AN IRON DEPOSIT NEAR BRAEMAR STATION, SOUTH AUSTRALIA.

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INTRODUCTION:

Braemar Head Station lies about 50 miles north east of Burra, and about 35 miles south of Yunta.

The iron deposits occur in two roughly parallel ranges of hills, Ironback Range to the north-west, and Little Ironback Range to the south-east. These both have a roughly NE-SW trend, and are about 5 to 7 miles apart, with some small undulating hills and much alluvial material in between.

The iron deposits were examined with a view to discussing their origin and associations. The beds were not mapped on this visit (May 1949) but it is hoped to be able, at a later date, to return and map the beds in detail. Thus at present, no indication as to their possible future economic utilization can be given.

The deposits were inspected at 3 general localities (see sketch map attached).

Loc. A: Ironback Range, approx. 2 miles east of Braemar-Tiverton track.

(Loc. B: Near the southern tip of the Little Ironback Range.

(Loc. C: About ½ mile north of Loc. B.

(Loc. D: About 1 mile north of Loc. C.

Loc. E: About 300 yards east of Braemar H.S.

The following Sections are also attached:-

Section 1. Diagrammatic Section from Little Ironback Range to Ironback Range. This is very generalized, and at present only represents the probable structure.

Section 2. Generalized Section of the Little Ironback Range, Loc. D.

Section 3. More detailed Section at Loc. C, Little Ironback Range.

Sections 2 and 3 show thicknesses which are approximate only, the profiles also being diagrammatic.

TOPOGRAPHY. The Ironback Range is considerably higher and more rugged that the Little Ironback Range, but in general, both consist of two high ridges of interglacial quartzite, and a lower ridge consisting of the iron formations.

Between the two main ranges is a broard, flat alluvial valley, with a few low undulating hills.

To the east of Little Ironback Range, the country is very flat, and represents a part of the Tertiary Murravian Gulf.

Rock exposures on and adjacent to the ridges are good, but are very poor in the valleys owing to the deep cover of alluvium.

Vegetation in general is sparse, the country all being sheep grazing land.

STRATIGRAPHY. The rocks of the area belong to the Middle Group of the Adelaide System, and consist mainly of the glacial series so common in this State. There is a great thickness of Sturtian Tillite containing numerous bands of interglacial quartzite. Above these, the tillite has a thickness of 800 ft., before passing up into laminated shales, which rapidly become more iron rich going upwards in the succession. (See Sections 1 and 3).

Tillite of at least an equal thickness (800 ft.) occurs below the quartzites, but further thickness could not be proved because of alluvial cover.

The bed forming the lower ridges on the northern side of the Ironback Range, and on the southern side of Little Ironback Range is usually the ferruginous tillite, together with ferruginous shales.

A detailed section (No.3) is attached, with approximate thickness:

A very similar succession was found at Loc. D. except that a possible strike fault occurred, beyond which a repetition of the ferruginous tillite and ferruginous shales was found.

At Loc. B, the same succession was observed, except that just above the iron rich tillite, a thin bed of ferruginous quartzite occurred (Spec. B6A).

At Loc. A, there were ferruginous shales, a thin bed of ferruginous quartzite, and ferruginous tillite above the normal tillite, as before.

At Loc. E, in the low hills near Braemar H.S., there occurred some beds rich in hematite. These were of a different character from the others, and possibly represent tillitic sediments in which the hematite has been reconcentrated (Spec.E1).
This occurrence has not been discussed in this paper.

STRUCTURAL GEOLOGY:

The general structure was interpreted as being a major anticline, both from air photos and from observations in the field. This is shown in Section No.1.

However, this should not be regarded as final, being merely the result of several sections.

The possibility of a number of faults occurring has not been overlooked, and it is hoped to map the beds and finalize the structural geology at a later date.

The fault observed at Loc. D (Section No.2) was found by virtue of a mashed, puckered and oxidized zone within the laminated shales, also reversal of dip, with repetition of beds.

PETROLOGY:

The sediments may be grouped for descriptive purposes into:-

(a) Normal Tillite.
(b) Shales with few hematite bands.
(c) Hematite rich shales.
(d) Ferruginous Tillite.
(e) Sandy ferruginous shales.
(f) Hematite quartzites.

Note: The prefix A, B, C, D to specimen numbers refers to the locality as shown on the locality plan.

(a) Normal Tillite.

Specimen D 1. with specimens of erratics D7, D8, D9 and D10, and striated erratics D 11.

The normal tillite is a light grey to brown rock, with erratics of all sizes up to several feet in diameter, set in a fine unstratified base.

Microscopically:- Consists of angular erratics of all sizes, the largest in this slide being about 8 m.m. in diameter, set in a fine grained partly recrystallized matrix. The erratics are mostly angular particles of quartz, with some of quartzite, shale and plagioclase (probably albite). Two or three erratics rich in calcite are also present.

The groundmass consists mostly of small particles of quartz, with sericitic, biotitic, and chloritic micas all present. A few scattered crystals of hematite are present, but only in accessory amount.

(b) Shales with few hematite bands:

These occur both below and above the main ferruginous sediments, Spec. C1 representing those above, and Spec. C9 representing those below. Actually Spec. C9, which was microscopically examined was an iron rich band, and will therefore be included with the descriptions of the ferruginous shales. Spec. C8, is a bed also poor in hematite, but containing some bands.

M4, is a shale with few hematite bands, occurring near Iron Peak.

C1 is a light brownish coloured shale, with sparse hematite rich bands, which show a suggestion of very shallow cross-bedding

Microscopically, it is a very fine grained sediment containing iron rich bands, although crystals of hematite are scattered irregularly throughout the whole rock. The maximum diameter of the hematite crystals is .1mm. A few quartz grains also occur, and the matrix appears to consist mainly of a brown mica with abundant sericitic mica. The parallel arrangement of the micas gives the rock an imperfect cleavage.

C4 is a more normal type of shale, not very rich in hematite, and showing little bedding.

Microscopically, it consists mainly of quartz particles, the average diameter of which is about .04 m.m. These are usually separated by thin wisps of colourless sericitic mica, and greenish chloritic mica, the wisps being generally parallel, giving a rudimentary cleavage. Scattered throughout the rock are idioblastic crystals of hematite, ranging through all sizes up to .08 m.m. in diameter. Much limonitic material is present, together with a few grains of tourmaline and apatite.

C8 is a very fine grained shale, with alternating bands rich in hematite. This has the appearance of a varved-shale. Microscopically, it is well bedded, and of very fine texture. It contains bands rich in hematite and others rich in quartz, these quartz rich bands as a general rule containing only very fine hematite, while the ferruginous bands contain an abundance of recrystallized hematite crystals up to .06 m.m. in diameter. Sericitic mica is abundant in the matrix, which also contains biotite. In one place, an aggregate of granoblastic quartz occurs, with inclusions of hematite.

The rock has been somewhat stained along bedding planes with limonitic material, and a few irregular cracks transverse to the bedding are filled with limonite.

A suggestion of graded bedding occurs, but due to recrystallization, is very indefinite.

M4 is a finely bedded ferruginous shale with a few iron rich bands. Microscopically, it consists of bands rich in hematite, alternating with much wider hematite-poor bands. Much limonitic matter is present, and biotite and sericite are abundant. The maximum diameter of hematite idioblasts is .14 m.m., but the average size would be about .06 m.m.

Hematite crystals are often rimmed with biotite.

Small aggregates of recrystallized quartz contain abundant fine hematite particles. Some plagioclase is also present with the quartz.

These shales which contain a few hematite bands seem to give support to the theory of a sedimentary origin. It is rather difficult to visualize a metasomatic origin for these very thin and widely spaced bands.

Analysis of various bands:

Analyses for total iron (calculated as Fe_2O_3)were carried out on specimens C2, C3, C5, C6, C7, C8 (see section No.3). The results obtained further emphasize the banded nature of the deposit, as may be seen from the table below.

Specimen	Spec. Grav.	Total Iron (as Fe_2O_3%).	Fe%
C2	-	26.9	19.3
C3	3.62	56.9	39.8
C5	3.74	70.4	49.2
C6	-	32.6	22.8
C7	3.78	72.3	52.6
C8	-	29.7	20.8

It will be noted that the specific gravity of C7 is apparently low for over 70% of Fe_2O_3, compared with the figure quoted for Hematite, vix. 5.2.

The determinations of S.G. were carried out by the hydrostatic method, and the porosity of the specimens probably accounts for these low values, as the calculated value for 72% hematite, assuming the remainder to be quartz, is approx. 4.5. It was considered unnecessary to determine the S.G. of the other samples.

Further analytical work was undertaken on C7.

(c) Ferruginous Shale.

These are the common types of the area, and are well bedded rocks consisting mostly of hematite. The alternating bands richer and poorer in hematite give them the appearance of varves. They are as a rule very fine grained, and partly recrystallized. The hematite crystals normally show perfect crystal outlines (trigonal) but sometimes show cubic forms, pseudomorphic after magnetite, and are often fringed with biotite.

Two of the richest specimens, C3 and C5 were kindly polished and examined in reflected light by Dr. A. B. Edwards, of C.S.I.R.O, who found residuals of magnetite in practically all of the idioblastic hematite crystals. The magnetite was seen to be altering to hematite along its octahedral cleavages. The presence of this martite therefore shows that magnetite was the preexisting mineral.

Rocks of this type nearly all show graded bedding with bands rich in hematite towards the base, becoming gradually more siliceous near the top. The next hematite rich band cuts sharply across the top of the preceding siliceous band.

This is the main evidence in favour of a varve origin of these shales.

Descriptions of rocks in this group are as follows:-

C9 is an iron rich band from laminated shale above the normal tillite. In it are some very thin bands, up to .1 m.m. across, rich in idioblastic hematite particles, separated by rather wider bands, usually approx. .4 or .5 m.m. wide, and containing less hematite.

Some rather large idioblasts of hematite occur, (often rimmed with biotite) set in a matrix of finer hematite, quartz, plagioclase, and secondary limonitic material [illegible] is a finely bedded shaley rock consisting mainly of hematite with some light coloured lenticular bands.

Microscopically it is very rich in hematite, the bedding being shown up by the fact that some bands are richer in hematite than the adjacent ones. The idioblastic hematite crystals range up to .1m.m. in diameter, and are sometimes, though not always, rimmed with biotite. Much fine hematite, quartz, plagioclase, and secondary limonitic matter make up the matrix.

A lenticular band with an average width of .05m.m. occurs parallel to the bedding, and consists mainly of clear quartz, and plagioclase containing dusty inclusions and sometimes showing twinning (Max.Extn.15° in symmetrical zone). A few smaller lenticular patches similar to this occur throughout the rock. They also contain some apatite.

A complete analysis was made in order to determine the chief impurities, and results are as follows:-

SiO_2	21.01
Fe_2O_3	69.13
FeO	1.75
Al_2O_3	4.07
CaO	1.08
MgO	Tr.
Alkalis	2.03 (Calc.as Na_2O)
P_2O_5	0.51
MnO	Tr.
TiO_2	+Tr.
S	Nil.
Ba	Nil.
H_2O (total)	0.83
CO_2	N.d.
Cl	N.d.
Total	100.41.

From the above, it may be seen that the chief impurity is silica, and taking into account the total bases present, it is obvious that the greater proportion of SiO_2 is present as free quartz. As regards the bases, it is probable that they constitute the micaceous and felspathic impurities that are found in the thin sections. The phosphorus is probably present as apatite, which was identified in the thin section. The low percentage of FeO indicates that only a little of the iron mineral is magnetite.

C5 is a finely bedded ferruginous shale in which the small hematite crystals sparkle by reflected light.
Microscopically the rock consists of alternating bands of densely packed hematite crystals, and bands with sparse hematite. The more leucocratic bands contain quartz and plagioclase, and one band was rich in apatite.
Tourmaline which is pleochroic from almost colourless to deep blue occurs in accessory amounts. The idioblasts of hematite are commonly fringed with biotite, and range in all sizes up to .1m.m. in diameter. A small crack filled with quartz crosses the bedding, but does not displace it at all.

C3 is a fine grained ferruginous shale, with very fine, sharp bedding.

In thin section the hematite rich bands are seen to consist of idioblasts of all sizes up to .1m.m. and are as a rule coarser grained than the adjacent hematite-poor bands, which contain isolated idioblasts up to .05 m.m., but a somewhat graded effect between the two extremes usually occurs. Both types of bands contain much secondary limonitic material, but not much mica.

In this section, a lenticular band of relatively coarse grained material occurs, consisting mainly of quartz, calcite and limonitic material, and containing a few scattered idioblastic crystals of hematite. This is thought to have been a particle of previously consolidated mud which sank slightly into the base of the non-consolidated iron rich mud, thus causing the bedding of the latter to become slightly down curved. Immediately above, or in contact with this particle is a hematite rich band which represents the next iron rich layer deposited.

A6. A well bedded ferruginous shale with elongated lenticles of light colour, resembling mud pellets.

Microscopically, the bedding is prominent by virtue of bands rich in hematite crystals, the average size of which is approximately .1m.m. in diameter.

The interstitial material of the lighter coloured bands is generally plagioclase, but some quartz also occurs. One small crosscutting vein of quartz, about 3.5 m.m. long, and .2m.m. wide occurs.

Limonitic matter is present, but there is very little mica. The lenticles consist of a granoblastic aggregate, mainly of plagioclase, with some quartz, and a few scattered hematite crystals. The plagioclase has a maximum extinction angle in the symmetrical zone of 14° and an R.I. nearly equal to Balsam, and is biaxial + ve. i.e. is albite.

The granoblastic texture is often well shown by small amounts of limonite along intergranular boundaries. These lenticles would thus appear to be small partly consolidated mud pellets which were probably deposited in times of swift deposition due to melting of ice, and were then quickly covered by iron rich muds again, and hence preserved.

Specimens M1, M2, M3 are further specimens of ferruginous shales from near Iron Peak.

M1 is a fine grained banded ferruginous shale.

In this section, it is seen to consist of alternating bands rich and poor in hematite. The latter contain quartz, plagioclase, calcite and a little apatite.

Some reasonably large aggregates of hematite crystals occur, up to 2m.m. in length. Individual crystals are of all sizes, the average diameter of the largest being about .1m.m. The calcite shows typical twinkling, and is uniaxial - ve. There is also some secondary limonite present.

M2 is a very similar type to M1.

Microscopically it consists of quartz rich and hematite rich bands. Calcite occurs, though not so abundant as in M1. Both greenish brown and brown micas occur, often rimming the idioblasts of hematite. Apatite and plagioclase (albite) both occur in the quartz rich bands.

Measurements of the thickness of bands were made, and are as follows:-

Hematite rich band			4.4.m.m.
Quartz	"	"	1.2 "
Hematite	"	"	2.2 "
Quartz	"	"	0.6 "
Hematite	"	"	0.94 "
Quartz	"	"	0.12 "
Hematite	"	"	1.2 "
Quartz	"	"	0.18 "
Hematite	"	"	1.2 "
Quartz	"	"	0.37 "
Hematite	"	"	0.93 "
Quartz	"	"	0.90 "
Hematite	"	"	1.15 "
Quartz	"	"	0.43 "
Hematite	"	"	1.86 "
Quartz	"	"	0.18 "
Hematite	"	"	0.97 "
Quartz	"	"	0.37 "

Aggregate Thicknesses.

Hematite Rich Bands 14.85 m.m.

Quartz Rich Bands 4.35mm.

In addition, the quartz rich bands of a much smaller average grain size than the iron rich bands.

The above table shows that in general, the quartz rich bands are much thinner than the iron rich bands. The former probably represent the finer material deposited under Winter conditions, the wider iron rich bands then would be the coarser and bulkier fraction deposited in the summer when ice melted and caused swift deposition. Thus these shales have a close resemblance to varves.

M3. is a ferruginous laminated schist which is not as rich in hematite as M1 or M2.

It is very noticeable that in this rock, the layers richer in hematite contain abundant calcite, while those poorer in hematite are also poor in calcite.

Idioblasts of hematite range in size up to .1m.m. in diameter. Greenish brown biotite is fairly abundant, and apatite also is present. Plagioclase (albite) and quartz again are the main constituents of the lighter coloured bands.

Thus it seems that the specimens from the vicinity of Iron Peak, which is on the northern limb of the anticline, are more metamorphosed than those of the Little Ironback Range, although bedding is still well preserved. However, the metamorphism could not have been of a very high grade, as no reaction has taken place between calcite and chlorite, or calcite and quartz.

(d) Ferruginous Tillite.

Specimens C6, A1, A5, B3, B4, D4.

This bed is represented on section No.3 as C6, and is also shown on section No.2. It is approximately 35-50 ft. thick, and contains many erratics, both large and small. In the Ironback Range area (Loc.A) the tillite is in the same relative horizon as before, and also contains many erratics, including several large blocks of limestone.

Microscopically, the rock consists of erratics of all sizes (the largest being about 4.0m.m. in diameter) and of varied composition, set in a matrix consisting largely of fine grained hematite and quartz, with abundant idioblasts of hematite. The most abundant erratics are quartz, with some of shale and quartzite. Most of the shaley erratics usually contain some hematite, although some idioblasts of this mineral have grown into quartz erratics. A few particles of plagioclase are also present. Many of the quartz erratics appear to be somewhat recrystallized, as they often show a marginal zone of different optical orientation from that in the core. Also they show strain shadow effects, and are often rimmed with chlorite.

The groundmass consists mainly of fine hematite and quartz, with secondary limonitic material. Scattered idioblasts of hematite are abundant in all sizes up to 1.5m.m. in diameter, often surrounded by a mantle of green chlorite which is quite abundant throughout the matrix.

In the hand specimen, the ferruginous tillite of Little Ironback Range contains well defined unaltered erratics which seemed to point against a possible metasomatic origin for these deposits. In the Ironback Range (Loc.A) however, some erratics do show a slight reddish border in about ⅛ of an inch from their edges (Spec.A5), but this could be easily accounted for by later percolating solutions rich in iron.

(e) Sandy Ferruginous Shales.

This group occurs near the top of the iron rich beds, and is represented by band C2 on section No.3. A similiar type of rock occurs just above the ferruginous tillite horizon in Section B (See locality plan), but this would be lower in the sequence at locality B that that at C2.

Specimen C2 is a dark grey shaley roch containing small gritty particles of quartz, and shows no bedding.

Microscopically it is a fine grained sediment, with quartz and shale particles up to .8 m.m. in length, set in a matrix of fine hematite and quartz, with some sericitic mica. Biotite often rims quartz particles. Idioblastic crystals of hematite occur irregularly throughout the rock, up to .2m.m. in diameter. A few particles of plagioclase (probably albite) and calcite occur. The shale particles are generally elongated parallel to the cleavage, as are numerous biotite flakes.

This group is rather similar to the ferruginous tillite, but the particles (erratics) are much smaller, and these sediments may represent deposits formed nearer the lake shores than the finer shales.

(f) Hematite quartzites.

A fairly thin band of hematite quartzite occurs just above the ferruginous tillite horizon at localities A and B. However, it was not found at localities C or D (Sections 2 and 3.), and may therefore be of a lenticular nature.

A3 is a quartzite containing alternating iron rich and quartz rich bands.

The quartz rich bands consist of quartz grains with an average diameter about .1m.m., with calcite, plagioclase, apatite, tourmaline and mica. Much limonitic material is present, also a few idioblasts of hematite. The tourmaline is pleochroic from light blue to dark blue-brown.

The mica in this rock is green in the centre of the grain, and usually rimmed by brown biotite of different optical orientation. Abundant calcite is present, and a few grains of zircon.

The hematite rich bands are fine, and generally of finer grain than the quartz bands. They consist of idioblastic hematite crystals up to .1m.m. in diameter, set in a fine grained matrix of very small hematite and quartz particles. The hematite crystals are frequently rimmed with greenish brown biotite.

B6A is a relatively coarse grained hematite quartzite occurring within the iron shales, just above the iron rich tillite. Microscopically, it consists of a granoblastic aggregate of quartz with some plagioclase and calcite, and with a few narrow bands rich in hematite. Secondary limonitic material is also present. The plagioclase is probably albite. The calcite occurs in rhomb shaped crystals usually fringed with limonite stains or siderite.

A few crystals of apatite are present, which, as in most of the other rocks, show evidence of having been recrystallized. They often contain inclusions of hematite.

The quartz usually shows strain shadow extinction.

Other examples of most of these groups were collected, and a summary of the specimens presented is as follows:-

(a) Normal Tillite.

2 Specimens D1, erratics D2, D7, D8, D9, D10, and A7 (3 specimens).

(b) Shales with few hematite bands.

C1, C4, D5, M4

D6 is a shale from the fault zone which has been impregnated with reddish ochreous hematite.

(c) Ferruginous Shales.

C3, C5, C7, C9, A6, A4, D3.

B1, B2, B5, B6, B8.

M1, M2, M3 (Specimens from near Iron Peak, lent by Sir D. Mawson).

(d) Ferruginous Tillites.

A1, A5, B3, B4. C6, D4.

(e) Sandy Shales.

C2, B7.

(f) Hematite Quartzites.

A2, A3, B6A.

The Origin of the deposits.

Two alternative modes of origin may be postulated:

(1) Deposition as original sediments.

(2) Metasomatic replacement of preexisting sediments.

(1) Strong evidence in favour of a Sedimentary origin.

(a) The anticlinal structure of the area, with hematite rich beds overlying a normal unaltered tillite on both limbs of the fold.

(b) The fact that the interbedded shales etc. do not appear to have suffered the degree of metamorphism which would be expected if the beds had been depressed to fairly great depths. and then metasomatically replaced by iron rich solutions.

(c) Negative evidence, in the absence of any sulphides or other metallic minerals other than hematite, magnetite and limonite.

(d) The fact that the iron rich beds grade both above and below into more normal types of shale which contain only a few widely spaced hematite rich bands.

(2) Evidence in favour of either Sedimentary or Metasomatic origin.

(a) Presence of well defined bedding, often of a graded nature, and which appears to be of a varve character.

(b) Presence of unaltered particles of quartz and shale in a matrix of quartz and hematite. (Ferruginous Tillite).

(c) Presence in Spec. C5 of a band rich in apatite, and containing tourmaline.

(d) The presence in some specimens (especially A6) of lenticles consisting mainly of quartz and plagioclase, which often cause the bedding to become slightly dented, and which presumably represent small partly consolidated mud pellets which were swept out into the depositing basin, quickly covered and thus preserved.

(e) The fact that the hematite beds do not send out veins or branches into the normal shales or tillite.

(f) The presence of residuals of magnetite in the hematite idioblasts suggests that this mineral was deposited as detrital magnetite grains, but not necessarily so.

As regards a sedimentary origin, it is quite possible that the sediments were originally laid down either as detrital deposits, or as chemical deposits. Although the latter theory must be kept open as a possibility, it is considered that with such effects as graded bedding in the varve type rocks, probably would not be so conspicuous with a chemical origin.

In both a metasomatic and a chemical origin, a rather deep depression of the sediments during orogeny would have to be assumed, to convert any iron rich material to magnetite, then, on the sediments being folded, a later retrograde change from magnetite back to hematite or martite. This seems rather difficult to conceive, as the associated tillite and shales appear to have suffered very little metamorphism. Another difficult feature to explain by a metasomatic origin is the occurrence of shales containing only widely spaced hematite rich bands, although by "metasomatists", this may be explained by assuming a selective replacement whereby certain bands especially favourable alone were replaced. However, one would not expect to find such sharp boundaries between normal shales and hematite rich shale. Also, the presence of erratics of shale in the ferruginous tillite would seem incompatible with the fact of other shales being replaced by iron rich solutions. One might imagine that the more resistant quartz and quartzite erratics may resist attack, but hardly the shale particles.

A major difficulty of a detrital origin is the fact that the underlying tillite beds do not appear to contain any iron rich erratics, which would surely be expected, as well as the finely ground shaley material. (Actually a few very small pebbles of hematite were found, but not in sufficient quantity to be of any significance.

However, on evidence gained by work up to date, the authors feel that a sedimentary detrital origin best explains the observed facts, although it is realized that other possible features may have been overlooked by not mapping the beds in detail.

Other similar deposits in the State have been found associated with the Sturtian tillite (personal communication from Mr. R.C. Sprigg), and these should all be mapped, and considered together before any attempt is made to finalize a hypothesis of origin.

Assuming, for the present, a detrital origin for these beds, it is thought that the shaley varve-like rocks would have been laid down under quiet lake conditions consequent upon retreat of the ice. These varve deposits are supposed to be due to the fact that in Summer seasons, ice melts, and causes swift flowing streams which would be capable of picking up, transporting, and depositing the heavy magnetite. In Winter, however, the streams would be sluggish, and would only be capable of transporting quartz particles. The ferruginous tillite occurring in the midst of these varve-like deposits may be due to a temporary advance of the ice sheet, or may represent boulders etc. dropped from melting ice floating in the lake.

The thin beds of ferruginous quartzite would be interpreted as a near shore deposit of coarser grain than the deeper water deposits.

CONCLUSIONS.

Up to date the areal extent of the beds has not been mapped, and no estimation of tonnage could be given, but the fact that the deposits, necessarily low grade, occur so far from the coast must at present preclude an economic value. However, as other resources dwindle in years to come, these and other similar deposits will have to be examined more closely from the economic aspect.

ACKNOWLEDGEMENTS.

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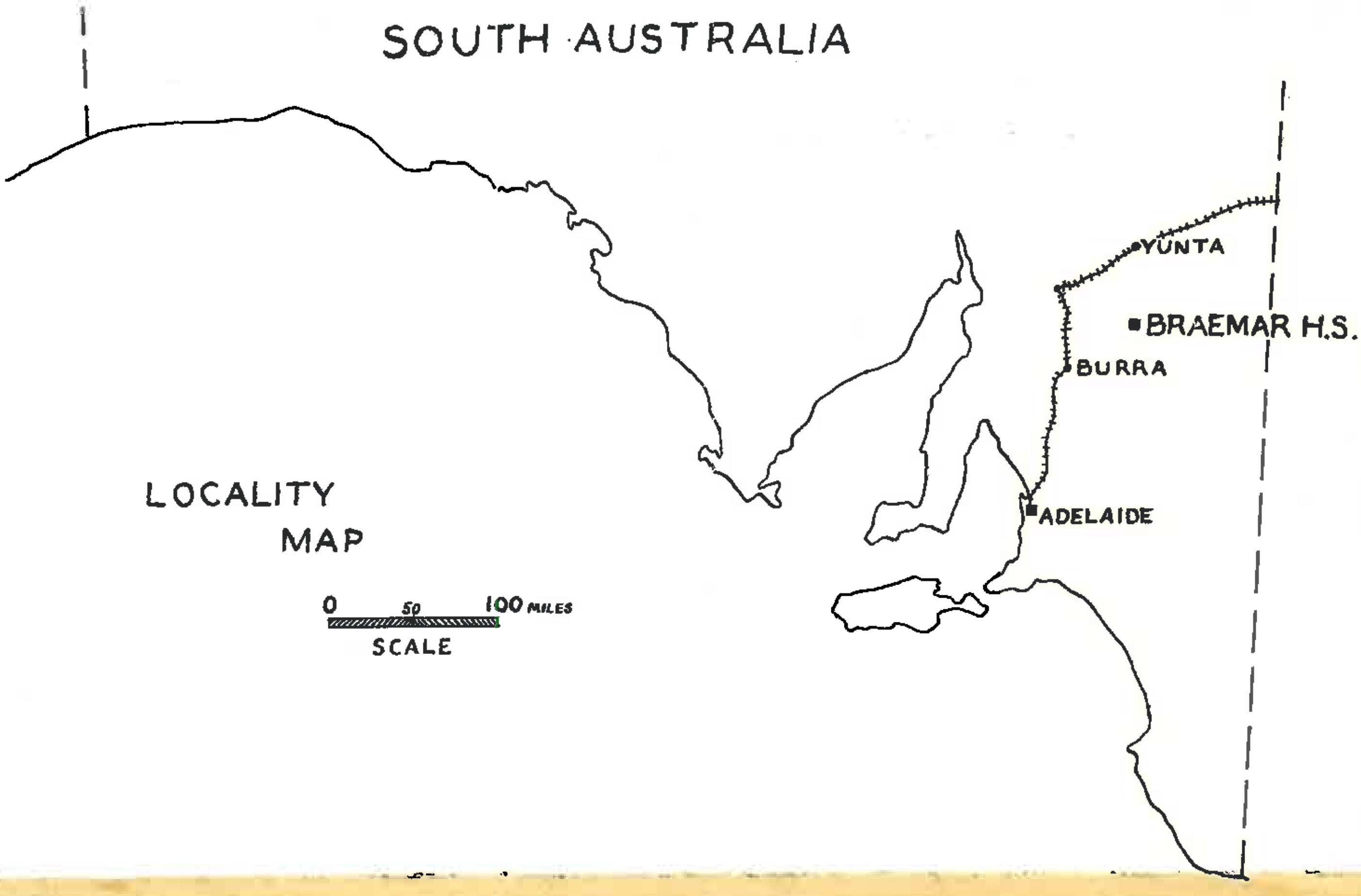
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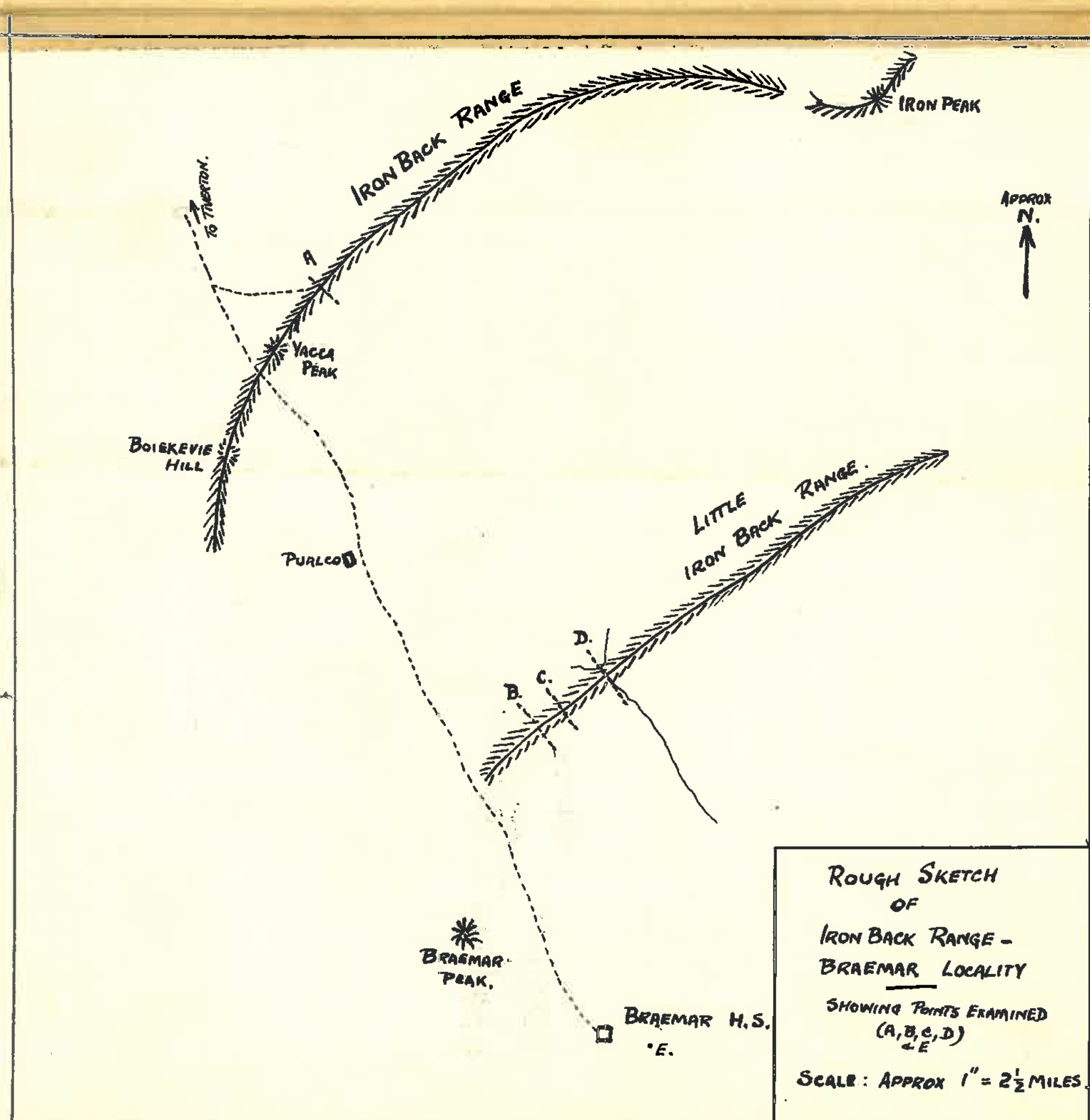
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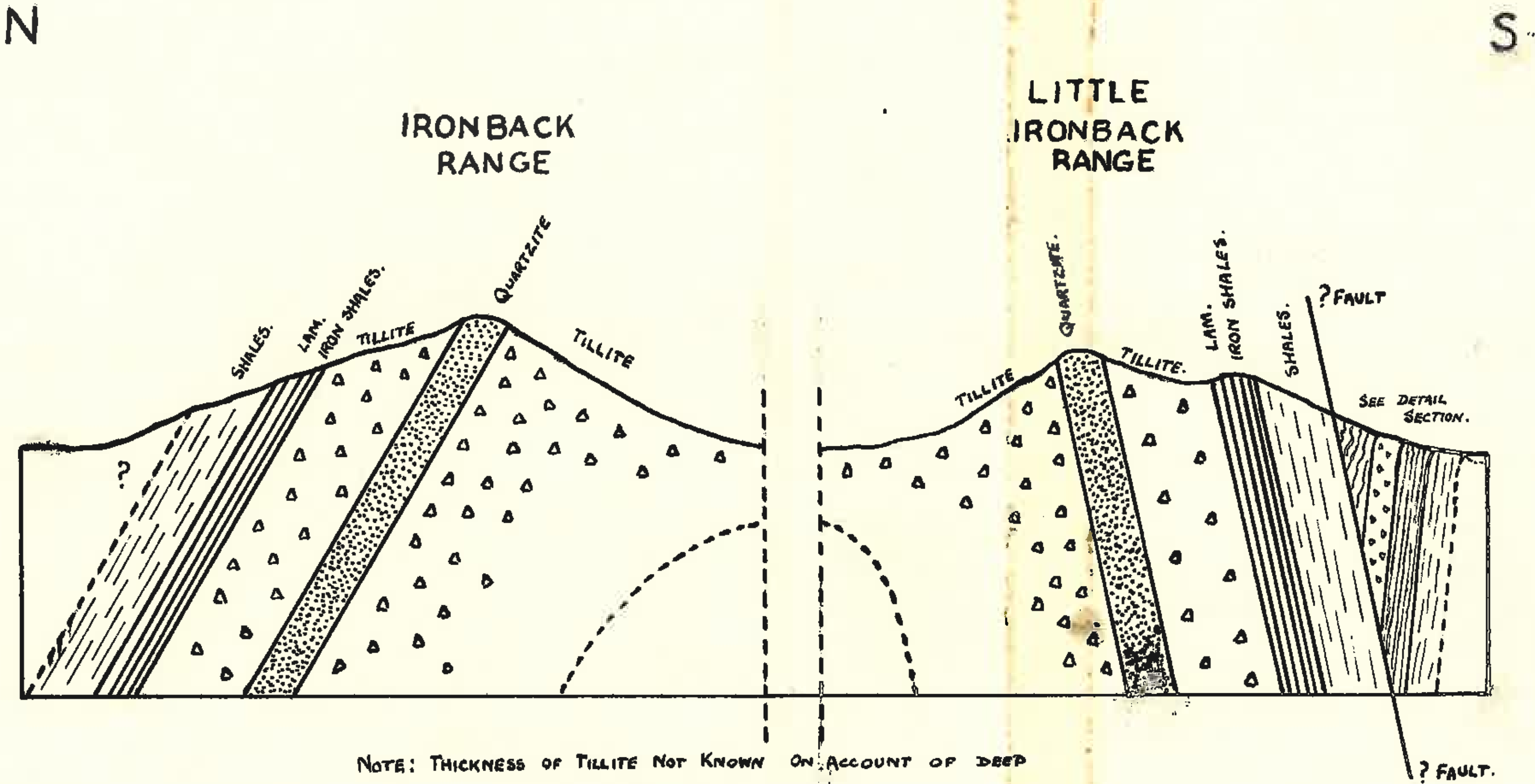
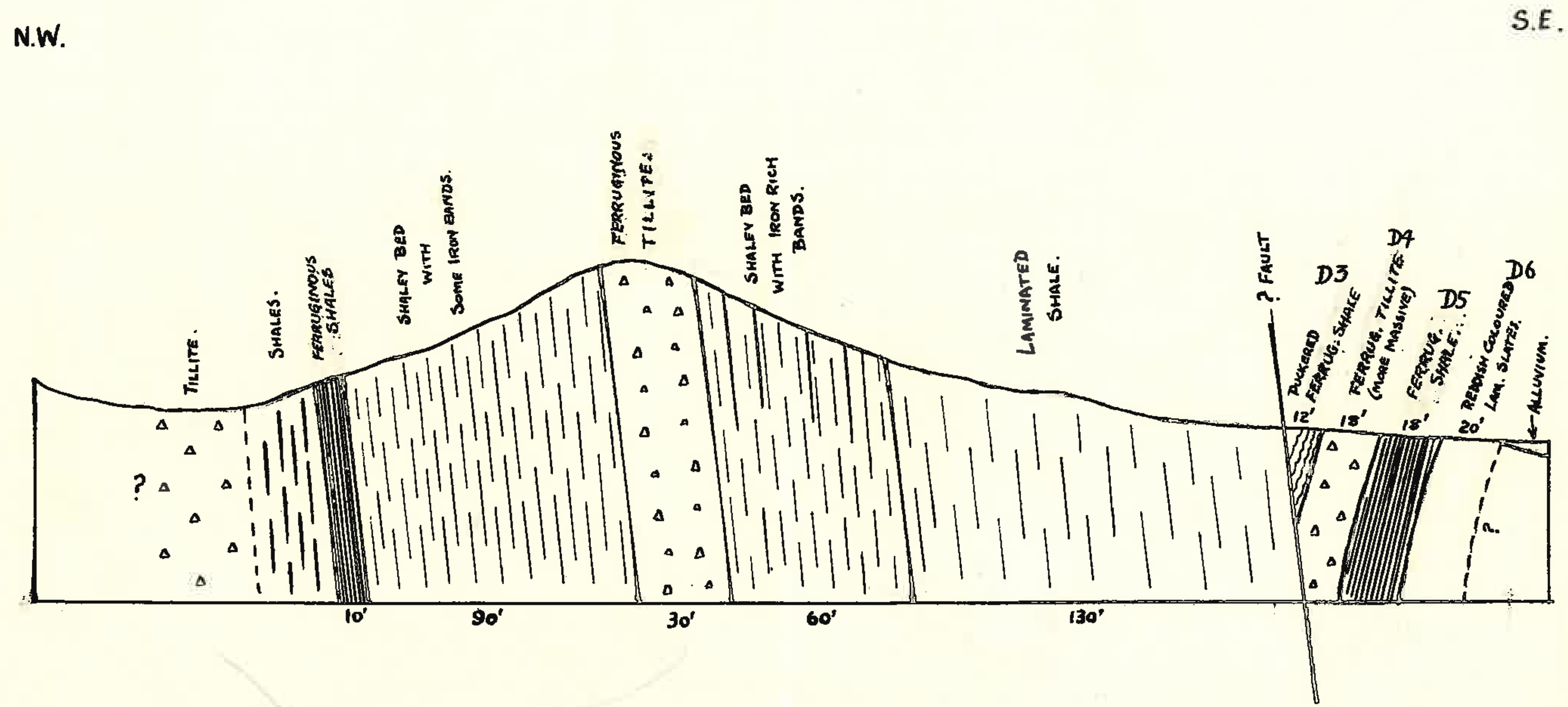
& E
SCALE: APPROX 1" = 2½ MILES



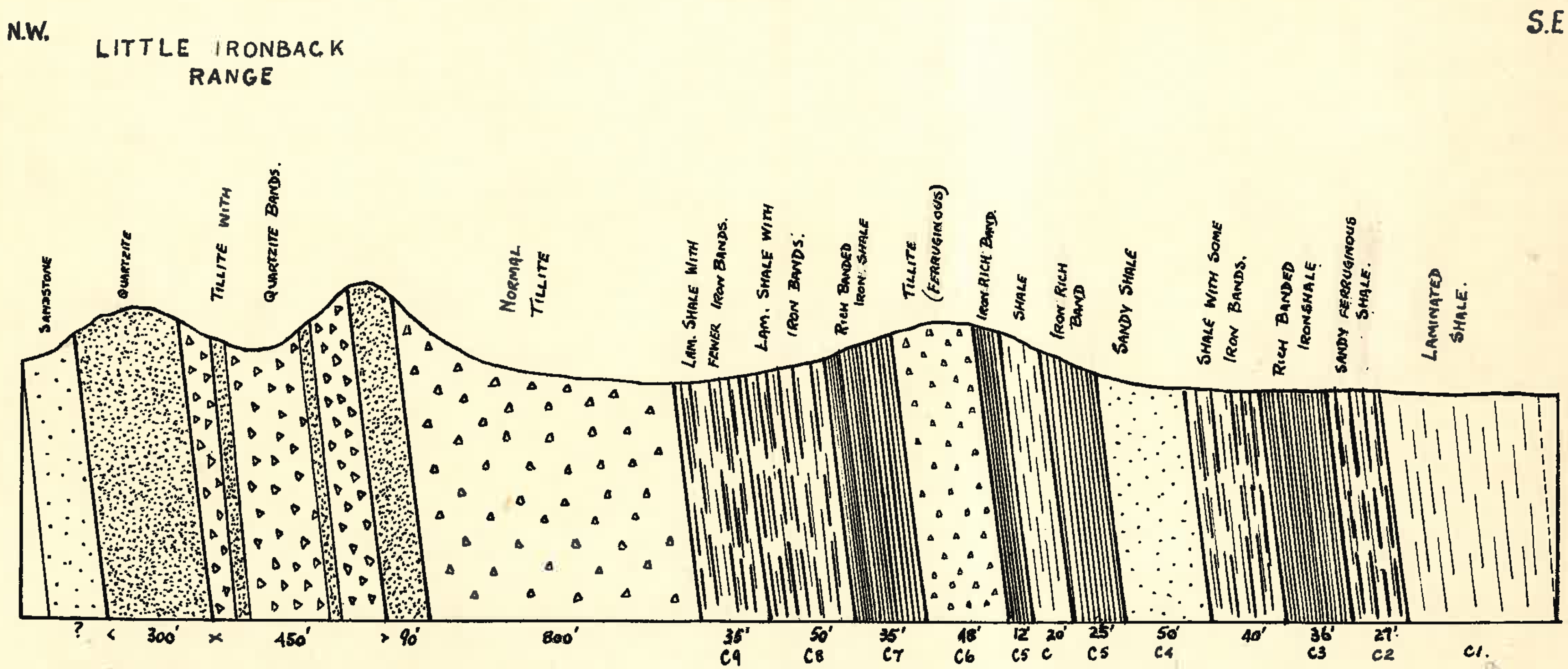
Note: Thickness of Tillite Not Known on Account of Deep Alluvium Cover Between Ranges.

Generalized Section Only.

SECTION No 1


N.W.
S.E.
TILLITE.
SHALES.
FERRUGINOUS SHALES
SHALEY BED WITH SOME IRON BANDS.
FERRUGINOUS TILLITES
SHALEY BED WITH IRON RICH BANDS.
LAMINATED SHALE.
? FAULT
D3
PUCKERED FERRUG. SHALE
D4
FERRUG. TILLITE (MORE MASSIVE)
D5
FERRUG. SHALE
D6
REDDISH COLOURED LAM. SLATES.
ALLUVIUM.
12'
18'
18'
20'
10'
90'
30'
60'
130'

SECTION No. 2.



NOTE: NOT TO SCALE. THICKNESSES SHOWN BELOW BEDS.

SECTION No. 3.