COMMONWEALTH OF AUSTRALIA

MINISTRY OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

BULLETIN No. 4

WAUCHOPE WOLFRAM FIELD NORTHERN TERRITORY

by C. J. SULLIVAN

Issued under the Authority of Senator the Honourable W. H. Spooner, Minister for National Development

1952

COMMONWEALTH OF AUSTRALIA

MINISTRY OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

BULLETIN No. 4

WAUCHOPE WOLFRAM FIELD NORTHERN TERRITORY

by C. J. SULLIVAN

Issued under the Authority of Senator the Honourable W. H. Spooner, Minister for National Development

1952

MINISTRY OF NATIONAL DEVELOPMENT

Minister: SENATOR THE HON. W. H. SPOONER

Secretary: H. G. RAGGATT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Director: P. B. NYE

Deputy Director: J. M. RAYNER

This Bulletin was prepared in the Geological Section

Chief Geologist: N. H. FISHER

CONTENTS

APPENDICES

ILLUSTRATIONS

SUMMARY

Wauchope wolfram field* is situated 260 miles by road north of Alice Springs, Northern Territory. Wolfram occurs in a series of quartz reefs—the series is traceable over a strike-length of 3,000ft. and the reefs are 6in. to 18in. thick. The main production has come from three reefs 12in. to 18in. thick.

The field was discovered in 1917 and, from then until 1941, the deposits were worked at such times as tungsten prices were favourable (Fig. 2). Most of the mining was done on tributing basis, and the exploitation of the field was rather unsystematic. Production during that time was approximately 1,000 tons† of concentrate, obtained from an estimated 10,000 tons of quartz mined. Mining had ceased when the Commonwealth Government took over the field in April, 1942, and there were no accessible working faces. Employing Chinese labour, the Government drove 2,800ft. of exploratory and developmental adits, drives, and rises and stoped a small amount of ore. Five drill holes aggregating 1,108ft. tested the reefs ahead of the workings.

The results of the testings were disappointing. It was found that payable ore was largely confined to one shoot (Shoot "A")—with a maximum strike-length of 300ft. and extending down-dip for 120ft. to 200ft.—from which most of the ore had been extracted. The shoot occurs near the outcrop of the vein system, and the long axis is roughly parallel to the outcrop. Vein-contouring shows that it is situated in a structural basin in the beds and reefs (which are mainly parallel to the bedding).

Of 151 samples taken from the quartz remaining within the structurally favourable ground, the weighted mean content was 0.96 per cent WO_3. Ore from within the shoot-limits yielded 1·2 per cent WO_3. On the basis of these figures it was estimated that, when the Government ceased mining at the end of 1943, 5,000 tons of quartz averaging 1·2 per cent recoverable WO_3 remained in Shoot "A" (Plates 4 and 5).

Beyond the limits of the ore-shoots, the average grade was found to range from 0 to 0·25 per cent WO_3. The diamond drilling intersected, for the most part, only narrow reefs with low wolfram content (for details see Appendix 4).

Shoot "B" (Plate 5) appears to be continuing in depth, and diamond drill hole No. 3 (Plate 4; Plate 6, Section E-F) intersected a 30-in. quartz vein at a productive horizon, down-dip from the known position of this shoot.

Since 1943, prospectors have produced approximately 30 tons of concentrate per annum (67·3 tons in 1945). Some of this was obtained from ore exposed in adits by Government operations, and about 30 tons has been obtained from Shoot "B" in the vicinity of The Russian's Shaft and Tarka's Shaft (Plate 5). Payable ore was being obtained from the latter shaft when the writer visited the field in July, 1949. Small patches of ore have been obtained from various other places on the field.

The field appears to be suitable for exploitation by small parties only. Independent miners, known as "gougers," are able to extract pockets of ore from awkward positions where regular mining would be unpayable. The narrowness and lenticularity of the veins, their low average tungsten content, and the fall in grade with depth render large-scale mining impracticable.

---

* In some previous official publications this has been called the Wauchope Creek wolfram field. Locally it is always known as Wauchope and the Northern Territory Mines Department adopted this usage in its Annual Report for 1948-49.

† All tonnages in this bulletin are in long tons (2,240 lb.).

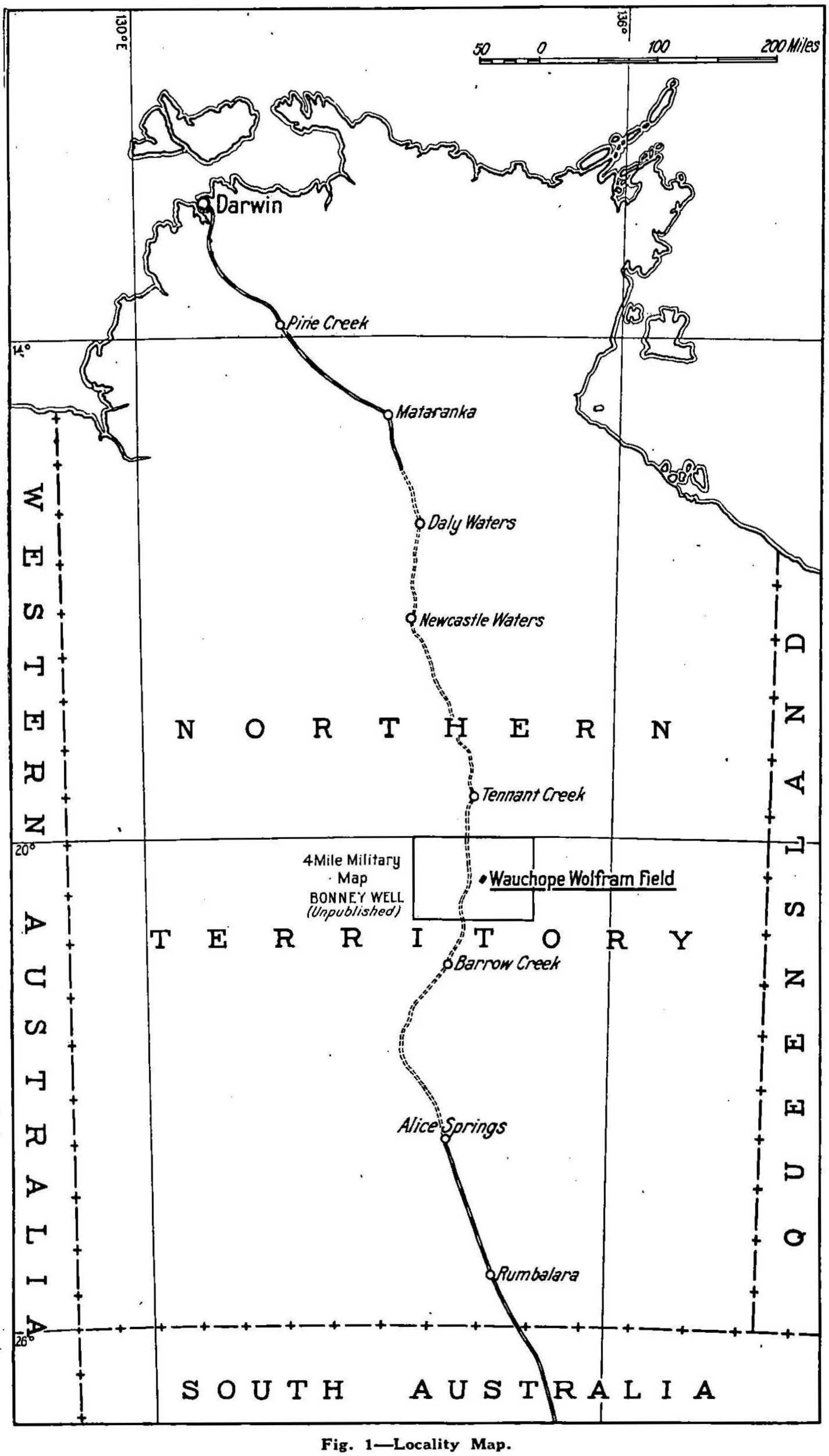


Fig. 1—Locality Map.

INTRODUCTION.

Situation, Access, Communications.

Wauchope wolfram field is situated at the north-western end of the Davenport Range in the Northern Territory of Australia. Wauchope Well is on the Stuart Highway and north of the railhead at Alice Springs. The mine is 7 miles by road east of the well. The road from Alice Springs is part of the main highway to Darwin and consists of a bitumen strip 16 feet wide, well bedded on a gravel foundation. Supplies are brought by motor truck from Alice Springs, the road freight being approximately £8 per ton.

There is a hotel at Wauchope Well and also a post and telegraph office. The excellent communication services and the good roads were installed to meet military requirements in the Northern Territory during the years 1939-45.

Topography.

In the vicinity of Wauchope field, the Davenport Ranges consist of hills rising 200 to 500 feet above the surrounding plain which is 1,000 to 1,200 feet above sea level. In the areas where flatly-dipping quartzite formations predominate, the hills have a steep escarpment on one side and a gentle dip-slope on the other. The tops of the hills are residuals of a peneplain, possibly of Miocene age, which is now being dissected. Remnants of this peneplain are found over most of the Northern Territory.

Small rock-bottom creeks dissect the area, but they are dry for most of the year. A few rock-holes occur in which water is protected from evaporation and remains over periods of several months.

Fairly extensive swamp areas are found east of Wycliffe Well and approximately 6 miles south of the Wauchope Hotel.

Climate, Vegetation.

The winter climate is cold to mild with occasional showers of rain. Cool south-easterly winds are common during this period, and necessitate the use of overcoats and other warm clothing. The windy days are, however, interspersed with frequent periods of mild sunny weather, in pleasant contrast to the generally colder and wetter conditions prevailing in the southern part of Australia during this period.

Parts of the summer months are inclined to be unpleasantly hot with temperatures up to 112° F. or higher. During heat-wave periods, maximum temperatures may remain over 100° F. for 40 to 50 consecutive days. Thunderstorms are of fairly frequent occurrence, and most of the annual rainfall of approximately 14 inches per year occurs during the hotter part of the year.

Vegetation is typical of the semi-arid conditions of the region. The plants include spinifex (*Triodia* and *Plectrochere*), mulga (*Acacia aneura*), snappy gum (*Eucalyptus pallidifolia*), ghost gum (*Eucalyptus papuana*) and a tall white gum (*Eucalyptus comaldalensis*). In addition, there is a wide variety of flowering plants and shrubs, wattles, mallee, grevillea, and field grasses.

The mulga is a tough, strong wood resistant to white ants and to dry rot; consequently, it is valuable as mining timber and fencing-posts. It takes a fine polish, and may be used for making furniture and wooden ornaments.

During the 1939-45 war, the Australian army developed a very successful garden at Wycliffe Well (16 miles south of Wauchope Well) and grew tomatoes and green vegetables. This was made possible by the substantial underground water supply available there.

HISTORY.

According to a private report dated May 1920, by E. Copley Playford, then Chief Mining Warden of the Northern Territory, an aborigine discovered wolfram in the field in March 1917. Soon afterwards Messrs. Curtis, Scott, Weldon, and Moar applied for, and each was granted, a 10-acre lease, viz., Nos. 211, 212, 213, and 214. Subsequently, Mr. H. J. Turner was granted lease No. 242; in 1919 Mr. Turner acquired all the leases.

In 1915 the British Government had guaranteed a price of 55s. per unit* of tungstic oxide, and in 1917 the price was increased to 60s. per unit. It is stated by Mr. Turner that the price paid on the field was 52s. 6d. per unit. The Australian Government also gave a bonus of £18 per ton to cover the cost of transport of the concentrate to railhead, then at Oodnadatta—some 500 miles in a direct line to the south. The concentrate was carried by camel teams owned by Afghans.

By June 1917, 12 tons of wolfram had been sent away, and there were 12 men on the field. The number of men had increased to 22 in 1918, and the production for the year was 59 tons of concentrate, averaging 68 per cent WO_3. Hand steel was used exclusively in mining. Rich ore was hand-cobbed and bagged, and poorer material was "burned" in a kiln with wood. This rendered the quartz brittle, and made it possible to break the wolfram out by hand tools. The broken material was then hand-jigged.

The price was guaranteed for the duration of the war and for six months thereafter. As soon as this period elapsed, the price fell to 10s. to 15s. per unit, and the field was almost abandoned. A small amount of work was done during the periods 1931-32 and 1934-36, but it was not until 1937 that the field again "boomed." In September of that year the price of concentrate rose to over £7 per unit (about

* A unit of tungstic oxide is one-hundredth of a ton of tungstic oxide. One ton of standard wolfram concentrate contains 65 units of tungstic oxide or 65 per cent WO_3.

£450 per ton of standard concentrate), and averaged nearly £300 per ton for the year. This resulted from the Japanese invasion of China (formerly a major tungsten producer) and from the onset of the world re-armament programme. Late in 1937, a treatment plant consisting of a jaw crusher, rolls, trommel and two "Curvilinear" tables was erected. Power was supplied by a 28 h.p. Crossley engine. These factors resulted in increased production and, for the year ended 30th June, 1938, the output from the field was 240 tons of concentrate—the maximum obtained in one year. There were 240 white people on the field at that time.

Mining was at a comparatively high level until the end of 1939 when a business dispute led to the closing of the field. However, in June 1940, about 40 men began tributing under the supervision of Mr. Turner. Work proceeded for a year, and 69.2 tons of concentrate was produced to June 1941. The field was again almost abandoned during the latter half of 1941.

The Commonwealth Government took over the field in April 1942 as no work was being done by the owners and tungsten was badly needed by the Western Allies. A royalty of 10 per cent of the gross value of ore mined was to be paid as a compensation to the lease-holders.

The Government engaged Chinese labour, which had previously been employed on the phosphate workings of Nauru and Ocean Island but had been evacuated to Australia soon after Japan entered the war. Considerable difficulties were experienced and the output per man-shift was small. Approximately 190 Chinese were employed on the field.

In November 1943, the Government decided to cease operations. This decision was made because:—

(1) It would have been difficult to obtain labour to replace the Chinese, whose contract had expired and whom it was not desired to re-engage.

(2) As a result of the sampling campaign carried out prior to this, it had been found that the field had not responded well to development, and it was considered that the margin of profit, if any, would be small and would not enable the Government to recoup its losses.

(3) The tungsten supply position had improved very considerably, and it was believed that the King Island scheelite mine could supply future requirements.

The development carried out by the Government was as follows:—

	Feet.
Inclined shafts	1,720
Drives	920
Rises	160
	2,800

The standard shaft, drive, or rise, was 7 feet wide and 7 feet high. No. 4 incline (Plate 4), which was meant to be a main haulage way, was 11 feet wide and 9 feet high. In addition, 1,108 feet of diamond drilling was completed.

After the cessation of work by the Government, tributers, by arrangement with the Department of Supply and Shipping, began to mine ore that had been exposed by Government operations. They paid a 20 per cent royalty to cover the use of plant owned and maintained by the Government. From December 1943 to August 1944, the tributers produced 19.7 tons of wolfram concentrate. In August 1944 the leases were handed back to the lessees who again let tributes to small parties. This was continued to the present (September 1949).

Production.

The following table of production, which is based on the records of the Northern Territory Mines Department, is regarded as an approximation only. In some cases, production was not reported in order to avoid the payment of royalty (2½ per cent on gross proceeds of the sale of concentrate) but, in many cases, miners simply neglected to inform the proper authorities. In some years the production for separate fields in the Northern Territory has not been recorded, and it has been necessary to allocate the amounts to the various localities in accordance with the best information available.

The average grade of concentrate produced by the Government (1942-43) was 62.07 per cent WO_3. Concentrate produced prior to this was usually high-grade as it was cleaned by hand-jigging, but the actual tungsten content has not been consistently recorded.

TABLE 1

Production of Concentrate, Wauchope Wolfram Field

Year*	Tons	Value £
1916-17	12·00	2,402
1918	59·00	12,066
1919	66·50	11,098
1920	92·50	15,912
1921	35·00	3,346
1931	6·88	192
1932	34·00	1,369
1934	15·00	1,168
1935	39·63	4,428
1936	28·50	2,916
1937	38·00	4,669
1938	240·32	59,864
1939	164·21	29,318
1940	69·18	12,239
1941	70·35	11,119
1942	34·60	5,921

TABLE I—*continued*

Year*	Tons	Value £
1943	21·60	7,439
1944	35·79	12,290
1945	36·89	12,416
July-December, 1945	32·45	11,283
1946	30·29	9,799
1947	34·27	13,482
1948	30·85	13,150
Totals	1,227·81	£257,886

* For 1916-1945, year ended 30th June; for 1946-1948, year ended 31st December.

It will be seen from Figure 2 that, during the history of the field, tungsten prices have fluctuated widely and that production has depended on these prices. By about 1939, the easily-won wolfram had been exhausted and production has since been small in spite of high prices.

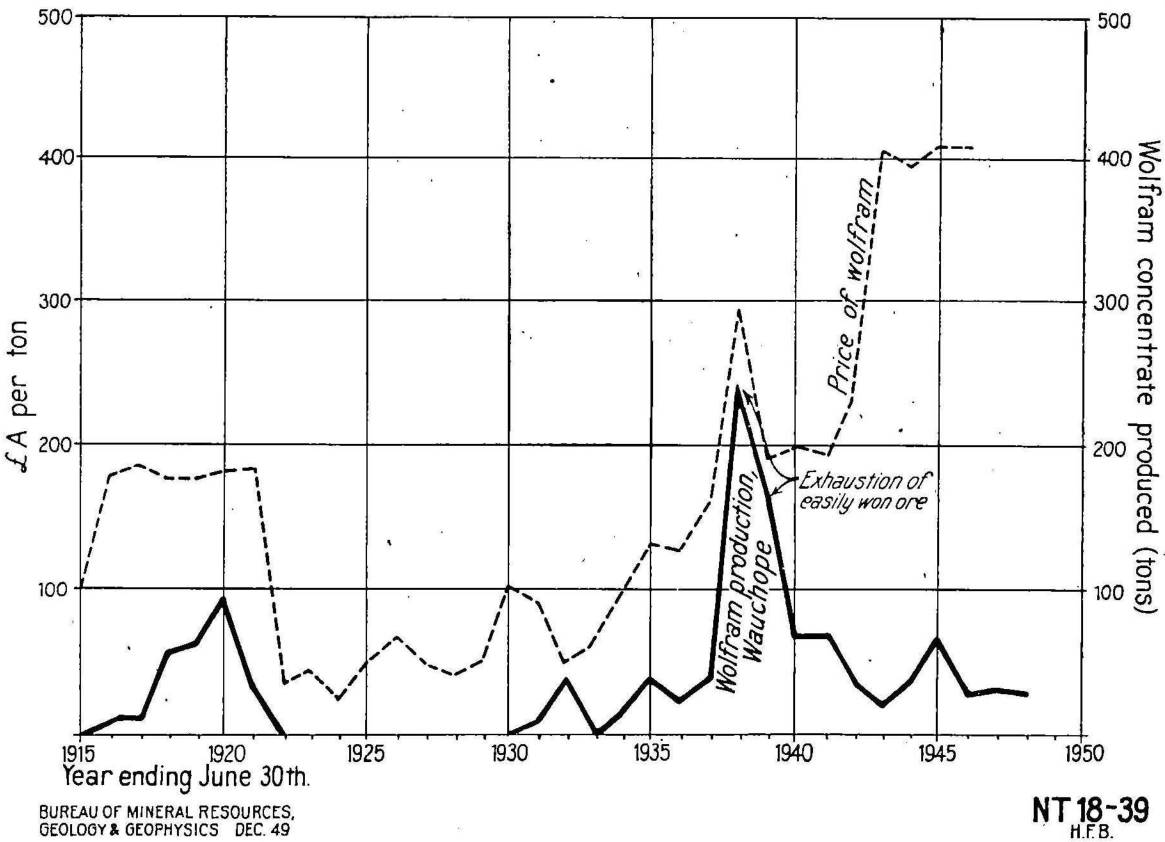


Fig. 2—Graph showing approximate value of wolfram concentrate exported from Australia, 1915-48, and production, Wauchope wolfram field, Northern Territory.

Time Spent in Field.

The periods 30th October to 2nd December 1939, and 16th April to 16th July 1940, were spent in the field by a party of the Aerial, Geological and Geophysical Survey of Northern Australia, led by the author. This field party was part of the Northern Territory geological party of which Mr. P. S. Hossfeld, Senior Geologist, was in charge; V. M. Cottle and S. N. Kiek, Assistant Geologists, completed the party. During this period, approximately 150 square miles of the surrounding country was geologically mapped on aerial photographs, and a detailed survey of the mineralized area was made. The surface was surveyed by plane table, and the underground workings by chain and compass (A.G.G.S.N.A., 1939, 1940).

In April 1942, the Commonwealth Government decided to work this and other fields in the Northern Territory in an attempt to meet the wartime demand for strategic minerals, and the writer returned to the area.

Many visits were made to the field during the next two years in order to advise on, and assess the results of, the exploratory work.

The writer, accompanied by W. B. Dallwitz, visited Wauchope in July 1949.

GENERAL GEOLOGY.

A geological map of the area is shown on Plate 1.

Sedimentary Rocks.

The most abundant rock-type in the area is generally termed quartzite, and includes blue quartzite of medium grain, bands of white quartzite of moderately coarse grain, fine-grained white sandstone, grit, and some conglomerate. In places, all these rocks are current-bedded. The rocks are of shallow-water origin, and the beds are lenticular.

There are also two beds of fine-grained rock in one of which the orebodies occur. The fine-grained rocks were originally mudstones but, in the vicinity of the ore deposits, they have been converted to hornfels. Petrological work by W. B. Dallwitz (Appendix 1) shows that the outcropping fine-grained rocks consist predominantly of sericite-quartz-tourmaline hornfels. Small sections of the rock have been almost completely replaced by tourmaline and topaz.

The metamorphism of the rocks has not obliterated the bedding; ripple-marking is also well preserved. The general field appearance of the hornfels is illustrated in Figure 3.

Examination of bore cores from Nos. 1 and 5 diamond drill holes (Appendices 3 and 2 respectively) revealed also that, at depth, in the neighbourhood of the mineral deposits, the fine-grained rocks consist

Fig. 3—Face of flatly-dipping fine-grained hornfels with quartz vein parallel to bedding—vein indicated by hammer.

Fig. 4—Devil's Marbles granite

largely of hornfels comprising biotite hornfels, quartz-chlorite hornfels, quartz-sericite rocks resulting from alteration of mudstone, and a small amount of epidote-garnet hornfels with some scheelite and fluorite.

IGNEOUS ROCKS.

Granite, containing microcline-perthite, quartz, plagioclase, biotite and muscovite, crops out in the north-west corner of the area mapped. Large round and oval boulders appear to be balanced precariously on hill-tops and for this reason the locality has been named The Devil's Marbles. The main Darwin-Alice Springs highway winds through this outcrop, which is one of the notable sights along the road (Figure 4).

Boulders of light-coloured felspar perphyry were picked up on an alluvial flat covering predominantly sedimentary rocks east of the granite (Plate 1). No outcrops could be found.

STRUCTURE.

Folding.—As shown on Plate 1, there are two major regional folds in the area. These consist of a large saucer-shaped basin occupying the southern portion of the district, and a sharp anticline north of the basin. The dips in the basin range from 7 to 20 degrees, and on the anticline they range, in general, from 60 to 70 degrees. The mining field lies on the northern side of the basin and on the southern flank of the anticline.

Near the granite, the axis of the anticline trends in an east-north-easterly direction but, as the fold is traced east, the axis swings in a southerly direction until it trends south-eastward at a point 10 miles east of the granite.

Associated with these major folds are minor warpings; these are important in the localization of ore.

Faulting.—A considerable amount of faulting has taken place in the area (Plate 1). The most prominent fault is about five miles south of the field. It strikes north-east and probably dips south-east. It appears to be a hinge fault, being very prominent to the north-eastward and dying out in the opposite direction. For a distance of one to two miles its position is marked by a steep-sided gorge, 100 to 200 feet wide and 50 to 100 feet deep. It appears likely that the beds on the south side of the fault are a repetition of those occurring on the northern rim of the basin. There are several smaller faults parallel to this prominent fault and apparently closely related to it.

The set of faults second in importance strikes at 120 to 145 degrees.* The wolfram-bearing veins terminate at the southern end

* All bearings in this bulletin are magnetic.

of the field against a fault belonging to this set (Plate 2). In the case of the two most prominent of these faults, the rocks on the southern side of the fault are on the downthrow side.

Apart from the fault that terminates the reefs at the southern end of the field, the most important faults, from the mining point of view, strike at 20 to 30 degrees and dip east at angles of 20 to 30 degrees. One has a reverse vertical displacement of 18 to 20 feet (Plate 3). Numerous faults of this nature with displacements of 1 to 3 feet may be seen in the workings (Figure 5). Faulting of this type has led to mistakes in prospecting, as it has the effect of repeating the veins. A useful rule for the field is that, when driving down the dip, if a vein is faulted it will be found overhead, not underfoot as has generally been supposed.

Age of Rocks.

The age of the rocks shown on Plate 1 has not been definitely determined, but it is considered likely that they overlie uncomformably the sandstones and slates of the Warramunga Group which occur at Tennant Creek. The rocks exposed at Wauchope are part of a large group of which the Davenport Range is composed. This range extends for 60 miles to the south-east where similar rocks have been mapped on the Hatches Creek wolfram field. In the latter district, the sandy formations present at Wauchope are interbedded with tuffaceous formations and overlie uncomformably a group of sheared tuffs and porphyries. The sandy beds at Hatches Creek are uncomformably overlain by a group of gently-folded rocks consisting of sandstones, acid lavas, and pink shales. No fossils have been found in these gently-folded rocks, and it is thought that they may be late Pre-Cambrian in age (A.G.G.S.N.A., 1940b).

The Davenport Range quartzites and sandstones are very similar in type to the Ashburton Sandstone (Noakes and Traves, 1948) overlying the Warramunga Group north of Tennant Creek and have been subjected to about the same degree of folding. The nature and relationships of these rocks were probably first investigated by H. B. Owen (1939), and the results of his studies have been available to the writer. Owen recognized the Davenport Range sandstones and quartzites as a group separate from the Tennant Creek rocks—his Warramunga Series—and as probably overlying these rocks unconformably.

Owing to the lack of large-scale regional mapping, any correlations that can be suggested between the age of the Davenport Range beds and those of rock-groups occurring in the Pre-Cambrian of South Australia, or the northern parts of Western Australia and the Northern Territory, are speculative. At present it can only be said that these rocks form a very distinctive group characterized by predominantly sandy beds that have been thrown into comparatively open

Fig. 5—Quartz vein displaced by reverse faulting; throw three feet. Hammer lies along fault plane.

folds. Associated with the group is a distinctive tungsten-bismuth metalliferous province. It is interesting to note that the group is intruded by granite; the somewhat comparable Nullagine "Series", found elsewhere in Northern Australia, is less folded and is not intruded by granite. It is probable that the Davenport Range sandstones and quartzites are younger than the Warramunga Group, but possibly older than the Nullagine (late Pre-Cambrian). The youngest group of rocks, unconformably overlying the sandy beds at Hatches Creek (A.G.G.S.N.A., 1940b), appear to correspond to the late Pre-Cambrian (Nullagine "Series") found elsewhere.

WOLFRAM-BEARING REEFS.

General.

Wolfram has been found at three places in the Wauchope district; these are shown on Plate 1. A small quartz reef containing wolfram occurs on Dixon Creek in the Devil's Marbles granite, but it is of no economic importance. A second prospect has been found in the white sandstone formation approximately ¾ mile north of the granite, and is reported to have produced 5 to 10cwt. of wolfram. However, the prospect does not appear to be of much value. The main deposits, which are found on the Wauchope mining field, are described in some detail below.

Dimensions.

Fifteen separate reefs were mapped at the surface, but most of them are not of sufficient size to warrant mining more than a few feet below the surface. Wolfram has been mined from all the reefs, but principally from three reefs, viz., Nos. 8 (A and B), 9, and 10 (Generalized Section, Plate 3). Where exposed in the various workings, these reefs average 12 to 18 inches in width. The series of wolfram-bearing veins has been traced over a strike-length of 3,000 feet, but individual veins extend for a maximum distance of 700 to 800 feet along the strike; many of them lens out and make again over short distances (Plate 6). The largest ore-shoot was 300 feet long and had a maximum thickness of 160 feet. The ore-shoots are described in greater detail below.

Mineralogy.

The deposits have been mined in the oxidized zone only, where they consist essentially of quartz reefs containing variable amounts of wolframite. In places, cavities and cracks in the wolframite show thin incrustations of scheelite, but the scheelite is not found apart from the wolfram, and the total quantity present is small. F. L. Stillwell (Appendix 3) considers that the scheelite was probably formed by deuteric alteration of the wolframite. Bore cores from the sulphide zone revealed the presence of small quantities of pyrite, chalcopyrite, molybdenite, and probably some bismuthinite.

Apart from quartz, some non-metallic gangue minerals occur in the ore, and these are described in Appendices 1 to 3. Commonly, the veins have a selvage, ⅛ to ¼ inch thick, of ferriferous muscovite, though in some places the selvage is about 1 inch thick and consists of yellowish-white sericite (Appendix 1). Browne (Appendix 2) also noted sericite in the quartz vein intersected by No. 5 D.D.H., and considered that it may have been derived from felspar.

Aggregates of a very fine-grained, soft, pale greenish-yellow mineral are of widespread occurrence in the quartz veins; Dallwitz (Appendix 1) identified this mineral as damourite, formed by the alteration of muscovite.

The veins also contain smaller quantities of a clay mineral (possibly dickite) as well as some topaz, fluorite, limonite, and hematite.

The minerals in the ore cause no difficulties in concentration, and it has usually been possible to obtain a high-grade concentrate that is free from undesirable impurities.

A partial analysis by O. T. Lempriere and Co. Pty. Ltd., Sydney, of the concentrate obtained from the Government treatment plant is given below:—

	Per cent
WO_3	63·35
Tin	Trace
Arsenic	0·01
Phosphorus	0·07
Molybdenum	Nil
Alumina	7·95
Silica	4·8
Sulphur	0·02
Copper	Trace
Manganese	4·41
Iron	12·9
Bismuth	0·03
CaO	1·50

Wall-Rock Alteration.

During the detailed examination made in 1939-40 of all accessible shafts and other workings, it was noted that, immediately above No. 9 vein (called the "top reef" in the main workings), there were approximately 4 feet of soft, clay-like material, predominantly white, but containing brown bands due to impregnation with ferric hydroxide. This material is not a product of weathering, as it shows no relationship to the present surface. It has been formed by hydrothermal alteration of the sandy mudstone and represents kaolinized rock. The distribution of the kaolinized rock corresponds fairly closely with that of the better-grade wolfram-bearing ores. In some parts of the field, where quartz veins are prominent but little wolfram is present, the degree of kaolinization of wall-rock is quite moderate. The presence of the soft kaolinized rock is thus a guide to prospecting. A similar kaolinized rock is present in smaller quantities in places above No. 8 vein.

As described by Dallwitz in Appendix 1, the formation of the veins has also been accompanied by the introduction of tourmaline, hematite, and some topaz. The formation of sericite may also have been allied to the mineralization.

The development of the biotite-sericite-hematite rock near the major fault at the southern end of the field (Plate 2) is considered by Dallwitz as a possible result of a phase of the mineralization.

Ore-Shoots.

Dimensions.—On the accompanying plans, and especially on Plate 4, an attempt has been made to record as much information as possible concerning the places from which wolfram has been obtained. This, together with such sampling information as is available, should form a useful record for the future. All shafts and workings were mapped, and the reduced level, identity, thickness and grade of each reef exposure were determined.

The information recorded shows that the wolfram occurs more abundantly in certain sections of the vein-system. These enriched sections may be called ore-shoots. Within these shoots there is much quartz which is quite barren, but rich patches of wolfram also occur. In the past it was fairly common to find masses of wolfram, with subsidiary quartz, weighing 2 to 3cwt. Disseminated ore, which is common in other types of ore deposits, is relatively unimportant at Wauchope. It is locally called "spotted dog," and is valued mainly for the fact that it may lead the miner to richer ore.

The plan area of the major shoots so far discovered may be seen by referring to Plates 4 and 5. In the largest shoot, "A," wolfram has been found over a maximum length of 600 feet and over widths from 120 to 200 feet, but the richest portion of the shoot was 300 feet long with a maximum width of 160 feet. Within shoot "A," rich patches of wolfram were won from Nos. 8, 9, and 10 veins—mainly from the last two. Two smaller shoots, "B" and "C," occur on the same vein-horizons, and each of them appears to be approximately 70 feet wide. Numerous small "makes" of wolfram-bearing ore have been located elsewhere on the field, but the major production has come from shoots "A," "B," and "C."

Structure.—The reefs are for the most part confined to the mudstone, and are usually parallel to the bedding, though in places they cut across the bedding for short distances. The general arrangement of the reefs in plan and section is shown on Plates 2, 3 and 6. It will be seen that the reefs have a general strike of 20 to 25 degrees, and dip south-east at 10 to 15 degrees.

It will be noted that the long axis of shoot "A" trends at about 20 degrees, which, at this point, is parallel to the trend of the axes of the regional folds (Plate 1). Shoots "B" and "C" trend at 100 to 110 degrees, which is the bearing of other minor fold axes.

Where possible, the top of No. 10 vein (Plate 3) was contoured relative to an inclined plane with approximately the average strike and dip of the vein. In the No. 6 adit area—where No. 10 vein was not encountered—No. 9 vein, which occupies much of the same stratigraphic horizon, was contoured. As shown on Plate 5, the main shoot, "A," occupies a structural basin. The reason for ore deposition in this position is suggested in Figure 6.

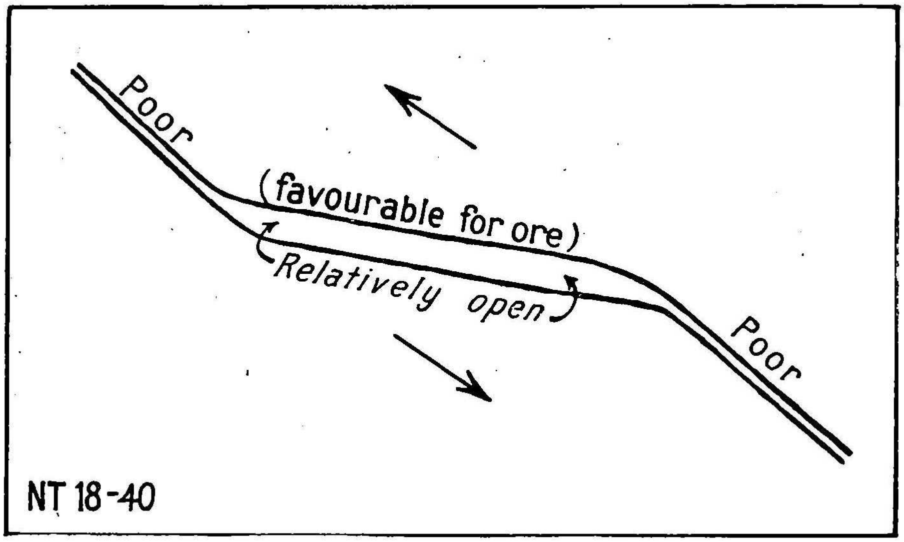


Fig. 6—Diagram showing development, during folding, of openings between relatively flatly-dipping beds.

Movement of the upper beds towards the anticline (Plate 1) would tend to cause openings to form between the beds where these have a relatively flat dip. That such movement has taken place is confirmed by numerous striae preserved on the hangingwall of the veins.

Shoots of type "B" and "C" (Plate 5) appear to be related to folding which trends at 100 to 110 degrees. This east-west folding is shown on Section A-B, Plate 2. On "Diorite Hill," small shoots of wolfram were noted in structural valleys in the anticline; the valleys, which may be 10 feet wide, trend parallel to the folds illustrated in Section A-B. Insufficient survey data were available in the vicinities of shoots "B" and "C" to determine the exact form of the folding.

It was found that, within the favourably-folded areas, minor structures have influenced the deposition of wolfram. In some places the down-dip portion of a vein may be buckled upwards in a small fold having the appearance of an incipient reverse fault. In other instances beds enclosing the veins have actually been faulted a few inches. It appears that this buckling and minor faulting may have been actually proceeding at the time of ore deposition; many rich masses of ore have been found near such minor structures. As shown in Figure 4, the compressive forces apparently continued after ore deposition had been completed, and in some instances caused considerable faulting of the reefs.

Between The Russian's Shaft and Winn's Shaft the reefs cut abruptly across the bedding and then follow a higher lithological horizon (Section G-H, Plate 6). In both these shafts, rich ore occurred near the "jump." This phenomenon was also noted in the 120-foot level south drive from No. 2 adit (Section C-D, Plate 3) where No. 9 vein cuts across five feet of mudstone and then again occupies a position between bedding planes. Both in the "jump" and immediately alongside it, wolfram occurred abundantly. Thus, minor structures—which may have caused temporary stoppages in the circulation of ore-bearing fluids—have served to localize patches of ore within the major favourable structures.

Temperature Control.—As mentioned above, high-grade wolfram ore was found mostly in shoot "A," which is near the present surface; exploration at depth gave unpromising results. Even where No. 2 adit crossed what is apparently a favourable structure (Eastern portion, Plate 5), little high-grade ore was found.

Reference to Appendices 1, 2, and 3 will show that there is a marked similarity between the dominant types of hornfels found at the surface, in the workings, and at depth in the drill cores. The grade of metamorphism in the sandy and argillaceous hornfelses is everywhere low; the most marked changes are those due to metasomatism, and they are expressed by the presence of tourmaline, hematite, and topaz. An epidote-garnet hornfels from No. 1 D.D.H. was described by Stillwell; it is probably a special case (Appendix 1) and does not necessarily signify an increase in metamorphic grade; however, the presence of felspars (orthoclase and plagioclase) in this rock may well mean an increase in temperature, as such felspars were not found in rocks collected from the surface or in underground workings.

Browne, too, noted orthoclase in a specimen from No. 5 D.D.H., and it seems likely, as he has suggested (Appendix 2), that granite occurs not far from this bore. It is probable that the relatively high temperatures at such depths were unfavourable for deposition of wolfram, and that most of the tungsten content of the ore-forming fluids was deposited over a limited vertical range. Somewhat similar conditions were noted by N. H. Fisher (personal communication) at Mount Murphy, Victoria, where the wolfram content of a quartz vein appeared to decrease as the vein approached a granite intrusive.

APPRAISAL OF FIELD.

RESULT OF MINING PRIOR TO 1942.

At the time of the examination carried out by the Aerial, Geological and Geophysical Survey of Northern Australia (1939-40), it was estimated that approximately 1,000 tons of wolfram concentrate had been obtained from some 10,000 tons of quartz extracted. This grade was obtained by selective mining.

By 1941, when the Government took over, mining activity had reached a very low ebb, due largely to the depletion of readily accessible ore. The field was, in general, worked on a tributing basis, each party being allotted a small area. Each party sank its own vertical shaft and, as the veins were followed down-dip, shafts had to be sunk progressively deeper. By 1941, miners, in most cases, had to sink about 100 feet through barren rock before reaching the most productive veins. The major output of the field occurred where these veins could be intersected at a depth of 10 to 30 feet.

GOVERNMENT OPERATIONS, 1942-43.

The Government sought to avoid the sinking of shafts through unpayable ground by driving a number of inclined shafts along the most productive veins; the extent and location of this work is shown on Plates 2 and 4.

Grade of Ore from Development.—The Government carried out 2,000 feet of development, mostly in the plane of the veins. Of the estimated 2,458 tons of quartz obtained from these workings to the end of September 1943—when most of the development ore had been crushed—an estimated 855 tons was discarded, and the remaining 1,603 tons, which came mainly from within the ore-shoot boundaries shown on Plate 5, was put through the mill. In addition, 315 tons of dump material was milled. The total recovery was 21.4 tons of WO_3. If it be assumed that the recovery from the dump was 0.25 per cent WO_3, the recovery from the mine ore milled would be 1.23 per cent WO_3. The average recovery from the 2,458 tons of quartz mined (assuming the discarded quartz was barren) was 0.82 per cent WO_3.

Sampling Results.—Nos. 2, 4, and 6 adits, and the drives off them, were sampled at 5-foot intervals. The channels were 6 inches wide, and were cut to a depth of 2 inches. Of the 315 samples assayed for WO_3 content, 171 came from within the supposed limits of shoot

"A" (Plate 5). The weighted arithmetic mean WO_3 content of the 171 samples was 0.96 per cent, the average width of the samples being 11 inches. The average combined widths of the two reefs normally present in this part of the workings was 22 inches. The sampling average of 0.96 per cent compares with a recovery from this ore of 1.23 per cent WO_3. The recovery would not be more than 80 per cent of the head value. The discrepancy may be due to the difficulty of sampling wolfram deposits—in which ore distribution is erratic—and to the fact that miners remove wolfram showing in the walls of development openings. The weighted arithmetic mean of the 315 samples taken, including those from outside the limits of the supposed shoots, was 0.58 per cent WO_3.

Estimated Ore Reserves, 1943.—When the Government ceased operations in November 1943, the writer estimated that approximately 5,000 tons of quartz had been developed, which contained about 60 tons of WO_3 recoverable with the plant available on the field. This estimate allowed for safe mining practice, which would have necessitated leaving much quartz in the mine.

Some ore was then showing in No. 9 adit (Plate 2), but this was not taken into account.

Diamond Drilling Results.—Five holes, totalling 1,108 feet, were drilled; they were aimed at targets down-dip from the present workings. Their locations are shown on Plate 2, and the detailed results are given in Appendix 4.

Several veins, generally less than 6 inches in width, were intersected, and some of these contained wolfram. A 30-inch quartz vein was intersected by No. 3 D.D.H. on the line of No. 2 adit, 530 feet from the portal. The reef contained no wolfram where intersected.

Small amounts of molybdenite were cut by No. 5 D.D.H., and a little scheelite was intersected by Nos. 1 and 2 holes.

In general, the drilling did not intersect deposits of economic size or grade.

Mining and Exploration, 1944-49.

Mining of Ore Exposed in Adits.—After the field was handed back to the lessee at the beginning of 1944, all accessible ore was taken from the adits and associated workings.

Downward Extension of Shoot "B."—A good deal of attention was also paid to the area situated on the downward continuation of shoot "B" (Plate 4). This work has shown that wolfram persists in the vicinity of Tarka's, Campbell's, and The Russian's Shafts.

No. 9 Adit.—Some further ore has also been exposed in No. 9 adit (Plate 2).

Assessment of Potentialities of Field.

As shown in Table 1, current output is at the rate of about 30 tons of wolfram per year and, unless a marked rise in price occurs, this is probably the upper limit of production to be expected.

It appears likely that some further rich patches of ore remain to be found, and there is a possibility that if shoot "B" (Plates 4 and 5) is followed down-dip a larger deposit of the "A" type might be found. A marked rise in price would certainly lead to renewed prospecting.

Speaking generally, however, the field is one for small parties and syndicates, and there is little indication of the presence of deposits of sufficient scale to warrant large-scale mining.

Canberra.
19th March, 1952.

REFERENCES

A.G.G.S.N.A., 1939—The Wauchope Creek area; *Aer. Geol. and Geophys. Surv. N. Aust., Rep. for period ended* 31*st December,* 1939, 10 (summary), 45-46.

A.G.G.S.N.A., 1940A—Wauchope Creek wolfram field; *ibid., Rep. for period ended* 30*th June,* 1946, 6 (summary), 18-20.

A.G.G.S.N.A., 1940B—*Idem., ibid., Rep. for period ended* 31*st December,* 1940, 7 (summary), 42-46. (With geological map of the area.)

BROWN, H. Y. L., 1903—Report on country recently examined in the Davenport and Murchison Ranges; *N. Terr. of S. Aust., Parl. Pap.* No. 82.

DAVIDSON, ALLAN A., 1905—Journal of exploration in Central Australia, 1898-1900; *ibid.,* No. 27.

FISHER, N. H., AND BALL, C. W., 1949—Tungsten; *Comwlth. of Aust., Bur. Miner. Res. Geol. and Geophys., Summ. Rep.,* No. 16.

NOAKES, L. C., AND TRAVES, D. M., 1949—Report on the geology and mineral resources of the Barkly Tableland, Northern Territory; *Comwlth. of Aust., Bur. Miner. Res. Geol. and Geophys., Rep.* (in preparation).

OLIVER, T. G., 1918—Report of Director of Mines: Wolfram—Wauchope Creek; *Rep. of Admin. N. Terr. for* 1915-16 *and* 1916-17, 19.

OWEN, H. B., 1939—Report on Tennant Creek gold field; *Dep. Interior, Canberra, A.C.T.* (unpubl.).

WOOLNOUGH, W. G., 1939—Report on Tennant Creek gold field, Northern Territory; *Comwlth. of Aust. Bull. N. Terr.,* No. 22.

APPENDIX 1.

THE PETROGRAPHY AND PETROLOGY OF CERTAIN ROCKS FROM THE WAUCHOPE WOLFRAM FIELD.

BY W. B. DALLWITZ.

DESCRIPTION OF SELECTED ROCKS AND MINERALS.

W. 1: Granite from Devil's Marbles, 3 miles north of Wauchope.—In the hand specimen this is seen to be a granitic rock of coarse but variable grainsize, with a strong tendency to be porphyritic in microcline perthite. One crystal of this mineral is about 3 cm. long and numerous grains are over 1 cm. long. The rock consists of about 55 per cent off-white felspar, 35 per cent semi-vitreous quartz, 7 per cent biotite and 3 per cent muscovite. Plagioclase is in excess of potash-felspar, but cannot be distinguished from it by colour. Reddish and brownish iron-stains are common throughout the rock.

Five thin sections were made so that the ratio potash-felspar : plagioclase could be gauged; by visual estimation this ratio was found to be about 4 : 1.

The potash felspar is microcline-perthite, and the plagioclase is andesine. The microcline-perthite is generally characterized by irregular boundaries, extensive kaolinization, numerous inclusions of other minerals (particularly small subhedral grains of plagioclase, but quartz, muscovite and biotite are also present), and by its coarse grainsize; the andesine, on the other hand, is notable for its subhedral outlines, sericitization, minor kaolinization and saussuritization, and smaller grainsize.

The plagioclase is commonly strongly zoned, the cores containing to 46 per cent or more of anorthite, though grains included in microcline-perthite and therefore protected from reaction may have an anorthite content as low as 35 per cent. Zoning is abnormal, for extinction angles and double refraction in the cores are considerably lower than in the more anorthitic outer shells; a 12° variation in extinction angles was observed, representing a difference of 18 per cent in anorthite content.

The quartz contains numerous fluid inclusions and is generally free from strain shadows.

Pleochroism in the biotite is from dark—almost opaque—nigger-brown to brownish-yellow. Some of the biotite has changed from brown to green, and a little has been converted to chlorite; the formation of leucoxene has accompanied these changes.

Slight pleochroism—from brownish-white to colourless—is characteristic of the muscovite. Both micas contain minute grains of (?)

zircon around which pleochroic haloes have been developed. On account of its pleochroism, both intrinsic and in haloes, the muscovite must be a ferriferous variety, probably magnesium-phengite, and this contention is substantiated by the refractive indices; α is slightly greater than, and β slightly less than, 1.590.

Accessory minerals occur in very small amount. Fluorite is probably the most interesting; where present in biotite it is a deep-purple; elsewhere—in plagioclase, muscovite and, rarely, in quartz—most of it has a pale to faint purple tinge only. Sphene may occur in biotite, and epidote and leucoxene (in part after biotite) in plagioclase. Zircon and apatite are present but, apparently, rare. A little golden-yellow nontronite occurs in many of the plagioclase grains; it is the most abundant accessory.

Hematite has been developed in cracks, and a grain of hematite was noted in muscovite. Finally, there is present in a plagioclase crystal a single grain of an unknown mineral; its properties are as follow:—Pleochroism from very pale pink to colourless; straight extinction; length fast; sign indeterminate. Its properties correspond most closely to those of andalusite, which could be present as the result of contamination by aluminous material; however, the possibility of its being a pale variety of dumortierite cannot be dismissed.

W. 16: Biotite-Sericite Rock near major fault of southern end of field.—Macroscopically this is a dark greenish-grey, fine-grained, soft, massive, and somewhat porous rock containing very pale buff flecks of leucoxene. It is iron-stained in varying degree, depending partly on the amount of weathering that has taken place.

Under the microscope the rock is seen to be composed of biotite (55 per cent, average grainsize 0.04 mm.), sericite (35 per cent), leucoxene (7 per cent), hematite (3 per cent), and rare sphene showing aggregate polarization. The biotite is pleochroic from dark brownish-green to greenish-buff.

W. 4: Hornfels from ore-bearing horizon in northern section of field.—A soft, light-grey, fine-grained rock showing bedding, and irregularly stained with iron oxide. Two narrow lenticular bands are considerably darker and harder than the main part of the specimen, and they owe their distinctive properties to the presence of a notable amount of fine-grained detrital quartz. The rock is apparently finely porous, for it absorbs water readily.

Microscopically it is seen to be composed largely of extremely fine-grained sericite. Set in this base are numerous unoriented stumpy prisms and needles of tourmaline; the tourmaline is pleochroic from dark grey-green to greyish-white, and the average size of the needles is 0.08 mm. by 0.02 mm. Granules and dusty particles of hematite are unevenly distributed through the rock.

A little leucoxene is present, a few quartz grains occur in one band, and a veinlet of quartz traverses part of the slide.

The rock is a *sericite-tourmaline hornfels.*

W. 5: Hornfels from ore-bearing horizon in northern section of field.—This is an irregularly banded light-grey and medium-grey rock. The darker bands are metamorphosed micaceous siltstone, and the lighter bands were originally a variety of claystone. The siltstone bands are markedly lenticular, and grade laterally and vertically into claystone. The bands range in width from almost nil to about 0.75 cm. Five bands appear in the section examined. One of the siltstone layers passes gradually into fine-grained argillaceous hornfels.

The finer-grained bands now consist predominantly of an aggregate of sericite and quartz, and represent original silty claystone. Cordierite may be present, but it could not be distinguished with certainty. Distributed through this groundmass are small flakes of biotite and small crystals of tourmaline probably partly derived from biotite. The biotite is pleochroic from dark-brown with a grey or green tinge to golden-buff, and the tourmaline from dark-grey or greenish-grey to greyish-puce. Small amounts of magnetite, leucoxene and dusty hematite occur throughout the rock.

The coarser bands represent metamorphosed clayey siltstone, and now consist essentially of quartz, sericite and biotite. Evidence for a small degree of marginal recrystallization of quartz is provided by the fact that sericite flakes encroach on the borders of some of the grains. The quartz grains are sharply angular, and even splintery in some cases, and their average grainsize is 0.04 mm. The biotite flakes are of similar size. Minor constituents are tourmaline (probably formed at the expense of biotite), detrital muscovite, magnetite, leucoxene, dusty hematite, and rare sphene.

The rock as a whole is a fine-grained, banded hornfels consisting of alternating layers of *sericite-quartz-biotite-tourmaline hornfels* and *quartz-sericite-biotite hornfels.*

W. 9: Country rock and part of quartz vein from J. Daniels' workings, No. 10 Adit, southern part of field (Plate 2).—The country rock is a dark- and medium-grey banded hornfels which is similar to W. 5 but considerably harder, and seems to be much more metamorphosed; the originally argillaceous bands are the darker.

Eight bands of different widths appear in the slide. Graded bedding is conspicuous, and the amount of sericite (representing argillaceous material) in the quartzose bands is variable. Some of these bands contain much more detrital muscovite than others. It will suffice to give descriptions of each of the two dominant types of bands, argillaceous and sandy.

The argillaceous bands are now converted to a very fine-grained mass of sericite containing abundant needles and stumpy crystals of tourmaline arranged in a decussate pattern, and a little fresh (?) cordierite of average grainsize 0.06 mm. Pleochroism in the tourmaline is from greenish-grey or greyish-green to greenish-white or colourless; the average size of the crystals is 0.1 mm. by 0.02 mm.

There is some doubt about the identity of the cordierite. At first the mineral was taken for quartz, but it shows sector twinning in which three to six more or less complete segments appear. The sign was found to be positive, and 2V was estimated at about 15°. Cordierite is generally optically negative, but positive varieties have been found; however, the optic axial angle is apparently lower than any previously recorded for positive cordierite, and so some doubt about the determination as cordierite must remain, especially as quartz can have an optic axial angle up to 10°. In addition to twinned grains as described above, simply twinned and non-twinned grains are common.

No pleochroic haloes were noted in the (?) cordierite, but this is presumably due to the absence of grains of zircon, etc., therein; minute grains of tourmaline and a few dark specks were the only inclusions found.

To sum up, it should be stated that the main basis for suggesting that the mineral is cordierite is that sector twinning was noted; twinning is rare in quartz and, even if it is present, it does not commonly appear with straight divisions between adjacent parts of twinned grains.

Minor constituents noted in the *sericite-tourmaline-*[*(?) cordierite*] *hornfels* bands are leucoxene, hematite (mostly dusty but some of it in veinlets), and extremely rare zircon. Limonite staining in the form of spots is fairly general.

The more siliceous bands in this rock show evidence of a somewhat greater degree of metamorphism than those in W. 5. The quartz grains are angular and of about 0.1 mm. average size, and have largely been recrystallized with the development, in some places, of incipient mosaic structure. Furthermore, newly-formed sericite encroaches on the quartz grains to a greater extent than in W. 5. Next to quartz, sericite is the main mineral; as already stated, its bulk varies considerably in different bands. These bands represent original argillaceous sandstone and sandy micaceous claystone now converted to *quartz-sericite* and *sericite-quartz hornfelses*. Accessory minerals are leucoxene, hematite, tourmaline, and rare zircon and sphene. The hematite occurs either as dendritic veinlets or in minute granules.

W. 5a: Hornfels from ore-bearing horizon in northern section of field.—The bulk of the specimen is hard, dark-grey, fine-grained, massive hornfels and the section examined was cut from this part. The remainder is lighter-grey and may be more siliceous; indistinct graded beddings is discernible therein.

Stumpy grains of tourmaline with maximum length 0.2 mm. make up about 70 per cent of the rock. Most of these grains are pleochroic from medium-brown to colourless, but some have either a bluish or a blue-grey tinge. Next in abundance is topaz, then sericite. The topaz is, in general, distributed more or less uniformly with the other principal constituents, but may also occur in enriched clots up to 1 mm. across; in these places, tourmaline is much less plentiful but is still a major component.

Although the average grainsize of the topaz is 0.02 mm., it was possible to obtain interference figures. These showed that the optic axial angle is, on the whole, of medium size, but variable over a relatively wide range in different grains. The sign of this mineral is positive, its relief markedly greater than that of balsam, and its double refraction similar to that of quartz; from this evidence and its associations, its identity as topaz is satisfactorily established.

Accessories are quartz, hematite, and leucoxene.

The rock is a *tourmaline-topaz-sericite hornfels* and has been derived from one of the fine-grained rocks of the ore-bearing horizon through the action of volatiles—particularly compounds of boron and fluorine.

W. 14: Part of quartz vein from J. Daniels' workings, No. 10 Adit.—The specimen consists of milky quartz containing pockets filled with an aggregate of dark-brown flakes of mica and/or its alteration product. Some of these pockets represent spaces (vughs) between partial crystals of quartz. The alteration product is a very fine-grained, soft, pale greenish-yellow mineral.

The mica is pleochroic from pale-brown to colourless, and is probably a ferriferous variety of muscovite similar to that in the Devil's Marbles granite; α is greater than 1.585 and β less than 1.585. In one part of the slide the change from muscovite to the pale greenish-yellow mineral can be studied to particular advantage. This change is to be seen in a pseudo-hexagonal basal section of the mica. The central part of the crystal is composed of muscovite with medium (normal) optic axial angle and greyish-white interference colour. This passes outwards into a zone of pale greenish- or yellowish-white, almost isotropic, mica with optic axial angle near 0°; beyond this zone is an extremely fine-grained aggregate of the same pale mica. Measurements of the refractive index of this fine material gave an average value of 1.562. From the evidence it is clear that the pale mica is damourite, an altered variety of muscovite containing more water or more easily removed water. Generally the muscovite appears to have changed directly to very fine-grained damourite but, in crushed material, some flakes of coarser damourite with a very low optic axial angle were noted.

W. 11: Kaolinitic mineral from veins in J. Daniels' workings, No. 10 Adit.—The fine-grained white clay mineral has associated with it variable amounts of quartz, hematite, limonite, and manganese oxide or manganiferous limonite. It seems to be less earthy and more compact than ordinary kaolin, and also has a soapy feel. Because of these characteristics and its occurrence in association with an ore deposit, it is possible that this mineral is dickite or nacrite rather than kaolin. The mean refractive index of powdered material was estimated at 1.5585.

W. 19: Part of quartz vein with selvage of mica, from northern section of field.—The specimen consists of milky quartz with a selvage of silvery-brown mica. The flakes lie at right angles to the border of the vein. Such selvages—which range in width from ⅛ to ¼ inch—commonly, though not invariably, occur on both sides of the veins.

In the specimen examined, α is approximately 1.585, and β slightly less. It is probably a muscovite containing a small proportion only of the phengite molecule.

W. 12: Part of quartz vein with damourite and wolfram, extreme southern end of field, near major fault.—This specimen illustrates very well the occurrence of damourite after muscovite in vughs outlined by partial crystals of quartz within massive quartz.

W. 17: Sericite selvage to quartz vein, near major fault, southern end of field.—In various places in the workings this pale greyish-yellow mineral forms easily-removable selvages about 1 inch wide on one or commonly both sides of quartz veins. It is fine-grained and fairly compact, and has a suggestion of fibrous structure in a direction at right angles to the border of the quartz vein. It breaks readily in this direction, and the surfaces of parting are somewhat greasy due to their being coated by a thin film of kaolin.

In crushed material aggregate polarization is most common, but some elongated mica-like flakes, or aggregates of flakes, appear. Measurements on these gave a value for α of 1.590 which, considered together with the physical properties and rather high double refraction, establishes the mineral as sericite.

W. 3: Soft rock interbedded with the coarse sandstone, etc., underlying the ore-bearing horizon, left bank of creek, about 700 feet west of treatment plant (Plate 2).—A light pinkish-grey, soft, somewhat friable, fine-grained rock with flakes of mica parallel to the bedding. The rock is surprisingly tough under the hammer, presumably because it is held together, in part, by small tourmaline needles. The surface of the outcrop crumbles and flakes off during weathering, leaving small hollows between raised parts that have been rendered more resistant through stronger cementation by local concentration of iron oxide. During grinding the specimen gave a red sludge, which is evidence for a rather unexpectedly high content of hematite.

Microscopically the principal minerals are seen to be quartz, very fine-grained sericite, flakes of detrital muscovite, and hematite. The quartz grains are angular, and some fragments are elongated and splintery. Their average grainsize is 0.08 mm.; the flakes of muscovite have an average length of 0.25 mm. Hematite occurs as aggregates of dusty particles making up 8 to 10 per cent by volume of the rock; it was probably introduced. Accessories are partly-sericitized felspar, magnetite, blue and brown tourmaline (introduced), and rare leucoxene.

The rock was originally a fine-grained, micaceous and argillaceous sandstone; now it is best described as a *low-grade quartz-sericite-hematite hornfels.*

PETROLOGY.

The rocks of the ore-bearing horizon at Wauchope are distinguished from the beds immediately above and below them by being much finer-grained and less siliceous. They were originally thinly-interbedded claystones, silty and sandy claystones, argillaceous siltstones, and fine-grained argillaceous sandstones; all except the claystones proper contain varying amounts of detrital muscovite. The underlying and overlying beds are sandstone, quartzite, and fine conglomerate, with some thin bands of pebble conglomerate. These siliceous beds were much less favourable for mineralization; they contain only a few narrow quartz veins carrying very little wolfram.

As stated by Stillwell (Appendix 3), the argillaceous rocks have, by virtue of their composition, been more susceptible to metamorphism than have the more sandy phases which are intimately interbedded with them. However, the grade of metamorphism is everywhere low. Metasomatism, involving the formation of tourmaline, hematite and, much less commonly, topaz, in these rocks has been the most conspicuous process. The presence of fluorite in the Devil's Marbles granite and in two rocks described by Stillwell (Appendix 3) and Browne (Appendix 2), and of topaz in one of the hornfelses (W. 5a), points to the fact that fluorine was an important agent in metasomatism and mineralization. Stillwell, in a letter addressed to H. G. Raggatt and dated 20-1-43, also reported topaz in a specimen from No. 8 adit. The rocks of the mineralized zone have been indurated in varying degree and the presence of tourmaline needles has especially contributed to their toughness.

In the claystones new minerals formed by simple thermal metamorphism are sericite, biotite and, rarely, (?) cordierite. Sericite and biotite alone are new in the more sandy rocks; the sericite in the more highly metamorphosed rocks in this group has, apparently, not been derived entirely from argillaceous material, but partly from felspar.

The presence or absence of cordierite in argillaceous sediments at an early stage of metamorphism does not necessarily indicate a difference in grade of metamorphism, but may show merely that the cordierite-bearing hornfelses were originally more chloritic than those in which cordierite has not formed; in such rocks biotite is not the first new mineral to appear, but is preceded by cordierite (Harker, 1939, p. 49). It is probably significant, therefore, that biotite is absent in the cordierite-bearing rock (W. 9).

Hematite is invariably present in the rocks of the ore-bearing horizon and was, presumably, introduced at the time of mineralization.

The small amount of magnetite in these rocks was probably not introduced, but owes its origin to the reduction of limonite in the sediments during metamorphism.

From the standpoint of metamorphic index minerals in the rocks studied, there is no evidence of any significant increase in grade of metamorphism within the ore-bearing horizon from the surface to the depths reached by diamond drill holes.

Rocks from two of these bores have been described by Browne (Appendix 2) and Stillwell (Appendix 3); apart from some special types not actually collected* at and near the surface, but not necessarily absent there, the descriptions indicate a striking similarity between dominant rock-types at the surface, in the workings, and at depth in drill cores.

The experience of miners suggests very strongly that the grade of the ore and the number of shoots in a given length of quartz vein decrease with depth. Deeper still, diamond drill holes—though by no means reliable in view of the sporadic distribution of wolfram—tend to confirm this suggestion. Probably the range of temperatures within which wolfram was precipitated was fairly restricted, *i.e.*, nearer the granite, conditions for its formation were less favourable. As stated, metamorphic index minerals indicate no significant—in purely metamorphic terms—increase in temperature with depth. However, an increase in temperature undetectable from the metamorphic standpoint may well be significant from the point of view of ore deposition.

The only signs of such increase in temperature in connection with vein formation are to be found in two specimens described by Browne and Stillwell. Browne has described a rock consisting of a fine-grained aggregate of orthoclase containing a little quartz and scheelite and abundant grains of fluorite. Stillwell reports on scheelite-and-fluorite-bearing epidote-garnet hornfels carrying, in addition, orthoclase and subordinate plagioclase which, from the description given, appear to have been introduced. As vein felspars were not noted in rocks collected on the surface or in underground workings,

* The writer spent only one day in the field at Wauchope.

it is probable that their presence indicates an increase in rock temperatures sufficient to inhibit deposition of payable wolfram shoots beyond a zone at some distance down-dip from the present workings. The epidote-garnet hornfels probably represents a calcareous mudstone, which would have been completely recrystallized at a very early stage in metamorphism, so that the minerals epidote and garnet in themselves are by no means definite indicators of an increase in grade of metamorphism. As topaz was found in a rock (W. 5a) from the workings, its presence in one specimen (No. 8) described by Browne cannot be taken as indicating an increase in temperature with depth.

At a late stage in the formation of the veins, and possibly concomitantly with, or not long after, the precipitation of the wolfram, some hydro-thermal action took place. This is expressed mineralogically in several ways. First, the country-rock above and, to a lesser extent, below some of the wolfram shoots is altered—over a width of as much as 4 feet—to a mineral of the kaolin group. The same mineral also occurs in the quartz veins in these places. As described above (W. 11), it is accompanied by hematite, limonite (possibly after pyrite), and manganiferous limonite. Secondly, we have noted the conversion, partial and complete, of muscovite pockets in quartz to pale yellow-green damourite; this damourite occurs throughout the field, but appears to be especially well developed—taking completeness of replacement of muscovite as a criterion—in the vicinity of the major fault at the southern end of the field. Thirdly, it is probable that the formation of the inch-wide selvages of sericite bordering parts of quartz veins, exemplified in specimen W. 17, are also attributable to the hydrothermal stage. Where these appear, the narrow selvages of muscovite (W. 19) are absent, having probably been incorporated in the sericite.

Finally it remains to explain the presence of the mass of biotite-sericite (-leucoxene-hematite) rock (W. 16) formed at and near the major fault which limits the field to the south. From its location and nature it seems probable that it, too, was formed by the action on the surrounding hornfels of volatiles or solutions which locally gained access along the fault. If this is so, these fluids must have been rich in magnesia and iron, and have metasomatically reconstituted the hornfels. Alternatively, it is possible that the rock represents a fine-grained minette in which the original orthoclase has been hydrothermally altered to sericite; however, under these conditions the biotite would almost certainly have been changed to chlorite. The former explanation of the origin of the rock seems the more probable, even though it is difficult, in the present state of knowledge, to postulate a source of magnesia.

REFERENCE

HARKER, A., 1939—METAMORPHISM, Methuen, London.

APPENDIX 2.

REPORT ON BORE-CORE SPECIMENS FROM No. 5 D.D.H., WAUCHOPE, NORTHERN TERRITORY.

BY W. R. BROWNE.

DESCRIPTIONS.

Nos. 1, 6.—These are of the same rock-type—an exceedingly fine-grained sericite rock with biotite. It has no schistosity and has the appearance of a hornfels, but is soft (H = 3) and consists of an aggregate of microcrystalline sericite with isolated little biotite crystals sprinkled through it.

No. 2.—A mottled pink rock which, under the microscope, appears rather nondescript. It is very much silicified, and consists predominantly of microcrystalline quartz with aggregates of tiny, ragged biotite flakes here and there, the whole much stained with limonitic material which gives the pink colour to the rock. There are a few chips of original quartz, and the outlines of what may have been felspar fragments or crystals can be detected. This may be a silicified tuff, but alteration has been so profound that I would not venture to say positively what it was originally.

No. 3.—A sericite-biotite rock stained with limonite. Predominantly of sericite with irregular clots of biotite here and there, associated with muscovite which seems to pass by decrease of grainsize into sericite. A little interstitial quartz is present. The grainsize is distinctly coarser than that of Nos. 1 and 6. Limonite is derived mainly from biotite, but some of it may have come from pyrite.

No. 4.—Vein-quartz with a dark-green mineral in aggregates of little micaceous scales or flakes. This appears to be a ferriferous muscovite. Red iron oxide scattered through the quartz in very tiny granules is possibly derived from magnetite.

No. 5.—This specimen attracts attention by its specific gravity, which is higher than that of the others. It is composed of a fine-grained aggregate whose principal constituent appears under the microscope to be orthoclase felspar (adularia) forming a kind of matrix for the other minerals. Microcrystalline quartz is seen in some patches, evidently a replacement, and there are abundant granules of what was probably magnetite, now converted into limonite. Of special interest are (1) abundant little crystals and grains of *fluorspar* embedded in the orthoclase aggregate, and (2) grains of a mineral—with high R.I. and strong D.R.—which is almost certainly *scheelite*. This mineral is of higher specific gravity than the others in the specimen, and gives a slight but identifiable reaction for tungsten.

No. 7.—Mostly vein-quartz with pinkish aggregates of sericite, probably after felspar. There is also a dark purple—almost black—mineral which is *fluorspar.* A longitudinal streak or patch of metallic mineral across one end of the specimen is *molybdenite* in fine scales; this also gives a reaction for *antimony.*

No. 8.—Minerals present are chiefly quartz and crystals of *topaz,* with much red iron oxide coating the crystals and filling spaces between them. Through the quartz are a few veinlets of scaly *molybdenite.*

REMARKS.

The general impression given by the collection is that the bore has intersected a vein and its country-rock. The latter gives evidence of hydrothermal alteration—chiefly sericitization and silicification. The vein-material appears not to have travelled far from the parent granite since it includes such pneumatolytic minerals as topaz, fluorspar, and molybdenite. It too has suffered some hydrothermal alteration.

The very common iron oxide and hydroxide are probably hydrothermal rather than the result of weathering.

APPENDIX 3.

*REPORT ON BORE-CORES FROM No. 1 D.D.H., WAUCHOPE CREEK, NORTHERN TERRITORY.

BY F. L. STILLWELL.

Samples of drill cores from No. 1 drill hole, Wauchope, Northern Territory, have been submitted for petrological examination by Mr. P. B. Nye, Mineral Resources Survey, Canberra.

The specimens, with one exception, are similar in type and consist of mudstones which have been indurated and have undergone slight recrystallization as the result of a low-grade, thermal metamorphism. They are, therefore, described as hornfels rather than mudstone or shale. They contain, in some cases, thin beds of micaceous sandstone which are less susceptible to metamorphism than the mudstone and can, therefore, be adequately described as sandstones. The uniform development of secondary biotite in R.808 and R.813 enables these specimens to be regarded as biotite hornfels. Tourmaline is present in most cases and in R.807 the even distribution of abundant, minute prisms of tourmaline contributes materially to the flinty fracture of the rock. This tourmaline is not detrital and has been introduced during metamorphism. Reddish tints and bands are due to the dissemination of abundant minute particles of hematite.

The exceptional specimen is R.812 which is rich in lime minerals, and may have been derived from a bed of calcareous mudstone. Abundant felspar and epidote, together with garnet, fluorite, and scheelite, are present. The presence of these minerals indicates that, in addition to contact metamorphism, there has been metasomatism and an introduction of material from an igneous source. Banding in the specimen appears to represent traces of the original bedding, so the rock is a replaced sediment, and not portion of a vein.

R. 805.—Depth 96 feet. "Sandy micaceous rock—top of shale band." This is an altered mudstone showing bedding. It consists mostly of fine sericite and quartz, but contains thin bands of a coarser sediment consisting of numerous and larger quartz grains and small flakes of colourless and pale mica. In these coarser bands the mica plates lie parallel to the bedding planes, and the exposure of a coarser band at each end of the core specimen had led to the above field description. Small octahedra of magnetite, 0.1 mm. in width, and thin needles of tourmaline, rarely longer than 0.16 mm. or wider than 0.015 mm., are scattered through the rock. Some bands are reddish from numerous minute particles of hematite.

---

* Mineragraphic investigations of the Council for Scientific and Industrial Research, Report No. 265, University of Melbourne, 14th December, 1942.

R. 806.—Depth 130ft. "Fine-grained grey rock, relatively hard —from shale band." This is a fine and even-grained hornfels with scattered octahedra of magnetite, thin needles of tourmaline, and an occasional thin bed of fine sandstone. Parts of the specimen are reddish from impregnation by hematite.

R. 808.—165 feet. "Grey slate (?) from upper shale band." This rock is minutely and evenly dotted with minute crystals of brown biotite about 0.030 x 0.035 mm., and may be called a biotite hornfels. Needles of tourmaline are rare.

R. 809.—175 feet. "Hard fine-grained rock (grey)." This hornfels is derived from a mudstone and is thinly speckled with white spots about 1 mm. in diameter, which consist sometimes of quartz but mostly of quartz and white mica. They appear in thin section as clear areas of much coarser grain than the mass of the rock. Occasional prisms of tourmaline and coarse grains of quartz are present.

R. 810.—180 feet. "Fine-grained quartzite." This hornfels is similar to R. 809, but the white spots are smaller and fewer. A little biotite sometimes occurs in the spots, and the section is traversed by a thin vein of quartz.

R. 811.—192 feet. "Banded shale, pink and grey." This is a banded hornfels. Some bands consist of very fine granular quartz and numerous small crystals of chlorite, which are similar in shape and size to the biotite in biotite hornfels (R. 808). Other bands are much richer in chlorite than quartz. Others, again, are very fine quartzite with little chlorite and, in places, grade into coarser quartzite in which the quartz crystals may be as large as 0.45 x 0.45 mm. Abundant hematite is present throughout and is sufficient in part to form massive areas with scattered chlorite. The intergrown margins of the quartz crystals in these coarser areas suggest that the quartz is of metamorphic or vein origin rather than detrital.

R. 812.—197 feet. "Very hard siliceous (?) rock, fine-grained." This rock is distinguished as an epidote-garnet-hornfels containing both scheelite and fluorite. The rock is banded and some bands contain ragged areas of sericitic mica which may be residual from the original mudstone. These areas are surrounded and invaded by felspathic areas consisting largely of slightly cloudy, untwinned orthoclase, but partly of lamellar twinned felspar. In some places the felspar appears as aggregates of coarse crystals and in others it is finely granular. A little interstitial calcite is present along the contacts of the felspar crystals. Embedded in these felspathic bands are isolated crystals or both large and small crystals of epidote, garnet, fluorite and scheelite. Other bands consist essentially of epidote with scattered fluorite, or of micaceous material, or of garnet, epidote and fluorite. A patch consisting predominantly of garnet occurs between an epidote-rich band and a felspar-rich band. Fluorite is colourless and isotropic with cleavage, has a refractive index lower than balsam, and some crystals are 1 mm. in width. Scheelite has an irregular distribution with a tendency to appear at the contact between bands, and the largest area is 1.30 x 0.7 mm. Scheelite is absent from a second thin section of this specimen, which is traversed in part by a thin vein of chlorite with iron ore along either wall.

R. 807.—210 feet. "Slate from shale band." This is an indurated mudstone or hornfels which is crowded with minute needles of tourmaline.

R. 813.—230 feet. "Fine-grained micaceous rock." This is a biotite hornfels—similar to R. 808—containing numerous small crystals of biotite which are dispersed uniformly through the rock. Occasional crystals of tourmaline are present.

R. 814.—245 feet. "Fine-grained grey micaceous rock." This specimen of core shows a pronounced bedding plane. The fine-grained sediment was originally a mudstone and may now be regarded as a biotite hornfels similar to R. 808 and R. 813, but with rather abundant needles of tourmaline. The coarser-grained bed is a fine-grained micaceous sandstone with sub-angular quartz grains of an average diameter of approximately 0.1 mm. The associated mica includes both biotite and muscovite. Contact metamorphism is less evident on this sandstone than on mudstone, but well-formed tourmaline crystals occur in the sandstone. The biotite in the sandstone is similar in form and size to that in the mudstone, suggesting that the sandstone could alternatively be regarded as a quartz-mica hornfels.

APPENDIX 4.

DETAILS OF DIAMOND DRILLING RESULTS, WAUCHOPE WOLFRAM FIELD, NORTHERN TERRITORY.

BY C. J. SULLIVAN.

A total of 1,108 feet of diamond drilling was carried out by the Government. In no case was wolfram in payable quantities intersected. The location of the bores (1 to 5) is shown on Plate 2. Notes on the bores are tabulated below:—

No. 1 D.D.H.; final depth 245 feet; vertical.

Depth., ft.	
0– 96	Sandstone and quartzite; 7in. quartz vein at 96ft.; *no wolfram.*
96–245	Mainly fine-grained hornfels with biotite, quartz, epidote, garnet, muscovite, tourmaline, fluorite, and occasional scheelite. Quartz reefs were encountered at the following depths:
112	3in. vein *containing wolfram.*
123	4in. vein *containing wolfram.*
135	4in. vein; *no wolfram.*
234	4in. vein; *no wolfram.*

It is known that this hole did not penetrate the full thickness of the ore-bearing beds. This is illustrated on Section K-L. Appendix 3 gives F. L. Stillwell's notes on the cores.

All cores were examined with a Mineralight for the occurrence of scheelite. None was found in the remaining cores near the horizon at which Dr. Stillwell had previously detected this mineral, but 2 inches of the core at a depth of 240 feet were found to carry small quantities of scheelite.

No. 2 D.D.H.; final depth 300 feet; vertical. This bore pierced 121 feet of sandstone and quartzite overlying the altered mudstones, and thereafter penetrated the full thickness of the latter; it finally passed into the basal quartzite. Reefs cut were:—

Depth, ft.	Width of reef.
110	4in.
121	4in.
143	4in., *wolfram in trough.*
164	4in.
197	1in.
217	7in.
224	1in.
227	3in.
284	3in.
287	4in.
293	1in.-3in., *wolfram in trough.*

At 260 feet, a 2-inch band of country-rock was found to contain scheelite when examined under ultra-violet light.

No. 3 D.D.H.; final depth 192 feet; inclination 80° north. This hole was drilled on the line of No. 2 incline to see whether the reefs continued to this point. The bore penetrated the altered shale horizon (ore-bearing beds) and the following reefs were penetrated:—

Depth, ft.	Width of reef.
139	30in., *no wolfram*; No. 9 or 10 horizon.
174	12in., *no wolfram.*

The finding of a 30-inch reef on the main ore-bearing horizon (No. 9 or 10), 530 feet down the dip of the vein from the portal of No. 2 adit, was the most encouraging result of the diamond drilling. The fact that it did not contain any wolfram is not at all conclusive, as wolfram has a most erratic distribution even within the payable sections of a vein.

No. 4 D.D.H.; final depth 150 feet; vertical. This hole was drilled in the southern portion of the field—formerly known as Martin's Gully. A considerable part of this area is covered with alluvium, and the hole was located with the idea of testing for the presence of Nos. 8, 9, and 10 horizons, which had been the most productive in the northern part of the field. Results were disappointing, the reefs intersected being as follow:—

Depth, ft.	Width of reef.
52	2in.
68	4in.
118	7in.
127	4in.

The country-rock consisted of altered shales to 150 feet, where the basal quartzite was penetrated.

No. 5 D.D.H.; final depth 221 feet; vertical. This hole is situated 465 feet south-east from No. 3 D.D.H., and is shown on Plate 2.

A report by W. R. Browne on selected cores from this bore is given in Appendix 2. The "mudstone" formation has been sericitized and silicified, and iron oxide is thought to have been introduced. Dr. Browne concludes that the rocks have been subjected to considerable hydrothermal alteration.

The reefs encountered were not of mineable width: they are tabulated below:—

Depth, ft.	Width of reef.
8–14	*Wolfram in trough* (from small veins?).
48	3in., *some wolfram.*
55	3in.
124	3in.
164	½in.
203	7in., contains molybdenite, fluorspar, tourmaline, topaz.
217	2in., molybdenite.
218	2in., molybdenite.

The basal quartzite was encountered at 220 feet.

It will have been noted that the results of the diamond drilling were disappointing.

Appendix 5.

UNDERGROUND WATER SUPPLIES, WAUCHOPE WOLFRAM FIELD, NORTHERN TERRITORY.

BY C. J. SULLIVAN.

The water supply for Wauchope wolfram field was obtained from a series of bores the situations of which are shown approximately on Plate 1.

When the Government took over the field (April 1942), the most westerly bore (No. 1, Plate 1), situated approximately 1 mile from the centre of the mining field, was the sole source of water supply. This bore was put down by the Northern Territory Administration, Department of the Interior. It is situated in a relatively soft white sandstone, and yielded a supply of 500 to 700 gallons per hour from a depth of approximately 140 feet.

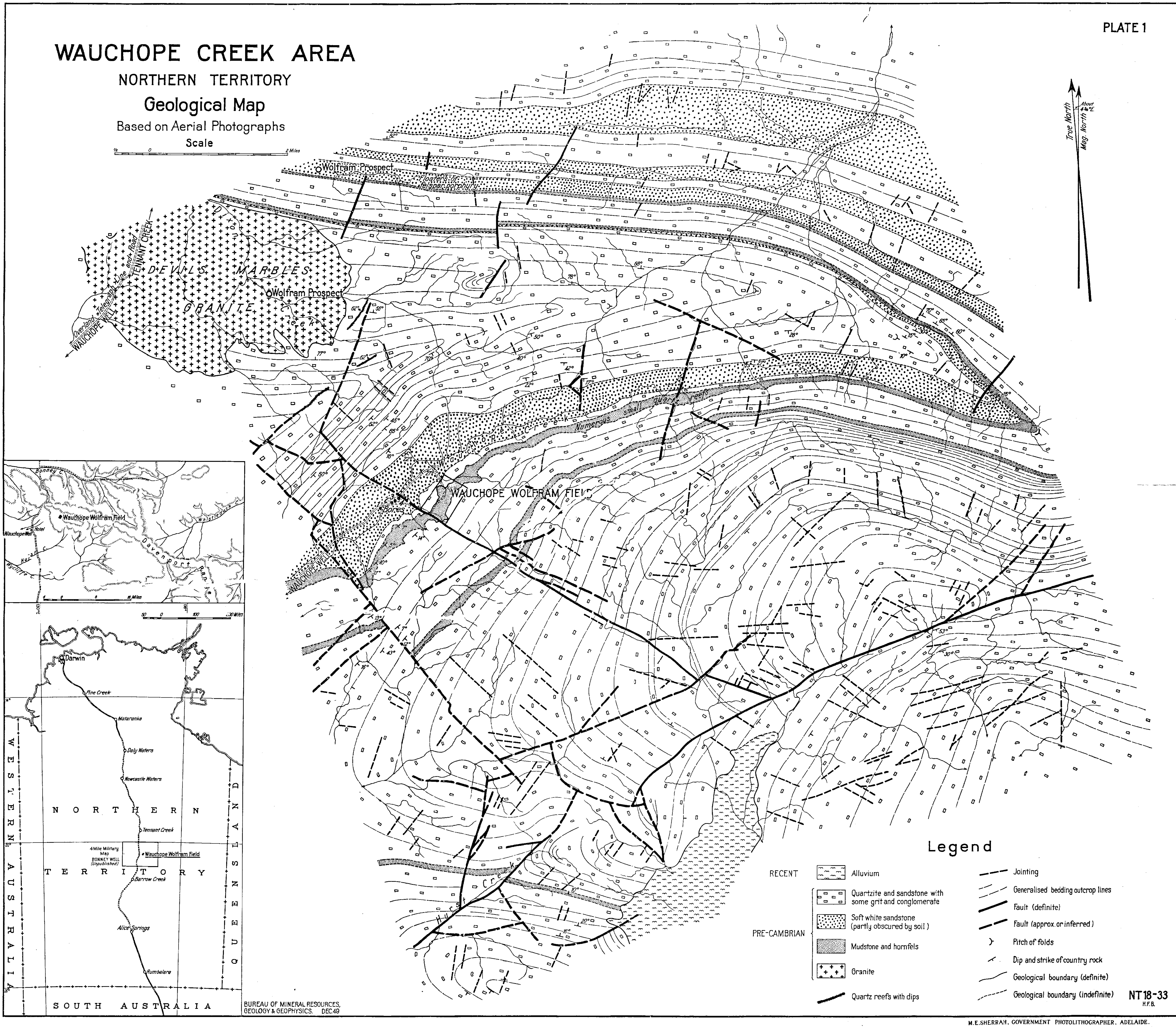
In order to cope with the increased water requirements of the field, the Government sank three additional bores in a line extending from the original Government bore to the field; each of these yielded up to 500 gallons per hour.

The system of bores was connected by a pipe-line through which water was pumped to the mill and to the various houses and quarters.

It was found that, with the type of mill in operation at Wauchope, and taking into account the use of return water, approximately 2 tons of water were required for each ton of ore milled.

In selecting sites for water bores at Wauchope, care was taken to drill in the relatively porous white sandstone formation, particularly where it was fractured or faulted. Normally, bores were put down at points estimated to be 150 to 160 feet above the underlying hard, relatively impervious quartzite formation (Plate 1). This was done because the water-table was known to be approximately 140 feet below the surface.

At present only the original bore (No. 1) is in use.



M.E. SHERRAH, GOVERNMENT PHOTOLITHOGRAPHER, ADELAIDE.

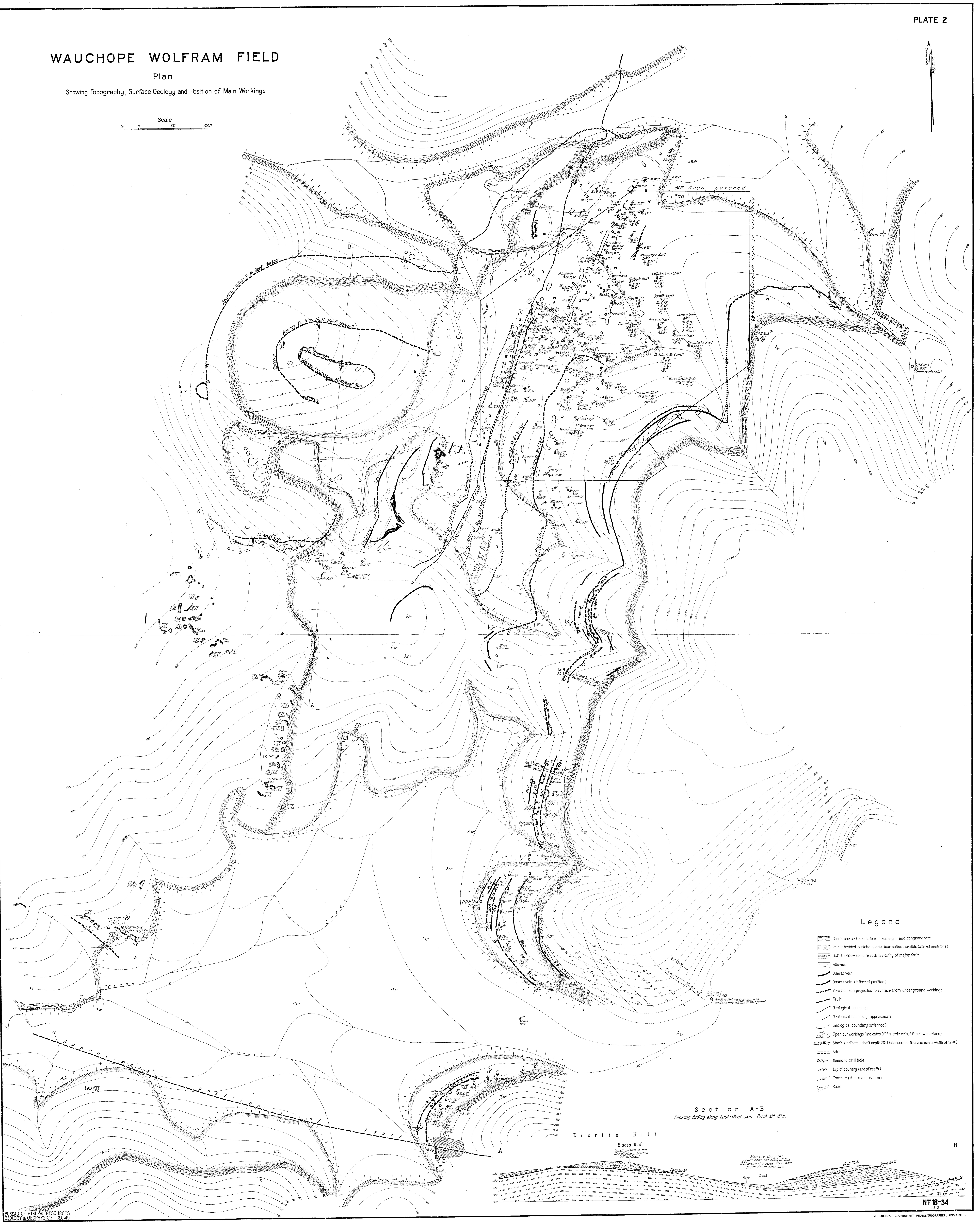


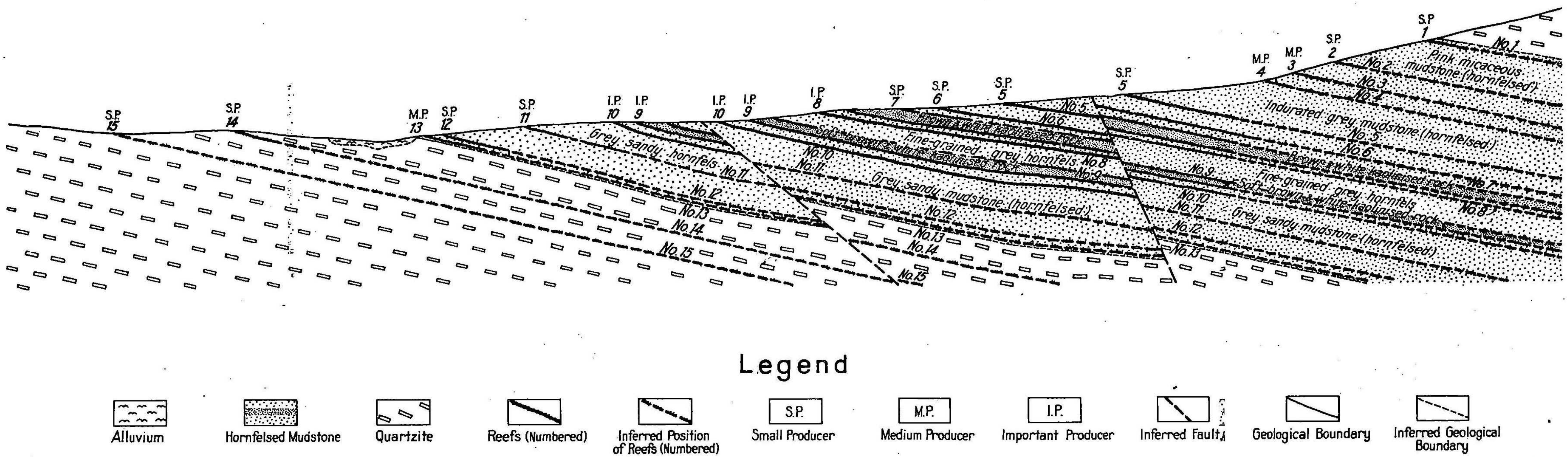
PLATE 2
WAUCHOPE WOLFRAM FIELD
Plan
Showing Topography, Surface Geology and Position of Main Workings
Scale
Area covered by plan of main workings
Legend
Sandstone and quartzite with some grit and conglomerate
Thinly bedded sericite-quartz-tourmaline hornfels (altered mudstone)
Soft biotite-sericite rock in vicinity of major fault
Alluvium
Quartz vein
Quartz vein (inferred position)
Vein horizon projected to surface from underground workings
Fault
Geological boundary
Geological boundary (approximate)
Geological boundary (inferred)
Open cut workings (indicates 9ins quartz vein, 5 ft. below surface)
Shaft (indicates shaft depth 20ft. interseeted No.9 vein over a width of 12ins.)
Adit
Diamond drill hole
Dip of country (and of reefs)
Contour (Arbitrary datum)
Road
Section A-B
Showing folding along East-West axis. Pitch 10°-15°E.
Diorite Hill
Slade's Shaft
Small puckers in this fold pitching in direction 110° (not shown)
Main ore shoot "A" occurs down the pitch of this fold where it crosses favourable North-South structure
Vein No.13
Road
Creek
Vein No.10
Vein No.11
Vein No.14
A
B
Approximate position of fault
BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS DEC.49
NT18-34
H.F.B
M.E.SHERRAH. GOVERNMENT PHOTOLITHOGRAPHER. ADELAIDE.

PLATE 3

WAUCHOPE WOLFRAM FIELD

COMPOSITE PROJECTION AT RIGHT ANGLES TO STRIKE
NORTHERN PORTION OF FIELD
Showing Approximate Position of Vein Horizons

Scale
50 0 100 200 ft.
No vertical exaggeration



BUREAU OF MINERAL RESOURCES
GEOLOGY & GEOPHYSICS. DEC. 49

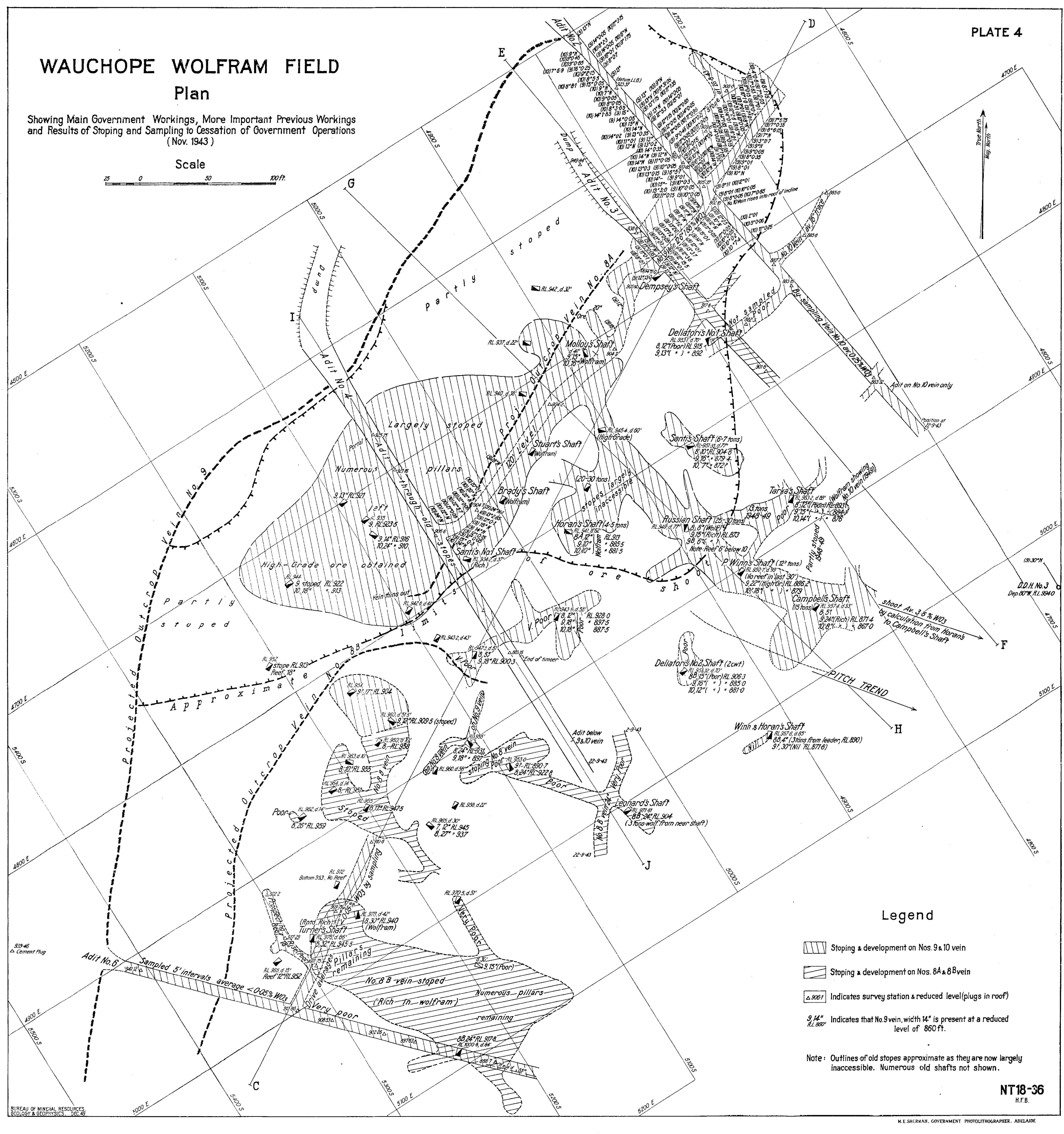
NT 18-35
H.F.B.

M.E. SHERRAH, GOVERNMENT PHOTOLITHOGRAPHER, ADELAIDE.

WAUCHOPE WOLFRAM FIELD

Plan

Showing Main Government Workings, More Important Previous Workings and Results of Stoping and Sampling to Cessation of Government Operations (Nov. 1943)



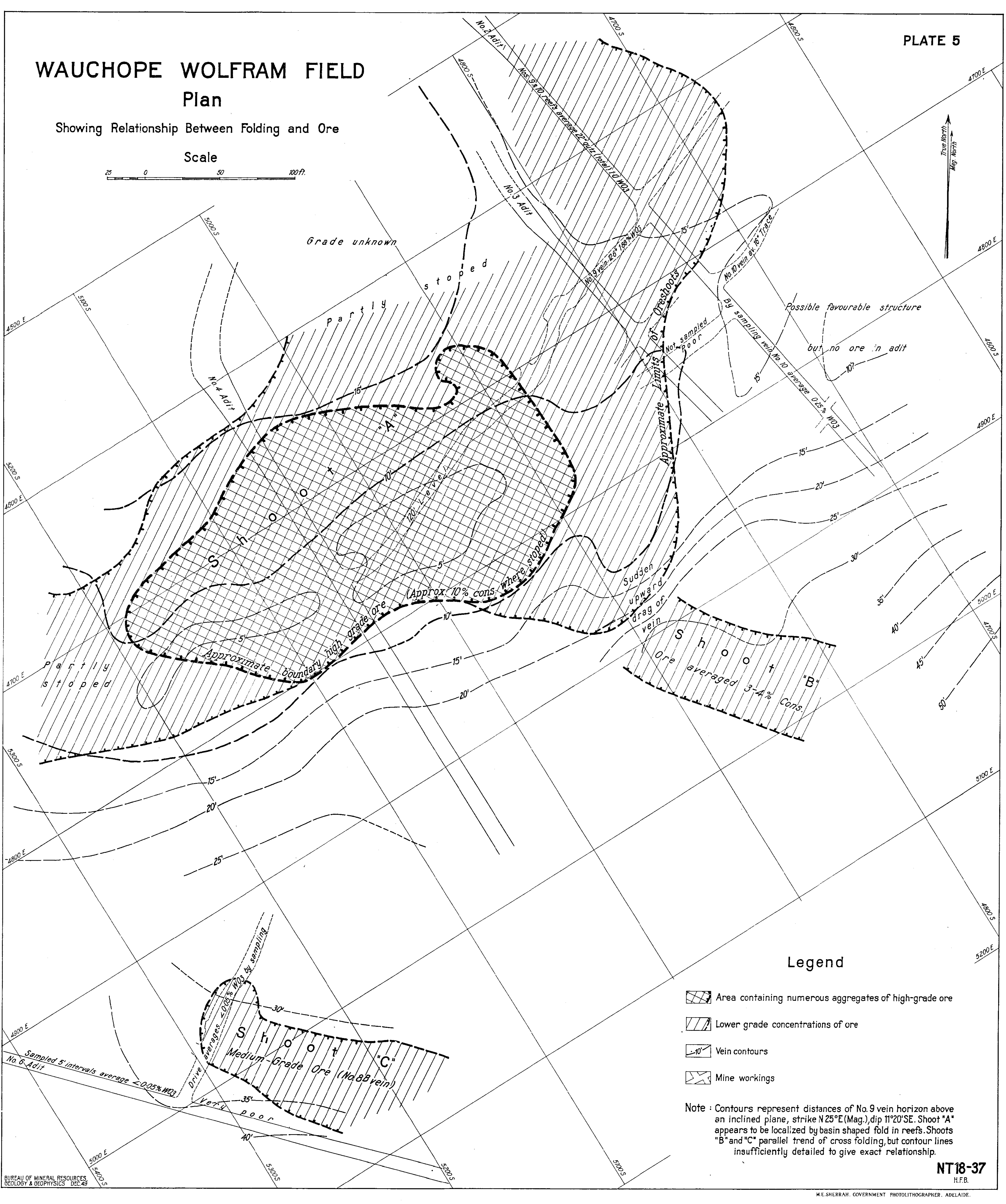


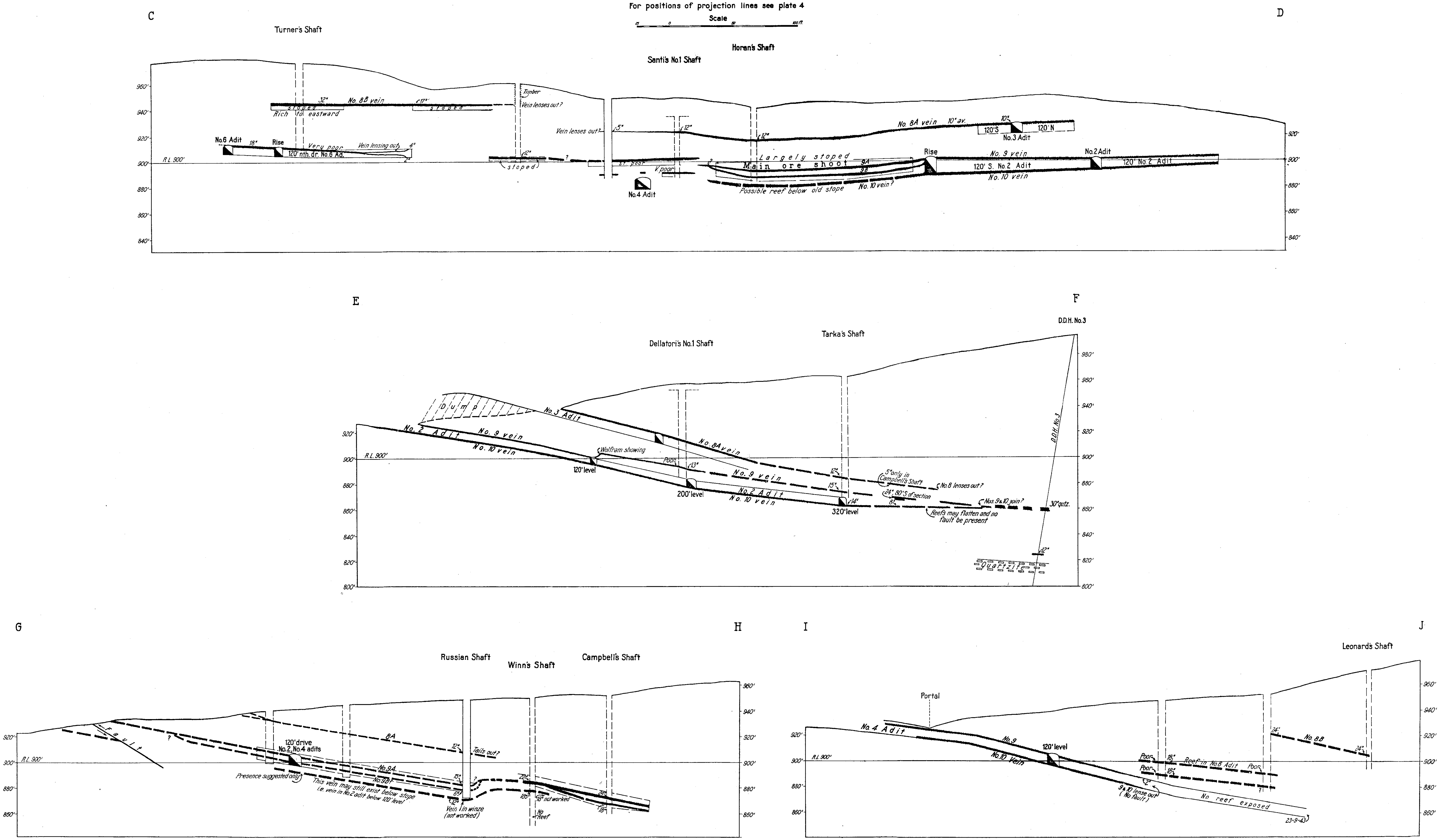
PLATE 5
WAUCHOPE WOLFRAM FIELD
Plan
Showing Relationship Between Folding and Ore
Scale
25 0 50 100 ft.
True North
Mag. North
No. 2 Adit
Nos. 9 & 10 reefs average 22" qutz (total) 1.0 WO3
No. 3 Adit
No. 9 vein 12.6" 1.88% WO3
No. 10 vein av. 16" Trace
Grade unknown
Partly stoped
Limits of Oreshoots
Approximate
Not sampled
Poor
By sampling vein No. 10 average 0.25% WO3
Possible favourable structure
but no ore in adit
No. 4 Adit
Shoot "A"
120' Level
(Approx. 10% cons. where stoped)
Approximate boundary high grade ore
Sudden upward drag of vein
Shoot "B"
Ore averaged 3-4% Cons.
Partly stoped
Shoot "C"
Medium-Grade Ore (No. 8B vein)
Drive averages ∠0.05% WO3 by sampling
Sampled 5' intervals average ∠0.05% WO3
No. 6 Adit
Very poor
Legend
Area containing numerous aggregates of high-grade ore
Lower grade concentrations of ore
Vein contours
Mine workings
Note : Contours represent distances of No. 9 vein horizon above an inclined plane, strike N 25°E (Mag.), dip 11°20' SE. Shoot "A" appears to be localized by basin shaped fold in reefs. Shoots "B" and "C" parallel trend of cross folding, but contour lines insufficiently detailed to give exact relationship.
NT 18-37
H.F.B.
BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS DEC. 49
M.E. SHERRAH. GOVERNMENT PHOTOLITHOGRAPHER, ADELAIDE.

WAUCHOPE WOLFRAM FIELD

VERTICAL PROJECTIONS ALONG LINES C-D, E-F, G-H, I-J

The projections illustrate lenticular nature and arrangement of quartz veins.

For positions of projection lines see plate 4



BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS. DEC 49

NT18-38
H.F.B.

M.E. SHERRAH, GOVERNMENT PHOTOLITHOGRAPHER, ADELAIDE.