring in the Chillagoe Formation and transitions from shale with chert pods into massive chert are seen again.

(ii) The Koorboora area. The sediments here stretch from Almaden to east of Koorboora and are surrounded by granite and porphyry. They occupy a similar position with respect to the Chillagoe Formation as do the Redcap sediments, though the succession is here broken by granite. Their position, together with their close similarity to the Redcap rock types, is considered grounds for a correlation.

The sequence is again one of sandy and silty beds, with suspected tuff content. The differences from the Redcap sediments are of degree rather than kind: the ratio of greywacke to quartz greywacke is higher; chloritic shale is more noticeable; graphite shale appears (presence of impure coaly sediments is reported by Jensen, 1928, p.21); mica content is in places higher (this may be a pneumatolytic effect rather than depositional property); irregular ddposition is more evident - cross-bedding, sedimentary breccias and lensing are more common.

South of the Tennyson structure (Jensen, 1923 - a twelve-mile arc passing the Tennyson mine south of Koorboora) the greywacke and sandstone are accompanied by white, more or less friable quartzose beds, and rocks of similar appearance are intercalated in the porphyries of the same region. In thin section, all are seen to be essentially quartz-sericite rocks and all contain at least a fraction of fine-grained material (c. 0.02 mm.). In these respects they resemble bleached siltstone; some however carry both euhedral and corroded grains of quartz and shadowy relics of large feldspar crystals, which show volcanic origin. Questions outstanding are: Is the similarity between porphyritic and phenocryst-free varieties primary or secondary? If primary, is the entire group sedimentary or is it volcanic? If secondary, what process has made sediments and volcanics converge to end products so closely allied?

The size of the beds is significant: although individual expanses are small (e.g. 1 mile by ¼ mile) thicknesses are at least 200 feet in several places. This is too great for greisenisation to be accepted in answer to question 3, without reservations; a possible reconciliation of the facts can be made however by suggesting that the white rocks are largely tuff. Then similar deposits in both sedimentary and volcanic successions are feasible. Moreover, since tuffs are particularly susceptible to pervasive alteration, original rough similarity may perhaps be enhanced even through thicknesses of 200 feet by greisenisation.

(iii) The Petford-Emuford area. The sediments of this area stretch from about 1½ miles south of Petford to Emuford and beyond. They are mainly bounded by granite but are overlain by volcanics to the north-east. Similarity to the Koorboora sediments is marked, the only positive difference being the presence of a conglomerate member far thicker and more extensive than any other in the succession. In area it covers at least three square miles, and valleys cut into it 300 ft. deep fail to expose its base. The pebbles are very well rounded. Many are normal sediments but granite from the Dargalong complex is widespread and, as with the Chillagoe conglomerates, rare volcanic pebbles are found. In this region, the chloritic shales have been discussed by earlier workers; the suggestion of Jack and of Skertchly that they are altered basic dykes is not upheld, but again a tuff hypothesis has been put forward, this time by Jensen (1923).

The Hodgkinson Formation

(i) General. The north-eastern corner of the Chillagoe sheet is occupied by sediments of the Hodgkinson Formation (Jack, 1884 - "Hodgkinson Beds"). They are steeply folded and tilted micaceous greywackes, siltstones and shales, interbedded in a broadly uniform series, with occasional horizons of bedded chert which are identical in appearance with the cherts of the Chillagoe Formation. The greywacke ranges from coarse to fine-grained and grades into siltstone. The degree of sorting and rounding of the particles is variable. When fresh, the colour is pale or dark grey or greenish grey, but it turns to yellow-brown or purplish-grey on weathering. Quartz greywacke, resembling that of the Redcap Creek area, occurs particularly in the south-west of this region, and throughout the pebbly and gritty variants and the lensing and tonguing recall the greywackes of the Chillagoe Formation and the Herberton Beds farther west. The shale is soft, smooth and fissile, generally grey or greenish grey and probably chloritic, though black shale recurs. Structurally, the shale is the less significant, forming only thin horizons in the greywacke. The greywacke is commonly massive and structureless though the finer fractions have a tendency to show bedding, with thickness about 1 ft.

In spite of the general resemblance of these rocks to those farther south and west, there is one important respect in which they differ: they carry fairly widespread plant fossils. The relics are all stem fragments and so are very poor guides to dating. However, Lepicodendron australe (McCoy) is reported (Jensen, 1923) and at least it can be said that the sediments are Devonian or later. They are thus younger than the limestone with Silurian fossils in the Chillagoe Formation.

(ii) Correlation and depositional environment of the Herberton Beds and the Hodgkinson Formation. The separation of the areas described above, and the scarcity of palaeontological evidence make correlation uncertain. For instance Jack (1891) considered the Hodgkinson beds to be equivalent to those at Redcap Creek. Jensen (1923) equated the Koorboora sediments with those around Emuford but rejected the commonly-held opinion that these were of Hodgkinson age. However, in view of the network of similarities which link the separate areas described, and the gradualness with which their few differences develop, the conclusion is here drawn that even if the rocks are not strictly coeval, they are all parts of one depositional episode and were laid down in one depositional basin. A direct link between the Hodgkinson and Redcap Creek beds may exist to the north of the area mapped, where they are no longer separated by the Featherbed porphyry range.

The depositional environment naturally varied with time and also from place to place. Periods of slow deposition, indicated by the fossiliferous Chillagoe Limestone, were followed by times of subsidence and rapid deposition, as testified by the large volumes of poorly sorted quartz greywackes. At no stage however is there evidence of deep water; sedimentation has been paralic throughout and terrestrial, lagoonal littoral deltaic and shallow neritic conditions probably alternate. The paralic character is shown by the lensing and tohguing of the units in the Chillagoe Formation; shallow depth is shown by the coral fauna, the cross-bedding and the wave-platform breccias; and temporary emergence is shown by the local unconformities with scour-and-fill structures, by the plant remains in the Hodgkinson Formation and by the coal seam reported near Koorboora by Jensen (1923).

Dappler (19-7) distinguishes "platform-type" and "basin-type" deltas. The beds of the Hodgkinson Formation fit the description given for the former:

"quartz-muscovite type sandstones are typically accumulated in an environment associated with large alluvial rivers emptying into regions of extensive tidal flats. Sorting is moderate within an individual deposit, but between deposits a wide range of grain sizes may exist ..... Fossils are plant fragments."

The quartz greywackes of the Redcap Creek area on the other hand are more similar to the "basin-type" deltaic sediments, which are described as poorly sorted.

Their environment is near-shore marine and fluviatile, where bars and deltas cause alternations from agitated to quiet water and the supply of detritus is heavy. It is supposed that the Redcap Creek deposits are continuous upon the Chillagoe Formation with supply from the west. An anomalous direction, from the east, is shown by consistent cross-bedding near Almaden, but this may be due simply to the presence of islands or land tongues in the east.

Palaeozoic Igneous Rocks

(i) Granite. "Granite" is used in this report to include all acid rocks over 1 mm. in grain size; it extends over adamellite, granodiorite, syenite and monzonite compositions and includes textural modifications such as granophyre.

Granite occupies the southern and western parts of the Almaden sheet and the western part of the Chillagoe sheet; smaller areas are exposed east of the Featherbed Range and within the Dargalong granite-gneiss, this granite does not contain muscovite (except in greisenized portions) but often has both hornblende and biotite. Within the group, divisions may be made by texture and some may be subdivided by composition:

(a) Normal homogeneous granite - adamellite (widespread).

(b) Normal homogeneous granite - monzonite (south-west of Koorboora; beside Tennyson dyke near Lappa).

(c) Aplitic granite (by Dargalong-Bolwarra track; ½ mile north-east of Chillagoe; etc.).

(d) Granophyre (south of Koorboora and west of Boxwood).

(e) Pegmatitic granite (widespread south and east of Koorboora).

(f) Porphyritic granite, groundmass normal, phenocrysts abnormally large (widespread).

(g) Porphyritic granite, phenocrysts norma_, groundmass abnormally fine (widespread).

Sharp boundaries between these subdivisions are less common than gradations.

The hornblende-biotite adamellite is the most common of all the varieties. It is usually grey and fine-grained (0.5 to 2.0 mm.) and tends more commonly to granodiorite than to more alkali granite; the proportion of biotite to hornblende varies widely from place to place. Usually the outcrops of adamellite are massive and low-lying, but in a few conspicuous localities bare hills stand up. The bedrock on these hills is entirely hidden by piled boulders which measure up to fifteen feet. They have angular shape, quite commonly clear flow patterns and a ringing sound when struck. It is the last characteristic which causes the mounds to be known locally as "metal hills". The flow pattern is attributable to planar concentration of the mafic minerals, the planes being one or two inches apart and exposed.as arcs measuring several feet in length and radium (Fig. 7). Jensen (1923, 1941) regards the ringing rock as a marginal contact phase of the granite and this is the most plausible view; however no confirmation can be gained by micro-study, for the "metal hills" material shows no significant difference from the surrounding granite.

Similar small but conspicuous hills are also formed from the aplite variety of granite. This is poorer in mafic minerals and tends to pink rather than grey. Although generally aplitic, the even texture is sometimes upset by clotting of such mafic minerals as remain, and by the aggregation of some of the quartz into glomero-phenocrysts.

The term "pegmatitic" is used here not to suggest dyke form but to refer to the coarsest variety of granite. It has, however, small mafic content, like a dyke pegmatite, is more consistently sharp-bounded than the other varieties, and occurs partly in small bodies as if by segregation. Only rarely the pegmatitic granite forms rather extensive ill-defined patches, for example on Oaky Creek south-west of Boxwood and against the Tennyson dyke south-west of Koorboora.

Marginal effects of the granite body are:

(a) self-greisenisation);

(b) metamorphism of the surrounding rocks.

Greisen development is fairly widespread, but commonly the effects are limited to sotening of the granite and the degeneration of the biotite. It is only where the volatiles have been concentrated most effectively that constructive change has resulted. However, at Bamford Hill and at Wolfram Camp, muscovite has been formed in centimetre flakes and it is almost certainly the same late fluids that have emplaced the wolfram, molybdenite and bismuthinite. Similarly toward Emuford, it is in an area of extensive greisenisation that the very wide variety of ores has been emplaced, viz. copper, silver, lead, tungsten, molybendum, antimony and bismuth, with fluorspar.

Metamorphism of surrounding rocks is common. Boundaries are sharp and simple, with small apophyses but no contact zone of disruption. Effects include induration, silicification, hornfelsing with mineralogical change, and pneumatolytic alteration; of these, effects in the limestone are of economic interest and those in the volcanics are guides to the dating of some of the rocks. The common-change at limestone contacts is recrystallization to a very coarse grain size - 5 mm. is typical. This is accompanied by bleaching and by local generation of tremolite, wollastonite, epidote, zoisite, granular-andradite garnet and probably pyroxene; in the Mungana lodes it is in the garnetiferous skarns that lead, copper, zinc and iron are also localized.

A minor economic product of limestone metamorphism may be the silica quarry at Chillagoe; this is interpreted by some as an extreme case of contact silicification by the granite on its northern side. In contrast to the coarse rather permeable calcite developed from pure limestone, there are also very tough dense calcsilicate hornfelses; these, being developed in planar bodies along siliceous layers in the original limestone, give a resulting banded rock which weathers to resemble bands of chert in limestone.

The metamorphism in the volcanics is much less easy to see since the texture is dominated by the phenocrysts while the metamorphism affects mainly the matrix. However, micro study shows that near granite contacts some of the phenocrysts have crenellated margins whose depth is related to the coarseness of the matrix. The matrix is also conspicuously uniform and granular with equidimensional grains, and while a specimen close to granite has mean grain size 0.10 mm. specimens from further away are 0.03 to 0.01 mm. in average diameter. All observations point to thermal recrystallization which can, for instance on Emu Creek, be used to show the volcanics to be older than the granite, not younger.

(ii) Volcanics. The volcanic rocks are difficult to classify, firstly because there are many without evidence of origin, whether intrusive or extrusive, and secondly because there seem to have been emplacements of similar rocks at different times. However, three categories can be established:

(a) the acid porphyry flows in the Chillagoe succession and in the Herberton beds, already mentioned (pp. 6, 12, 16)
(b) acid and intermediate dykes; these intrude the Dargalong Metamorphics, the sediments, the granites and some of the volcanic rocks, and in places are sufficiently numerous to constitute swarms. It is only in the younger porphyries of the Featherbed Range that they may possible be absent; and
(c) acid and intermediate porphyries in extensive spreads. The

most conspicuous spread is that of the Featherbed Range, which occupies the centre of the Chillagoe sheet and much of the north centre of the Almaden sheet. These rocks are probably extrusive. Only two subdivisions are recognized but there may well have been more than two emplacement episodes, since recurrence of similar rocks at different times is thought likely.

The porphyries in the sedimentary successions are much like the later volcanics. Their composition is acidic; quartz and feldspar are the normal phenocrysts, embedded in a felsitic or micro-crystalline matrix which is commonly pink or pale grey but rarely dark.

The dykes normally have small-sized phenocrysts (1-3 mm.) but there is a variety with phenocrysts of feldspar up to 2 cm. long. The normal type, of which the most persistent swarm strikes north-east through the Dargalong rocks towards Cardross, weathers pink, yellow, buff, grey-green or white; when fresh it is usually grey. The phenocrysts are quartz and feldspar embedded in a flinty felsitic or micro-crystalline matrix. Rarely the matrix carries spherulites, presumed to be after glass, and kelyphitic rims on phenocrysts are also developed in some places. Beside phenocrysts, another textural feature visible in a few of the dykes is flow banding. The striking coarse-grained porphyry which occurs as wide dykes and also as less regular elongate bodies, has a similar matrix, and the phenocrysts too are similar in many respects to the smaller ones: the feldspar is pink or white, idiomorphic, zoned and often altered at the core as well as at the rim; the quartz is water-clear and sometimes euhedral, from 5 to 10 mm. across. With these similarities, it is not surprising that rarely the fine type appears to develop into the coarse; but the coarse type has a mineralogical difference in that mafic minerals are present, mainly chlorite after hornblende, and at most localities the division between the types is rather marked. Thus it is possible at some localities to detect fragments of the fine type in the coarse (Fig. 8).

Basic dykes are also known but are far less common than the acid ones. The intrusive magmatic origin of these is very clearly shown at some contacts with the granite, both in thin section and in the field (Fig. 9A).

The extensive spreads of acid porphyry are divisible into two groups according to the size of the phenocryst fraction. In one division the phenocrysts are sparse and average 1 mm. in diameter, while in the other they are closely spaced and more commonly about 2 mm.; thus, in the second group the phenocrysts may constitute 30% of the rock while in the first they are usually less than 5%. Fortunately these distinctions are usually accompanied by others which make the two groups readily separable in the field. The fine porphyries very commonly show flow banding from angular rubble and though grey when fresh, weather to white, cream, pink, yellow, pale brown or pale green rocks; on the other hand the coarser rocks are commonly structureless and weather to boulders while retaining their dark grey colour. With the proviso that the terms refer to weathered appearance and are not justified for every member of either group, they will be called shortly the pale porphyries and the dark porphyries.

Note with reference to these terms that the Tennyson porphyry group is mainly phenocryst-poor and pale, whereas the Featherbed porphyry group is mainly phenocryst-rich and dark. However, Tennyson and Featherbed are groups specified by geographical extent whereas the pale porphyries and the dark are groups specified by composition.

The pale porphyries are rather variable in texture and composition. Quartz, plagioclase and potash feldspar all occur as phenocrysts. It is rare for any one of these to be wholly absent, but proportions vary widely. The matrix is fine, dense and commonly felsitic.

Beside the flow banding, vesicles and amygdales are seen in some places, and breccia or agglomerate texture in others. The last is more common in the Tennyson ring structure than elsewhere. Some of the breccias contain fragments of sediments and these, being particularly common near sediment-volcanic boundaries, are likely to be bottom-flow breccias.

Spheroidal horizons are also sporadic in the pale porphyry. In the Tennyson structure, spheroids range from ¼" to 2" diameter and are clustered like bubbles in contact; elsewhere, particularly on the sides of the Walsh River valley, spheroids are from 1" to 3" across, and close-packed but apparently not with interpenetrating forms. Spheroids sometimes have a porous heart or irregular central cavity; sometimes such a space is filled with opal; and sometimes the spheroid is entirely dense and flinty. The horizons so distinguished are of unknown attitude in the Tennyson structure, but along the Walsh River some can be bound with steep dip and some with gentle northward dip. Broadhurst has suggested (oral communication) that the latter are old peneplains in order to account for their planar form and their discordance with the flow-banding below. However, it is believed that the boundary between successive flows can show these features without any significant time-lapse or erosion, the plane surface being simply the horizontal top of the earlier flow, and the occurrence of two or three similar horizons close together in the succession makes this the more probable reconstruction.

Coming now to the dark porphyries, we find again quartz and pink and white feldspars forming the phenocryst fraction. Breccia horizons are also found again but none of the other inhomogeneities seen in the pale porphyry is at all conspicuous. The dark porphyry occurs in the centre of the Featherbed Range, where it appears to overlie the pale-type, and again in the east of the Almaden-sheet and the north of the Mungana sheet. In both the last two localities it seems to be metamorphosed by the granite (p.23). A sequence of events based on these observations is proposed on p. 28.

With regard to the origin of the porphyries, the spreads of the pale type are taken to be surface or near-surface flows on account of the structures contained. In spite of its similar structures, the Tennyson ring body is regarded as a dyke, but the discrepancy in interpretation is made less by remembering that its width approaches one mile and that if its present level of erosion is not far below that at which it spilled out into lava flows, we may reasonably expect to find flow inhomogeneities still exposed, for these are bound to extend to some depth within the fissure. The dark porphyries are more problematical: tuff content, as reported by earlier workers, and the breccia horizons seen by this party point to extrusive origin, at least in part; but of other possible clues - a horizontal chert-like layer in the rocks north of Petford and a volcanic vent a little further east - neither is specific. The first fails to distinguish sills from flows and the second is not associated sufficiently definitely with either the pale porphyries or the dark.

Age relations of the volcanics have often been a problem to investigators, though the difficulties arise mainly from trying to fit all the porphyries into a single episode. This mistake was avoided by Ball (1915) who distinguished a pre-granite porphyry and a post-granite porphyry, and by Jensen (1941) who, though claiming most of the porphyry as pre-granite, dated some, including the Tennyson ring, as post-granite.

It has been mentioned (p. 28) that dark porphyry overlies pale porphyry in the Featherbed Range; now the pale porphyry is believed associated with the pale dykes which cut the granite, and the granite in turn metamorphoses other masses of dark porphyry. Two emplacements of dark porphyry are indicated, in a sequence, thus:

(a) Dark porphyry - granite - pale porphyry - dark porphyry.

Other evidence confirming this sequence may be listed:

(a) Showing granite younger than adjacent porphyry -

apophyses of aplite in porphyry (Wolfram Camp, Ball, 1919).

porphyry feldspar sericitized at granite contact (ibid.)

porphyry orthoclase clouded at rim at granite contract (ibid).

granite chilled to fine variety at porphyry contact (north of Wolfram Camp, seen by this survey).

(b) Showing porphyry younger than adjacent granite - inclusions of granite fragments in the porphyry dykes.

(c) Showing dark porphyry younger than pale type - inclusion by dark porphyry of fragments of the very coarse dyke-rock which is seen to intrude the pale porphyry.

(d) Showing pale type younger than dark porphyry - dykes of pale type in dark porphyry.

Most parts of the above sequence are thus well corroborated and since the evidence under (a) all relates to dark porphyries, no early episode of pale porphyries need be postulated. The link most difficult to justify concisely is the equating of the pale flows with the dykes. However, when the exposures for example north of Koorboora and in the Tennyson dyke south of Koorboora are compared, the similarity is unmistakable; and again where the dyke cuts the Almaden-Koorboora road, it is so hard to find a boundary between the narrow dyke and the broad spread to the north that continuity has to be supposed.

Mesozoic

Mesozoic sandstone, correlated with the Blythesdale Group, near Roma, makes its appearance in the western part of the Mungana 1-mile area, first on mesas up to 200 feet high and then as a coherent horizontal cover unconformable on the Dargalong Metamorphics. The unconformity is conspicuous, being marked by a change in vegetation as well as by the topography. Where the contact is disclosed, the base of the Mesozoic is seen to be a breccia bed 3 or 4 feet thick, composed of fragments of the underlying quartzites and mica schists. The sandstone following this breccia is quartzic, white to reddish-brown, and texturally and mineralogically very mature, with grain sizes from 0.5 to 1.0 mm. Mud cracks occur occasionally and cross bedding is well developed in many places. In the north-west the sandstone has disintegrated and now forms a blanket of loose white quartz sand, the edge of the vast sand plain which lies west of the area mapped. Locally in this part a kind of billy-quartzite was found, of sand-sized quartz grains in a dense, pale grey or cream siliceous matrix.

Within the sandstone formation, minor conglomerate and shale lenses occur. The conglomerate has pebbles up to 5 in. diameter, of quartzite, vein quartz, porphyry, schist and chert. The shale is white or light grey, weathering rusty; it is in association with the shale that sandy laminae with worm tracks are found.

The eastern limit of the Mesozoic is ill-determined but it appears to include Rookwood and Mungana. Jensen (1923) notes the close resemblance of some pockets of friable quartz sandstone in these localities to the Mesozoic farther west; they are similar in texture, composition and, as far as can be seen, in attitude. Their preservation in low lying localities distinct from the mesas to the west may be due to their being valley fillings in the pre-sandstone peneplain.

B. STRUCTURE

The area is composed of sediments which have been folded, probably in two periods. Subsequently they have been tilted, eroded and extensively intruded by granite and overlain by porphyritic volcanics.

Folding

The two periods of folding were pre-Silurian and post-Silurian. They are shown by intense folding in the Dargalong rocks and more open folding in the Chillagoe Formation.

The Dargalong rocks are generally strongly foliated, with steep dips on the foliation planes; these are most commonly parallel to the original bedding but exceptions are frequently found. Minor folding and crenulation, boundinage and plastic folding are observable but larger structures could not be traced because of the shortage of exposures on one hand and of marker horizons on the other. However, it can be said in general that the strike swings from north-east in the western part of the Mungana sheet to north-west in the eastern part. Discontinuity between the Dargalong rocks and the Chillagoe Formation has been discussed on p. 6 , where it was shown probable that the two sedimentary episodes were separated by metamorphism, uplift and erosion. It is presumed that the present structures were formed mainly in this interval. Refolding in the Palaeozoic episode remains possible but since fold trends nowhere intersect, no indications of such refolding are seen.

The post-Silurian folding of the Chillagoe Formation took place about north-west axes, in parallelism with the nearer of the basement rocks. The Koorboora structures trend more westerly and those near Emu Creek are nearly north but the Hodgkinson rocks are again folded on north-west axes, and the deviations are so small that the structures are regarded as a single smoothly-curving system. Beyond the strike trends, however, no major structural observations could be made.

<u>Faulting</u>

Three periods of faulting are distinguished:

(a) at the time of the post-Silurian folding;

(b) at the time of the granite emplacement; and

(c) at some time after the latest vulcanism.

Faults of the first period are comparatively inconspicuous. The faults of the second period are both prominent and important, for they often control the distribution of the economic minerals (see p.). The third group of faults is economically negligible but is prominent physiographically. The straight scarps such as bound the triangular patch of porphyry between Almaden and Koorboora are ascribed to faulting of this age, and it is also believed that faults mark off the morphologically young volcanics on the rim of the main porphyry area from the rounded volcanic hills in the centre. Jensen (1939) also has described block faulting, from the adjacent Herberton district, and it seems the probable way of relieving stress in a region made rigid by intrusion and earlier folding.

C. GEOLOGICAL HISTORY

The chronological table (fig.10) gives the succession of events considered most likely.

After deposition, metamorphism and folding of the Dargalong Metamorphics, a new period of sedimentation commenced during Silurian time. A shallow sea was characterized by a coral reef facies along its western fringe; clastic material was derived from a landmass in the west and became the dominant deposit in late Silurian and Devonian time. Epeirogenic movements caused minor emergences. During the Devonian age a shallow basin received detrital material probably from western as well as eastern and perhaps southern directions. Volcanic activity intermittently accompanied the sedimentation.

The Silurian and Devonian sediments were folded in late Palaeozoic time, were probably at this stage lifted above sea level and were subsequently intruded by grainites. Periods of strong vulcanism preceded and followed the emplacement of the granite; the most extensive took place after a lapse of time in which the folded sediments were partly eroded.

A Mesozoic subsidence brought the western part of the area again below sea level and wide spreads of sand and shale were laid down from an eastern source. Meanwhile block faulting was probably going on, and the whole region was finally tilted to the west. In the area mapped, denudation still prevails and little accumulation takes place, morphologically the landscape is mature in general but still young in places.

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TENTATIVE CHRONOLOGICAL TABLE

		LITHOLOGY	DIASTROPHISM	VULCANISM
MESOZOIC	BLYTHESDALE SANDSTONE	Sandstone with subordinate conglomerate and shale.	General tilt to west. Block faulting	
		disconformity or unconformity		
	FEATHERBED PORPHYRIES	Massive green grey porphyries with high proportion of phenocrysts.	Period of dyke intrusion and of hydrothermal ore-deposition.	Acid to intermediate volcanics.
	TENNYSON PORPHYRIES	Grey porphyries with light weathering colours, commonly flow-banded and breccious.	Emplacement of acid plutonics and contact-metasomatic ores.	
		unconformity?		
		Massive dark porphyries with high proportion of phenocrysts.	some folding ?	
		unconformity	Main phase of folding	
? DEVONIAN	HODGKINSON FORMATION	Greywacke, siltstone, shale (chloritic in parts), minor chert, with plant remains and intercalated lavas.		
	HERBERTON BEDS	Quartz greywacke, sandstone, siltstone, conglomerate with subordinate greywacke, shale, chert; intercalated acid lavas.		Acid volcanics.
SILURIAN	CHILLAGOE FORMATION	Limestone, chert, subordinate quartz greywacke, siltstone, conglomerate. Fossils: corals, brachiopods, sponges, gastropods.	Epeirogenic movements.	Basic and acid volcanics.
		unconformity		
	DARGALONG METAMORPHICS	Schist, gneiss, granulite, amphibolite.	Migmatisation and granitisation with folding.	Basic volcanics.

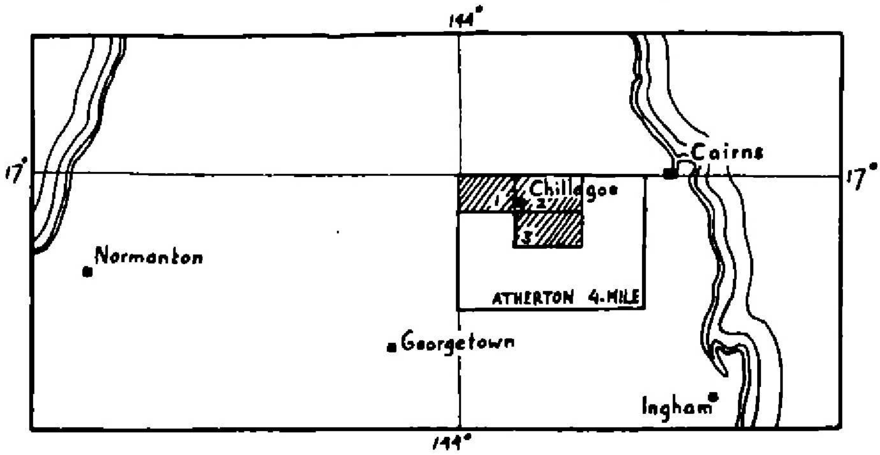


Fig. 1 Location diagram of the area mapped —

1. Mungana 1-mile sheet
2. Chillagoe 1-mile sheet
3. Almaden 1-mile sheet

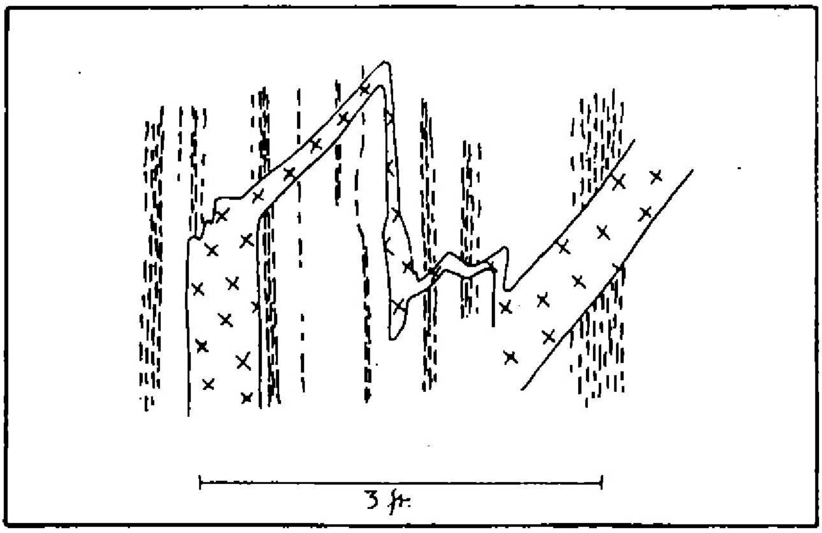


Fig. 2 Conformity and disconformity shown by a quarzo-feldspathic tongue in para-gneiss, Wandoo Creek.

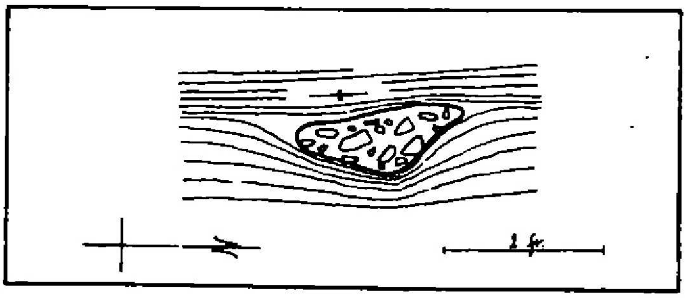


Fig. 3 From roadside 1½ mls. north of Rookwood, a volcanic bomb in bedded sediments or volcanics, which have been tilted to vertical; deformation of bedding shows top to west.

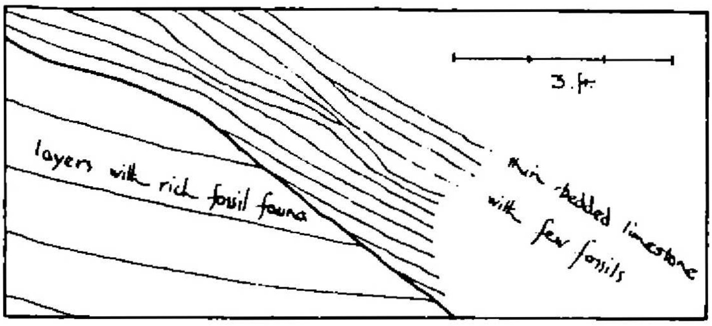


Fig. 4 Between Mungana and Rookwood, one side of an erosion channel exposed in bedded limestone.

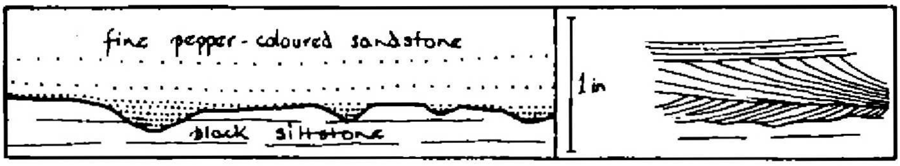


Fig. 5a

Fig. 5b

Scour-and-fill and cross-bedding structures in the Chillagoe beds.

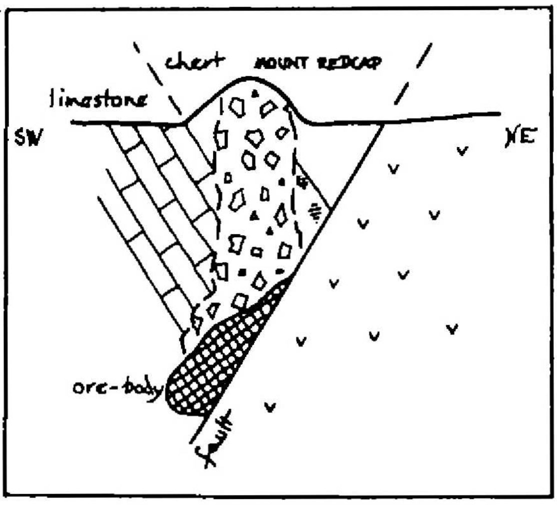


Fig. 6 Hypothetical section from SW to NE through Mount Redcap; if an ore-body were to exist as illustrated, its oxidation could cause shrinkage and so generate a collapse-breccia similar to that now exposed.

Fig. 7 From the "Metal Hills" north of Chillagoe, flow-banding in hornblende-biotite granite.

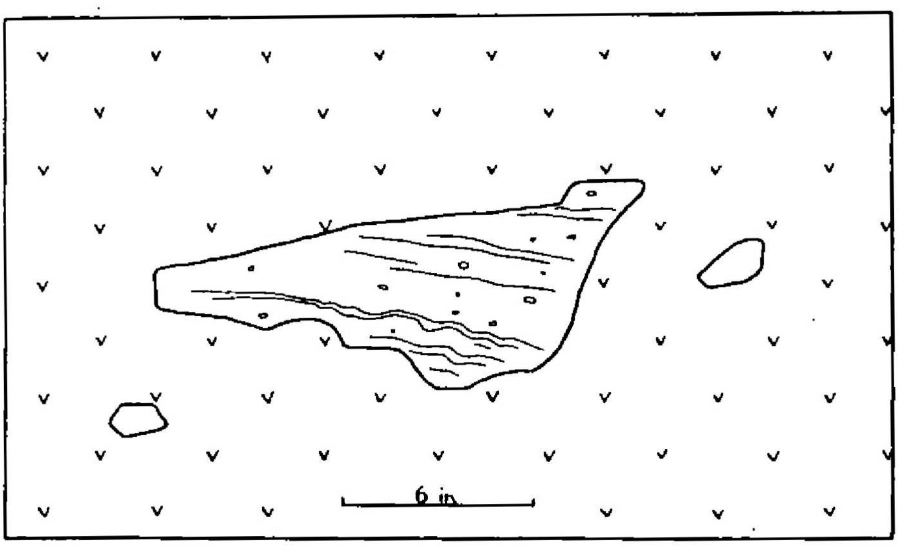
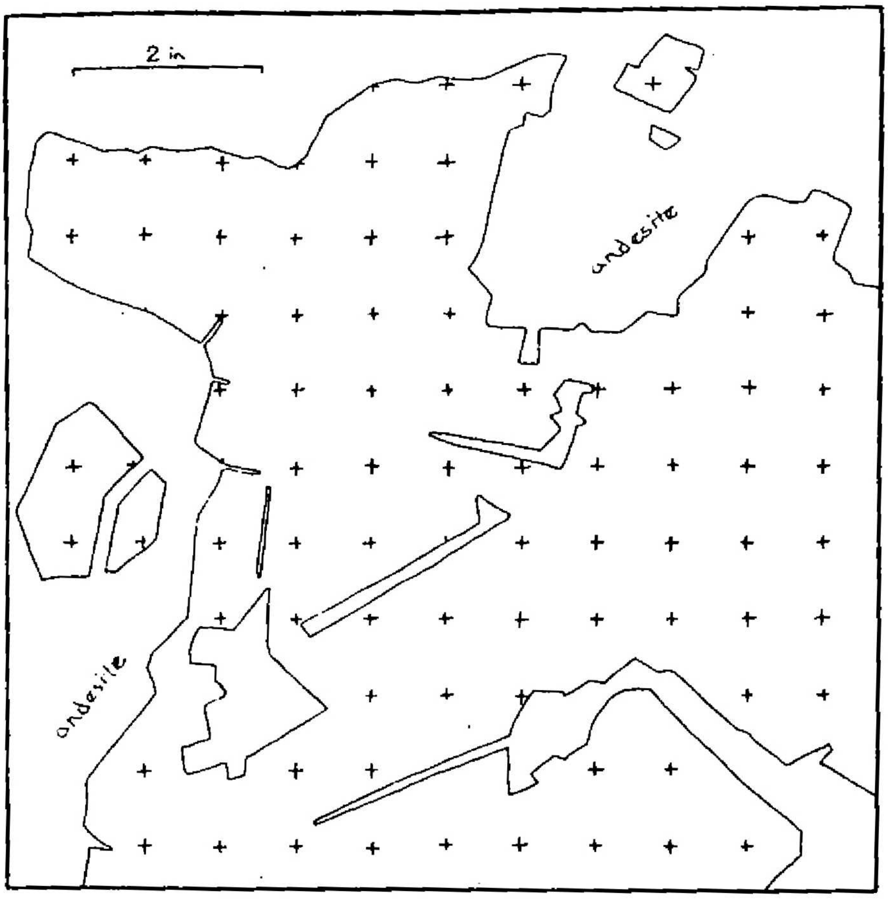


Fig. 8 From the Walsh River north of Rookwood, a flow-banded rhyolite boulder in very coarse quartz-feldspar porphyry.



A.

B.

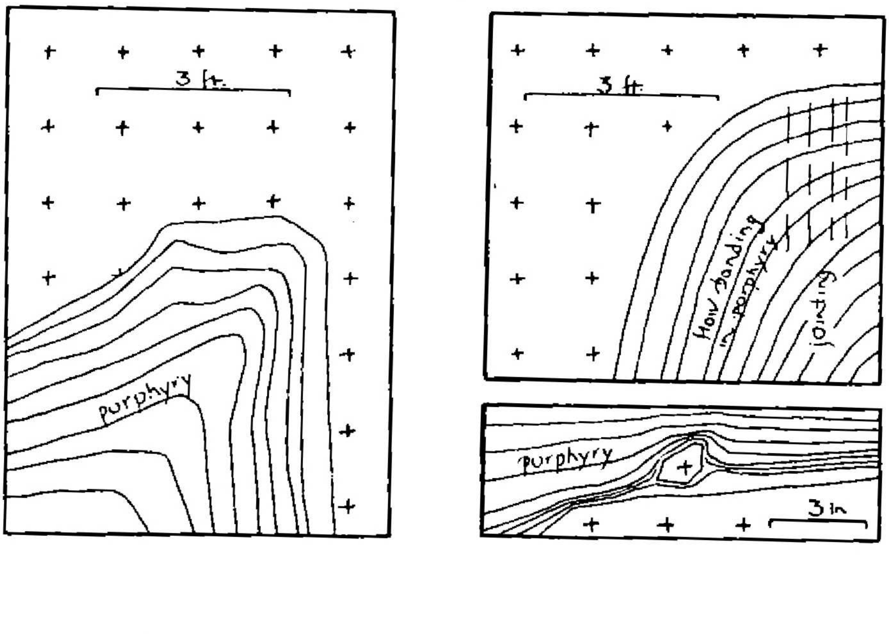
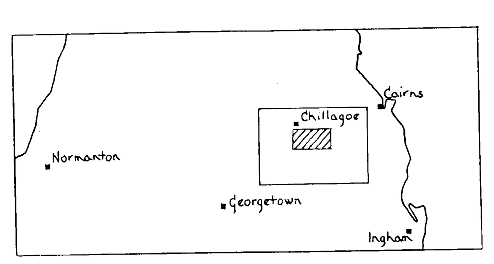


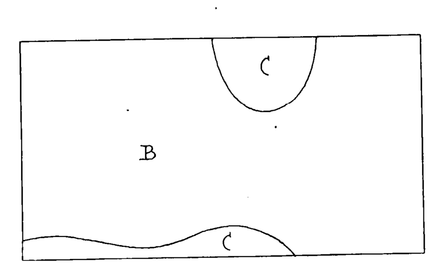
Fig. 9 Contact relations of dykes in granite –
A – in railway cutting near Lappa Junction – andesite.
B – West of Boxwood and south of Koorboora – porphyries.

ALMADEN E/55-5-60

field sheet only;
scale : 1 : 47300 or 1.36 ins. : 1 mile
true north parallel to sheet boundaries;
magnetic deviation 6¼° E in 1960.



Locality Diagram: the area covered by this sheet is shaded, and that of the Atherton 4 ml. sheet outlined.



Reliability Diagram:
A - areas of close study
B - areas of frequent traverses
C - areas of photo-interpretation

0 1 2 3
miles

Bureau of Mineral Resources, Geology and Geophysics 1958

CHILLAGOE

NORTH QUEENSLAND

FIELD SHEET ONLY

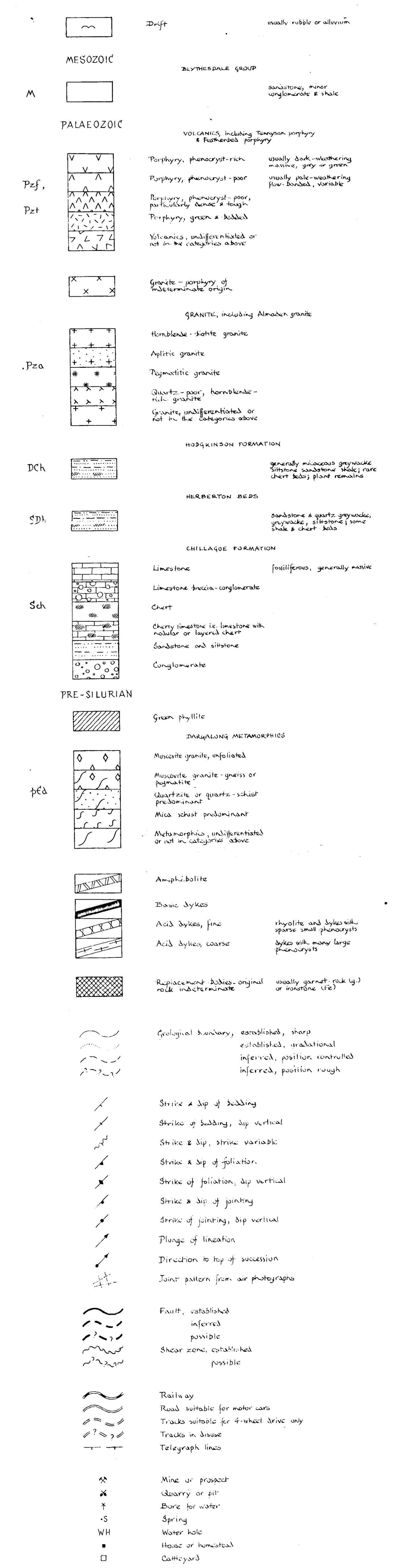
ONE MILE GEOLOGICAL SERIES SHEET E/55-5-55

MUNGANA

NORTH QUEENSLAND

FIELD SHEET ONLY

ONE MILE GEOLOGICAL SERIES SHEET E/55-5-51



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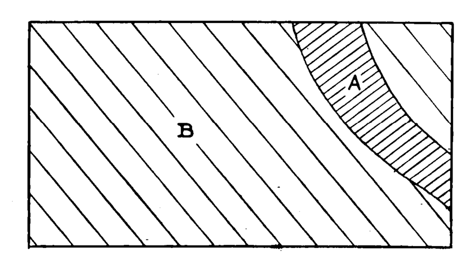
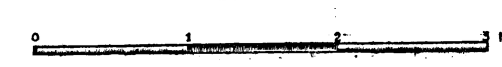


Reliability Diagram :

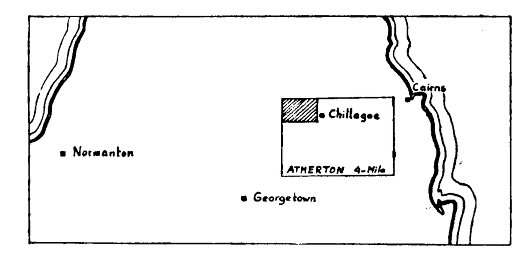
A _ detail mapping

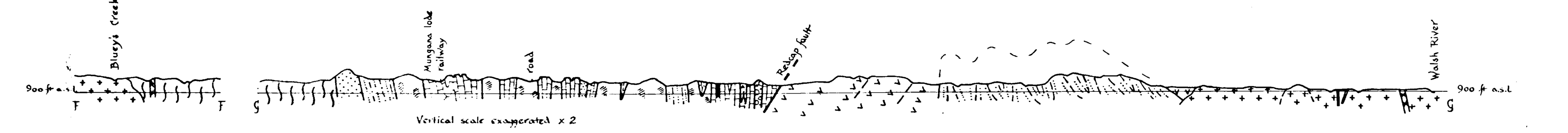
B _ traverses and photo-interpretation

Scale



MILES





Vertical scale exaggerated x 2