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GEOLOGICAL REPORT ON UPPER RIDGES MINE, WAU, TERRITORY OF NEW GUINEA.

by

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M A P S

SUMMARY

The Upper Ridges gold mine, $4\frac{1}{2}$ miles west of Wau, has produced to date 181,000 tons of ore, for 75,500 oz. gold. Underground ore is extracted by cut-and-fill stoping and treated by milling and cyaniding. Ore remaining in upper three levels is being removed by open-cut methods. Reserves (June 1957): Upper Ridges open cut -- 46,000 tons at 0·4 oz. Au per ton; No. 2 Adit -- 13,000 tons at 0·5 oz. Au per ton.

The mangano-calcite lodes occur in an explosion breccia which rests on Kaindi metasediments. Overlying the lodes is a large lens of porphyritic quartz-biotite andesite. The lodes are tabular veins with local irregularities in strike, dip, and dimensions. Small-scale, post-ore faulting has dislocated the lodes in numerous places, particularly in the weathered portion of the mine.

The lodes are shallow, epithermal deposits emplaced by fissure filling. Gold is associated chiefly with manganese minerals, quartz and pyrite. Other gangue minerals are calcite, galena, chalcopyrite and sphalerite. Near No. 7 level calcite ore gives way to sulphides. Gold occurs as electrum with 60% Au. Chemical enrichment has not been recognized in the mine by the writer but some mechanical concentration has occurred near No. 2 level.

INTRODUCTION

At the time of writing (October 1957), the final closing of Upper Ridges Mine is under consideration. Its total production during 18 years of operation - 75,500 fine ozs. of gold - is greater than that of any other underground gold mine in the Territory of Papua and New Guinea, except that of the Umana mine, Misima, which has yielded about four times as much gold but is no longer in production.

The mine is situated in the Morobe District, 2.15 miles (4.45 miles by road) on a bearing West 19° North from the top of Wau airstrip. The mine buildings, located on the lower slopes of Mt. Kaindi, have an elevation of 4,267 ft. above sea level. The climate is temperate with a yearly average maximum temperature of 84°F. and an average minimum temperature of 61°F. The average annual rainfall is 82 inches.

The slopes of the surrounding mountains are mostly covered with dense forest; except for areas of secondary scrub or grass, which are due, partly at least to the removal of the primary forest by cutting, burning or landslide.

Upper Ridges Mine underground workings are located in the spur between Namie and Anderson's Creeks. The ground on which the Mine is situated was pegged by New Guinea Goldfields Ltd. in 1930, and is currently held by them as G.M.L. 700.

PREVIOUS GEOLOGICAL WORK AND MAPPING

The earliest geological mapping in the Upper Ridges area was carried out for New Guinea Goldfields Ltd. by H.M. Kingsbury, who also directed the initial exploration of the original lode outcrops. His maps and reports cover the period from July 1931 to June 1935. From the latter date until April, 1938, when Graham Hall, on a brief visit from Mt. Isa, prepared a geological report and maps, (Hall 1938) geological information was not systematically and continuously recorded by the company.

Reports and maps by Fisher (1938) correlate the considerable information from bores and underground workings available by that time, and are the first comprehensive analysis of Upper Ridges geology.

J. McDonald was the mine geologist from 1938-1941, during which period a new set of mine plans and sections was produced.

Post-war geological mapping and consultation was carried out by the Resident Geological staff of the Bureau of Mineral Resources, first by J.E. Thompson, and later by N.J. Mackay who began work in March 1952. Mackay systematically re-examined and brought up to date the geology of Upper Ridges mine on a new series of plans (1 in. = 30 ft.) extending downwards to No. 7 level. Since Mackay's departure in September 1954, geological mapping was carried out jointly by J.G. Best and the present writer, as members of the Resident Staff.

DEVELOPMENT

The outcrop of the Upper Ridges Main Lode was found early in 1933 and an intensive prospecting campaign was initiated soon afterwards. On the basis of information obtained by systematic pitting and costeaning, underground development of the lode began by the driving of adits, at several levels, from the Namie Creek side of the spur.

While the underground workings were being developed, ore near the surface was extracted by open-cut methods. Until 1939, glory-holes made the largest contribution of Upper Ridges ore to the mill; but thereafter, most ore was obtained from underground sources. The open cut was connected by several winzes to No. 2 level which served as a haulage way for surface ore.

In October 1941, when production was suspended owing to the war, work was being carried out on five levels from No. 1 (5130') and No. 5 level (4950'). Little ore had been produced from No. 5 Level because the face of the drive was about 150 ft. from the expected position of the shoot when the mine shut down.

When mining operations were resumed in 1948, the pre-war workings had almost entirely collapsed during the period of disuse. It was then decided to drive a new level (No. 6) 35 ft. below No. 5 level in preference to opening the latter. No. 6 level became the main ore-transport level and the old No. 5 level was subsequently worked as No. 6 sub-level. Another adit (No. 2) was driven on No. 6 level from the Anderson's Creek side and this broke through to 6/K-25 cross-cut in 1956. Although ore of good grade was in No. 2 Adit, the main value of the connection was for ventilation. A short drive (No. 7 level) was put in 45 ft. below the No. 6 level, mainly for the purpose of exploiting No. 2 Lode. It is connected to No. 6 level by a series of rises.

In post-war operations the emphasis has shifted from the Nos. 1, 2 and 3 Levels to the lower regions of the Mine. The reasons for this change were partly the difficulty and high costs of maintaining workings in the upper, more weathered zone of the mine, and partly the discovery of ore extensions at the lower levels.

PROSPECTING

In 1937 an extensive drilling programme was carried out at Upper Ridges Mine. The first series of 21 holes was put down by Keystone drill; the greatest depth reached was 302 ft. A second series of deeper holes was sunk by diamond drill. The deepest hole in this series was 590 ft. All but three holes were vertical. The purpose of this programme was to test the ore ahead of the workings and at depth. (See plans and sections for details of locations.) It is of interest to note that many of the drill holes indicated a lower grade than was shown by underground sampling. This appears to be related to the loss of water in the vicinity of the lode.

Post-war drilling exploration consists of five diamond-drill holes with an aggregate length of 539 feet, put in during 1956. The holes, all approximately horizontal, were drilled on No. 6 level (see plates 7 & 8). Three holes were drilled from K-25 cross-cut and two from I-23 cross-cut.

Very little exploratory work has been carried out at Upper Ridges Mine. Development of the orebody was the sole source of geological information; even the necessity of probing for the continuation of faulted lode did not encourage the use of scout-drilling.

MINING AND MILLING METHODS .

Ore extraction at Upper Ridges has been chiefly by cut-and-fill stoping with square sets. The dip of the lode is generally sufficiently steep to allow the ore to rill out of the stopes. Large quantities of ore had to be left in pillars. In the lower levels these pillars were extracted during the final phases of underground mining and the stopes allowed to collapse. This method was impracticable in the upper levels and, consequently ore remnants from No. 3 level upwards could not be salvaged until open-cut mining (in progress since November 1957) was re-commenced.

Particulary detrimental to the development of the mine was the practice of driving in ore with little or no exploration. Structural problems, variations in the attitude, dimensions and tenor of the lode, etc. were not anticipated so that advance planning of main haulage-drives and extraction procedure were not possible.

Up to 1939 Upper Ridges ore was treated by direct cyanide leaching in vats, with coarse crushing only. The oxidized, manganiferous ore, largely derived from glory holes and No. 1 level, was particularly amenable to this treatment. The production of fresh, massive mangano-calcite ore from lower levels, however, required the reconstruction of Golden Ridges mill to provide fine crushing in ball mills and classification into sands and slimes prior to cyanidation. This new plant was in operation only until the end of 1941, when it was dismantled by Australian army troops.

Post-war milling was on a larger scale than prewar. The complete Edie Creek plant, which included a ball mill, large jaw-crusher, and a 15-head stamp battery, was installed at Golden Peaks and began working in April 1951. The cyanide treatment plant was not completed until April 1953; until that date, sands and slimes were stored in a tailings dam. Since July 1952, the mill has been treating between 3000 and 4000 tons of ore per month. For the year July 1955 - June 1956, the average gold recovery was 87.6%.

PRODUCTION, GRADE AND ORE RESERVES

Up to the end of June 1957, mining at Upper Ridges had produced a total of 181,119 tons of ore with an average grade of 0.449 oz. Au/ton, which yielded approximately 75,500 fine ounces of gold.

Table 1 (a) and (b) show the production details.

TABLE 1

(a) Production up to October 1941

Period ending	Ore Tons	Average assay oz. Au per ton	Total gold content (calculated) oz.
Total up to Sept. 1938	23,689	.496	11,793
Jan.-Sept. 1939	17,079	.507	8,667
Sept. 1940	21,884	.436	[illegible],546
Oct. 1941	14,786	.481	7,100
Totals	77,438	.479	37,106

(b) Production from April 1951 to June 1957

Period ending	Ore Tons	Average assay oz. Au per ton	Total gold content (calculated) oz.	Gold recovery
April-Sept. 1951	2,653	.531	1,408	25%
Sept. 1952	15,790	.574	7,870	50.9%
Sept. 1953	19,020	.442	8,404	60% up to March. 86% in Sept.
Sept. 1954	20,380	.365	7,795	87.1%
June 1955	16,854	.343	5,768	88.26%
June 1956	17,905	.365	6,535	87.6%
June 1957	11,079	.575	6,375	?
Totals	103,681	.425	44,155	

Actual gold product (average assay x $\frac{87}{100}$) : 38,410 oz.

The pre-1941 grades and gold yield were calculated from mill-head assays, and the grade of post-war ore was determined chiefly from daily grab samples. Percentage recovery for the pre-1941 period is not known and actual gold production could not be determined.

As the post-war gold production from underground workings was not recorded separately, the calculated gold-yield has been reduced by 13% (average loss since commencement of cyanide treatment) to obtain the actual gold yield. The low gold recovery during the years 1951-53 was due to storage of gold-bearing mill sands until the completion of the cyanide extraction plant.

Table 2 (a) shows that the average grade was highest on No. 2 level, decreasing progressively downwards to No. 4 level; open cut ore having a grade intermediate between No. 2 and No. 3 level. Calculations of grade from No. 4 to No. 7 level, however, indicate no such consistency (see Table 2b).

TABLE 2

(a) Production and average grade of ore from glory-holes, Nos. 1,2,3 and 4 levels up to October 1941.

	Glory holes & No. 1 Level	No. 2 Level	No. 3 Level	No. 4 Level
Total Ore Production Tons	31,770	10,116	21,312	15,240
Average grade oz. Au/ton	0.489	0.597	0.441	0.401

(b) Average grade of ore from Nos. 4,5,6 and 7 Levels, representative of the period 1951 to 1957. Owing to incompleteness of data, production totals and overall averages cannot be given. The figures represent ore production and grade details obtained from the years 1953, 1955 and 1957.

	No. 4 Level	Nos. 5 & 6 Levels	No. 7 Level
Ore Production tons	4,728	9,719	4,801
Average grade oz. Au/ton	.662	.435	.514

The high grade of the ore from No. 2 level is undoubtedly the result of a mechanical concentration of gold derived from the friable manganese-wad at or near the surface. The overall variation in grade throughout the mine is too erratic, however, to be explained solely as a function of the depth of ore. Later in this report an attempt will be made to relate the variations to compositional and structural features. It is sufficient to note here that the carbonate ore at Upper Ridges tends, in the vicinity of No. 7 level, to be replaced by sulphides. Although the gold content did not decrease significantly, lack of facilities for treating sulphide-ore caused the suspension of mining at No. 7 level. A notable exception is No. 7 lode on No. 7 level, No. 2 Adit, which, at the time of writing, is persisting as a 4-5 ft. wide calcite-rhodochrosite vein with a positive reserve of 12,700 tons of .50 oz. ore. (~~See appendix 2~~).

TABLE 3

Development, ore reserves, and ore production. A yearly comparative summary.

Period ending	Develop -ment (ft.)	Ore Reserves (in tons); Grade in oz. Au/ton. Positive	Possible	Total (a)	Ore product-ion for period (tons) (b)	Total ore product -ion to date. (tons)
Sept. 1938	2,079	33,000 (.40)	70,000	103,000		23,689
Sept. 1939	2,460	103,000	15,000	118,000	17,079	40,768
Sept. 1940	1,626	57,239 (.41)	15,000	72,239	21,884	62,652
Oct. 1941	101	50,134 (.37)	24,141 (.28)	70,275 (.34)	14,786	77,438
Sept. 1948	-	-	-	-	-	"
Sept. 1949	516	-	-	-	-	"
Sept. 1950	2,714	77,941 (.48)	9,141 (.28)	87,082 (.465)	-	"
Sept. 1951	4,537	?	?	133,366	2,653	80,091
Sept. 1952	1,583	?	?	125,492 (?)(.45)	15,790	95,881
Sept. 1953	1,763	?	?	103,235 (?)(.45)	19,020	114,901
Sept. 1954	2,839	?	?	132,557 (?)(.40)	20,380	135,281
June 1955	2,456	?	?	114,451 (?)(.40)	16,854	152,035
June 1956	3,240	38,336 (.47)	?	38,336 (.47)	17,905	169,940
		(Mainly No. 2 Adit)				
June 1957	949	13,600 (.52)	2,300	15,900 (.52?)	11,179	181,119
Reserves for U.R. Open Cut as at June 1957		36,940 (.425)	9,000	45,940 (.43?)		

? Figures not available.

(?) Figures estimated from totals - accuracy in doubt.

GENERAL GEOLOGY

The mineralization complex of Upper Ridges involves the following four main pre-lode rock units.

(a) Kaindi Metamorphics
(b) Lower Edie Porphyry
(c) Upper Ridges Breccia
(d) Younger Porphyry.

(a) The Kaindi Metamorphics -- a succession of fine-grained, extensively metamorphosed argillaceous rocks -- form the basement throughout the Morobe District and are currently considered to have their upper age limit in the Cretaceous age. These rocks have been correlated with the basement metamorphics occurring in New Britain, New Ireland and other parts of New Guinea (Fisher, 1943).

It should be noted, however, that the age of Omung Metamorphics, exposed on the Kubor Range, is considered by Rickwood (1955) to be Pre-Permian.

In the Wau area, the Kaindi Metamorphics are represented by phyllite, slate, schist, recrystallized limestone, and metamorphosed tuffs. The main component is a blue phyllite consisting chiefly of quartz granules and micaceous minerals (mainly biotite) with subordinate plagioclase and varying amounts of chlorite, pyrite, titanite, magnetite, ilmenite and rutile (Donnay, 1931). Shear effects are prominent and bedding is often locally obscured by secondary foliation. In the Morobe District the Kaindi Metamorphics form a series of broad folds, trending generally north-east.

(b) Lower Edie Porphyry. Intrusive into the Kaindi rocks is the Lower Edie Porphyry -- a well crystallized quartz-biotite andesite porphyry which outcrops extensively in the immediate vicinity but is not encountered in situ in the mine. At Upper Ridges it is represented as a major component in the breccia host-rock of the lodes. It is light-brown, very hard when fresh, with occasional small quartz veins. Microscopically it consists of more than 50% andesine which exhibits a general parallelism and strain cracks (Fisher, 1943). Biotite and quartz phenocrysts are present in approximately equal quantities and pyrite is abundant throughout.

(c) Upper Ridges Breccia. The host rock of the Upper Ridges lodes is an explosion breccia comprising chiefly fragments of schist, blue phyllite, Lower Edie Porphyry and pebbles of primary quartz. Pyrite is disseminated throughout. Fisher (1938 a.) has noted that thin sections show fragments of porphyry in which feldspars are largely replaced by calcite and which have a fine quartz-feldspar groundmass. Fragments of laminated schist with alternating dark and fine quartz-feldspar bands are present. Some fragments of schist are almost entirely replaced by secondary quartz in small grains. Many of the porphyry fragments in the breccia show diffuse and feldspathically enriched borders. In unweathered portions of the mine the breccia is hard and compact. In its weathered state (as in the vicinity of lode, faults, and surface,) it acquires the properties of a dense clay with little rigidity and a marked tendency for plastic deformation. Although the majority of fragments are conspicuously rounded, evidence that water-action played a significant role in the deposition of the breccia is absent; sorting and preferred orientation of the pebbles have not been observed. In the absence of contrary evidence, it is suggested that the breccia represents the reconstituted product of an explosively disintegrated alluvial deposit, which provided the rounded pebbles, together with underlying igneous and metamorphic rocks (which provided the larger part of the angular fragments and rock-flour) penetrated by the explosive vent.

(d) Younger Porphyry. Intrusive into the breccia is a porphyry which bears an important structural relationship to the Upper Ridges Lodes. Except for the fact that it definitely post-dates the breccia, the time of its emplacement is not known. In composition it resembles the Lower Edie Porphyry, described above, but is generally of finer grain. It is a light-grey rock with abundant white feldspar, occasional large quartz phenocrysts, and biotite altered to anauxite (Fisher, 1938b, states that the biotite -- anauxite alteration is typical in rocks associated with late-Tertiary mineralization in the Wau-Edie Creek area). Feldspar is generally completely altered to sericite and kaolin. Calcite occurs in the groundmass and replaces biotite. Pyrite is abundant in veins and around the edges of other minerals. The groundmass is very fine and comprises chiefly feldspar and quartz. In J-25 cross-cut, No. 6 level, a lens of porphyry, strongly mineralized with pyrite, galena, and sphalerite, and carrying about 0.4 oz. gold per ton was encountered. The deposit was abandoned, however, because the sulphides upset metallurgical operations for the recovery of the bullion.

The configuration of the breccia body is not known, but information from drill-holes and mine-workings suggest that it rests on an irregular bottom of Kaindi Metamorphics -- near the 4,800 ft. horizon at Upper Ridges Mine -- which also form a wall to the breccia on the West. The sections show that the lodes tend to plunge towards the "corner" formed by wall and bottom. The body of porphyry has the same tendency but in this instance the metamorphic wall-rock is transgressed.

The close association of porphyry and lode was observed by Kingsbury (1932) who, suggested that porphyry and ore-bearing liquids originated from a common, deep-seated parent-magma and that the ore-solutions represented the final stages of magmatic differentiation, closely following the porphyry but along a different route. The interval between the two intrusive phases was long enough for the porphyry to consolidate and to act as a dam which localized the ore-deposit on its lower side as can be seen at Lower Ridges. In some localities of the nearby Edie Creek area (see sheet 1) the ore-bearing solutions escaped through the porphyry and moved upwards by way of more or less prominent fracture zones, thus forming the manganese-quartz stringers and veins common in the "mudstone" (chloritoid schist) regions. At Upper Ridges, however, the lode has nowhere been observed in contact with the porphyry and only one lode-breccia-metamorphic contact (near the portal of No. 3 level) is on record.

ORE GEOLOGY

(a) STRUCTURAL FEATURES :

The Upper Ridges lodes are discontinuous, roughly tabular, bodies of variable thickness. The maximum recorded thickness of the lode is 26 ft. (on No. 4 level). The overall strike of the ore-bodies is north-west. Dips range from 20° to 65° to the south-west, but commonly lie in the range 35° -- 55°. An outstanding feature of the deposit is the extreme amount of local variation in its strike, dip and shape. Undulations along dip and strike, with resulting troughs and ridges, are common. The lode pinches out abruptly at several places in the mine and this has caused some portions of the orebody to be isolated into discrete lenses.

To the north-west, the orebody terminates against the Kaindi metamorphics. No instance of the lode transgressing Kaindi rocks at Upper Ridges has been recorded. The single known lode-breccia-metamorphics contact on No. 3 level, has not yielded any significant information because of weathering.

It is, therefore, considered unlikely that further extensions of ore will be found in this direction. (~~See Appendix~~ ~~[illegible]~~) In the south-east the lode has everywhere ended by pinching out or faulting; but this observation does not imply that ore in that direction has been finally exhausted. The post-war finding and development of the orebody in No. 2 Adit, (plate 8) though not necessarily an extension of the main lode in Upper Ridges West, offers encouragement to the search for related lodes nearby. The area bounded by the east-west co-ordinates I to S, and the north-south co-ordinates 20 to 27 (see sheet 8) is thought to be particularly worthy of deep exploration by systematic drilling.

Faulting, generally on a small scale, has been recorded mainly from No. 3 level downwards. Most of the faults have a prominent component of horizontal displacement. The two largest faults recorded in the mine are F1 and F2. The maximum lateral distance over which fault F1 has been traced (with interpolations) is 230 ft. (on No. 6 level W.). Its dip averages 43°. The maximum distance over which the fault-plane has been traced down dip is 220 ft. (see section c-c'). Horizontal displacement ranges from 5 ft. (No. 3 level) to 70 ft. (No. 6 level), but most proved displacements are less than 10 ft. Fault F2 has a maximum lateral extent of 100 ft. (No. 6 level West), an average dip of 47°, and has been traced for 160 ft. down dip (see section d-d').

Faulted lode-segments can be correlated only tentatively. Neither breccia nor lode has any features which can be matched across the break, and segments have been correlated by similarity in size and shape. The tenor of the ore is too erratic to be useful as a test for continuity.

The present disposition of the lodes is largely the result of two phases of fracturing. The first set of fractures were formed in the hard, virtually unweathered breccia and served as ore-channels. The magnitude of the orebodies indicates that these fractures were long and continuous. Ground water was able to percolate down the lode-breccia contact and numerous minor fractures, weathering the breccia to a depth of several hundred feet. The plasticity which the breccia acquired upon weathering, made it susceptible to slumping -- particularly in the higher levels. This movement resulted in the small-scale but complex dislocation of the lodes.

With the development of the lower levels, the relationship between dislocated lode-segments became clearer and the earlier contention that Nos. 1,2 and 3 lodes were originally a single unit, has gained credence. The primary orebody probably consisted of several connected, parallel, sheet-like veins which were later dislocated by dip-faulting.

Mackay (Geological Monthly Report, Morobe District, August 1953) contended that No. 2 lode is the lower portion of No. 1 lode which has been relatively upthrust by a fault whose strike coincides roughly with that of the lodes but which has a gentler dip. In support of this contention, Mackay points out that following No. 2 lode from No. 6 level to No. 4 level, showed the orebody to be truncated by a fault just above No. 4 level. However, I am unable to agree with this hypothesis for the following reasons: Firstly, satisfactory evidence is lacking of continuity between the fault at the top of No. 2 lode and that at the base of No. 1 Lode. Secondly, granting its existence, a fault extending from the top of one lode to the base of another parallel to it cannot be taken as proof of overthrusting when other structural evidence is lacking. In fact, the proximity of the metamorphic bedrock to the base of No. 1 Lode (see section e-e') makes the accommodation of a large block of breccia -- downthrust several hundreds of feet -- most improbably. Furthermore, it does not follow that because both lodes are truncated, they were once joined.

How the orebody in the No. 2 Adit (shown on Plate 8) fits into the Upper Ridges picture is not clearly understood. The idea that it may be a faulted-off portion of the main orebody in the West, has been proposed at various times. Indications of major faults, have not been observed in No. 2 Adit and no reason is known why the two orebodies need be linked structurally.

Hall (1938) referred to the possibility of the former existence of a continuous belt of ore (presumably from Upper Ridges towards the Bulolo River) which was step-faulted into several segments. One of these segments would be represented by the Upper Ridges complex and another by Lower Ridges. Extensive faulting on a regional scale in the district (~~see appendix 5~~), makes the suggestion a feasible one. Direct evidence for the existence of a major fault which could have truncated the lodes of Upper Ridges and Lower Ridges is, however, lacking.

(b) MINERALOGY AND OCCURRENCE OF THE ORE.

The essential constituents of the ore are calcite, manganese minerals, quartz, and sulphides.

The calcite, when pure, is generally milky white and its texture varies from massive to granular to coarsely crystalline with individual crystals of up to 3/4 inch. It occurs commonly as columnar or botryoidal incrustation in cavities. In some localities (e.g. stope 4 G-20) well-formed crystals of "dog-tooth" calcite are laminated by the alternation of transparent calcite with an opaque, brown mineral -- probably siderite -- parallel to the crystal faces. When broken the crystals tend to fall apart into several discrete rhombohedral shells with generally a core of massive white calcite.

In the unweathered zone, the manganese occurs as rhodochrosite with similar texture and structure to the calcite. Its pink colour varies in intensity with the proportion of calcite accompanying it. In zones subject to oxidation by surface weathering or circulating groundwaters, the rhodochrosite readily decomposes to manganese oxides. In the upper levels of the mine, the chief oxidation products are manganite and pyrolusite. On the surface, however, the manganese occurs mainly as "wad". Manganese mineralization at Upper Ridges is intimately intimately associated with the occurrence of the gold.

Quartz is present as irregular blebs and veinlets within the calcite and rhodochrosite and as incrustations in small cavities. Its texture varies from massive to granular and its colour is a translucent white to colourless. It is present in minor quantities but ubiquitous throughout the lode. In portions of the lode where the calcite has been leached out and the rhodochrosite oxidized, the quartz may be seen as skeletal remnants in the wad. In the Golden Ridges area, which includes Upper Ridges, Anderson's Creek mine, Homestead and Golden Peaks (see sheet 1), the association of quartz and manganese wad is generally taken as an indication of high gold content.

Sulphides are found throughout the lode, disseminated or in clusters, but commonly concentrated at the lode-breccia contact. The most abundant sulphide mineral is pyrite, with galena, chalcopyrite and sphalerite in lesser amounts. The proportion of sulphide minerals generally increases downwards until near No. 7 level, they occur virtually to the exclusion of the carbonate ore.

The gold occurs as 'electrum' in which the Au-Ag ratio is about 60 : 40. The electrum (hereafter referred to as bullion or gold) is of microscopic dimensions and occurs free. Sampling throughout the mine has shown the gold to be closely associated with the manganese minerals, pyrite and quartz. Clusters of fine pyrite crystals -- especially on No. 3 level -- have been found to be indicative of high gold values (Fisher 1938b).

No regular relationship has been found to exist between the grade of ore and the thickness of the lode. Fisher (1938b) contends that " . . . where the lode is thick and well mineralized, values are good and consistent. As soon as the lode narrows, the values die rapidly away". This is certainly true of selected instances, but as a generalization it is untenable (see Table 4).

The runs of assay results from mine sampling (Upper Ridges assay plans, 1950, 1951) were selected because they show considerable variation in lode width.

From the table it is evident that the gold-silver ratio does not remain constant. This variation does not reflect a corresponding variation in the fineness of the bullion but merely indicates a local enrichment in silver-bearing sulphides. In this regard Thompson (1951) found that in the sulphide-rich portion of F-21 cross-cut (No. 6 level) gold values dropped well below the average but the silver content of the lode rose sharply. He attributes this to the presence of silver-bearing galena or tetrahedrite, and native silver or argentite in small quantities.

The effect of secondary enrichment is comparatively unimportant in the distribution of gold-values; the variation in grade is, most probably, a primary feature of the lode. Mechanical enrichment, however, certainly helped to produce the high values in upper portions of the lode. With complete oxidation of the manganiferous parts, the calcite goes into solution and the ore breaks down into an aggregate of quartz and manganese oxides relatively enriched in gold. Some of the gold thus liberated may have been carried, by percolating waters, into lower regions of the mine.

It has been empirically established at Upper Ridges that, where the lode consists of coarsely crystalline, white calcite, it is generally barren of gold. Microscopic examinations of lode specimens by F.L. Stillwell (1939) show that manganese minerals are present in all cases where gold is enclosed in calcite. Given below are the summarized results from several relevant specimens examined by Stillwell.

<u>No. 1</u> : Specimen from the cross-cut through the lode on No. 2 level. Average assay : 0.52 oz. Au/ton. The specimen in polished section consists of dark carbonates with sugary quartz, pyrolusite, and gold. The pyrolusite occurs chiefly as a border of acicular crystals to quartz-rich areas, along the edges of finely crystalline

TABLE 4

No. 3 LEVEL

3 F-18 Sub Level

Distance	Width of lode	Au. oz/ton	Ag. oz/ton
0'	36"	0.98	0.90
6'	45"	1.54	3.30
11'	30"	2.40	1.54
48'	24"	0.96	0.86
50'	20"	0.28	0.22
59'	32"	0.30	0.34
64'	37"	Tr.	Tr.
71'	41"	Tr.	Tr.
74'	43"	0.55	0.55
77'	48"	0.19	0.19
80'	48"	0.77	0.59
84'	42"	0.62	0.72
87'	16"	1.06	0.34
90'	33"	1.54	1.23
94'	39"	0.18	0.28
97'	41"	0.44	0.62

No. 4 LEVEL

4 I-22 Drive

Distance	Width of lode	Au. oz/ton	Ag. oz/ton
8'	58"	0.02	0.16
9'	36"	0.39	1.47
15'	23"	0.07	0.19
20'	13"	1.15	0.13
24'	24"	1.15	0.77
27'	26"	0.46	0.46
31'	30"	0.73	0.59
33'	26"	0.63	0.53
36'	27"	0.42	0.39
40'	41"	0.28	0.36

No. 6 LEVEL

6 G-20 Winze

Distance	Width of lode	Au. oz/ton	Ag. oz/ton
0'	33"	1.02	2.03
10'	60"	.51	.59
15'	62"	.62	.90
20'	68"	.78	.75
25'	56"	.76	.82
30'	49"	1.76	1.84
35'	51"	0.21	0.55
40'	50"	0.04	0.34
45'	27"	3.22	2.92
50'	50"	0.21	0.25
60'	35"	0.80	0.52
70'	17"	0.35	0.57
75'	22"	0.90	1.03
80'	18"	0.28	0.28
85'	20"	3.31	2.30
90'	12"	0.52	0.50
95'	12"	0.14	0.16
100'	12"	0.01	0.04

[illegible], and in joint-planes. The gold occurs in small, often equidimensional particles ranging in size from 0.006 to 0.042 mm. 90 particles of gold were seen, all in the calcite. Only two were associated with the pyrolusite, but these were actually surrounded by carbonate.

No. 2 : Specimen from calcitic lens, more or less isolated, on No. 2 level, ca. 250 ft. east of sample 1. Average assay : 0.52 oz. Au/ton. The specimen consists of crystalline calcite, veined by irregular bands of pink rhodochrosite up to ½ in. wide. The carbonates enclose fragments of partially replaced quartz-feldspar-biotite porphyry. Small crystals of pyrite and chalcopyrite are scattered throughout the carbonates as stringers ca. 1 mm. wide. A thin section of such a stringer revealed the presence of small amounts of chalcopyrite, tetrahedrite, sphalerite, and galena accompanying the pyrite and sometimes replacing it. 5 particles of gold, ranging in size from 0.002 to 0.10 mm., were observed. Of these, one was in the carbonate, although attached to a minute grain of tetrahedrite; 3 were enclosed in tetrahedrite, and one was enclosed in pyrite.

No. 3 : Core from drill-hole 18-A at 93 ft. The specimen consists essentially of pyrite and quartz, with a little galena. A polished section of massive pyrite shows irregular stringers of galena associated with very subordinate sphalerite crowded with inclusions of chalcopyrite. One particle of gold was observed embedded in pyrite.

No. 4 : Core from drill-hole 20 at 130 ft. The specimen consists of fairly massive pyrite associated with quartz. A polished section showed chiefly pyrite with disseminated galena and associated sphalerite and chalcopyrite. Sphalerite equals galena in abundance and is typically studded with inclusions of chalcopyrite. 4 particles of gold, ranging in size from 0.001 mm. to 0.015 mm. have been observed embedded in pyrite. A thin, discontinuous vein of gold occurs along the contact of the two crystals of pyrite.

No. 5 : Core from drill-hole 26 at 109 ft. The specimen contains considerable calcite associated with quartz, but less pyrite than either No. 3 or No. 4, above. A polished section shows crude bands of pyrite separated by seams of calcite. Galena, not confined to the pyrite, assumes a linear form within the pyrite. Sphalerite in subordinate amounts is present, crowded with inclusions of chalcopyrite. No gold was observed.

Though banding is not a prominent feature of the Upper Ridges orebody, several instances may be mentioned. In the G-19 stope, No. 4 level, white calcite alternated with black, manganiferous bands. The contacts between the bands are serrated and irregular, suggesting progressive fissure-lining. Calcite crystals at the interfaces are commonly partly dissolved and fine, black particles precipitated in the cavities. Farther from the adit, on the same level, black manganese-staining decreases and the pink tints of rhodochrosite become more prominent in the lode. Below No. 4 level, manganese oxides have not been observed to any significant extent.

A similar feature is found in O-25 rise, No. 7 level, No. 2 Adit, where the 6 ft. wide rhodochrosite lode shows distinct banding parallel to the walls. The bands are distinguished by slight differences in the manganese content, but there is no oxidation. As in the previous example, the contact between the bands is serrated or botryoidal, suggesting intermittent crystallization on the walls of an opening fissure.

Replacement of the country rock was prominent during the emplacement of the lode. Evidence of this process is seen at the contacts, which commonly show fragments of breccia in various stages of assimilation by calcite ore-material. In numerous localities the solid ore grades into stockworks of fine veinlets. Where the lode pinches out, solid calcitic ore commonly grades into a zone of pyrite-enriched breccia, which, in the weathered regions of the mine, is observable as characteristic iron-staining with little or no gold content. The breccia is ferruginised for distances of up to 3 ft., parallel to the walls of the lode in many places in the upper portions of the mine.

The process of mineralization is illustrated by the log of a typical core through a lode. The following section was obtained from the core of diamond drill hole No. 20.

	180-188 ft.	Small calcite veins in breccia.
	188-189 ft.	Calcite and quartz replacing breccia, strong pyrites.
	189-190 ft.	Manganese ore with small crystals.
	190-190'8"	Iron-stained breccia.
Lode	190'8"-191'7"	Calcite, quartz and manganese, slightly leached.
	191'7" - 194'	Mottled calcite-manganese ore, with streaks of more strongly manganiferous material.
	194' - 196'7"	Quartz and calcite with pyrites.
	196'7" - 198'	Mineralized breccia.
	198' - 208 ft.	Largely coarsely crystalline calcite. (Fisher, 1938b).

(c) PARAGENESIS.

The chief lode minerals are calcite, rhodochrosite, quartz, pyrite, and gold; manganite, pyrolusite, and psilomelene occur where the lode is oxidised. Chalcopyrite, galena, sphalerite, marmatite, and tetrahedrite are found locally and in subordinate qu ntities.

The results from Stillwell's examination of mine specimens (1939) and drill cores indicate that the order of crystallization was as follows : quartz, gold, pyrite, calcite, chalcocite, and galena/sphalerite. The place of rhodochrosite in the sequence is not clear.

Fisher (1938b) gives the order of deposition within the main lode as : "quartz and pyrite, partly simultaneous rhodochrosite, which has been deposited in bands from repeated accessions of mineralising solutions, and calcite, showing even more banding in parts. Manga..ite, where observed in the fresh ore, seems to be earlier than the pyrite. Gold was, in one or two cases, observed in close association with the pyrite, but in general is very difficult to detect in the ore. Quartz veins of a later stage of mineralization are present in places".

Thompson (1951), from megascopic examination of mine ore rich in sulphides, notes that finely crystalline pyrite is abundant throughout and is associated with quartz. He too, suggests that quartz and pyrite are coeval. He further noted that the mangano-calcite was generally massive but that the metallic minerals and quartz were often crystalline, indicating that the mangano-calcite and metallic minerals with quartz belong to different phases of mineralization.

In synthesis, and from personal observations, the following sequence is proposed: quartz and pyrite more or less simultaneously; calcite closely followed by rhodochrosite (this order is indicated by the preponderance of calcite in the stockworks and the great variety of calcite-rhodochrosite mixtures in the lode); chalcocite, galena and sphalerite simultaneously; and finally tetrahedrite. Judging by the inclusion in a variety of minerals, the gold appears to have crystallized over a considerable period.

(d) LODE FORMATION.

The mineral assemblage, particularly the accessory sulphides, are characteristic of low-temperature deposits. The superficial nature of the breccia and the lack of evidence that great quantities have been removed by erosion, add support to the conclusion that the Upper Ridges lode is an epithermal deposit emplaced at a relatively shallow depth.

From their close association in the Golden Ridges area, it is reasonable to suppose that the youngest porphyry and the mangano-calcite lodes are genetically related. The fact that porphyry overlies the lode in every instance where they occur together, indicates that the emplacement of the porphyry preceeded and exerted a structural control on the lode. The porphyry and lodes were probably emplaced along a series of roughly parallel fractures.

SOURCES OF INFORMATION AND ACKNOWLEDGMENTS.

The following reports (all but one unpublished) have yielded information which has been utilized in the present report:

Donnay J.D.H., April 1931, "Petrographic Report on Specimens from N.G.G." Stanford University, California, U.S.A.

Fisher N.H., 1938 (a), "Preliminary Geological Report on the Upper Watut Area".

Fisher N.H., 1938 (b), "Geological Report on the Upper Ridges Lode".

Fisher N.H., 1943, "Outline of the Geology of the Morobe Goldfield".

Hall G., April 1938, "Report on Geological Observations at Edie Creek, Upper Ridges and Anderson's Creek" (for N.G.G. Ltd.).

Kingsbury H.M., June 1931 and August 1932, "Geological Reports on Koranga-Name and Edie Creek Areas, N.G." (for N.G.G. Ltd.).

Rickwood F.K., 1955, "Geology of the Western Highlands of N.G.". Journal of Geol. Soc. Austr., Vo. 2.

Stillwell F.L., February 1939, "Petrographic report on Auriferous Ore from near Wau, N.G." C.S.I.R.O. Melbourne.

Thompson J.E., 1951, "Mineralogical Determination of sulphide ore from Upper Ridges Mine, Wau."

Annual Reports by the General Manager of New Guinea Goldfields Ltd.

Monthly Mine Reports by the Mine Superintendent, New Guinea Goldfields Ltd.

Monthly Geological Reports for the Morobe District, by the Resident Staff, Wau.

Compilation of maps, plans and sections accompanying this report was based on the following :

Geologist or Draftsman	Scope	Scale	Date
N.J. Mackay	Geol. Mine plans : surface	1" = 30'	Up to Sept. 1953.
N.H. Fisher & J. McDonald	Composite plans with sections surface to No. 5 level	1" = 30'	Up to 1941.
N.H. Fisher	Geol. composite plan with sections; surface to No. 4 level.	1 : 500	Up to Sept. 1938.
N. Owers	Sections obtained from drillings.	1" = 30'	Up to Nov. 1937.
Resident Geol. Staff	Current mapping of progress.	1" = 30'	

Finally I would like to acknowledge the co-operation extended by the Managing Director and staff of New Guinea Goldfields Ltd., in the preparation of this report. The generous response to requests for information and literature greatly facilitated the investigations.

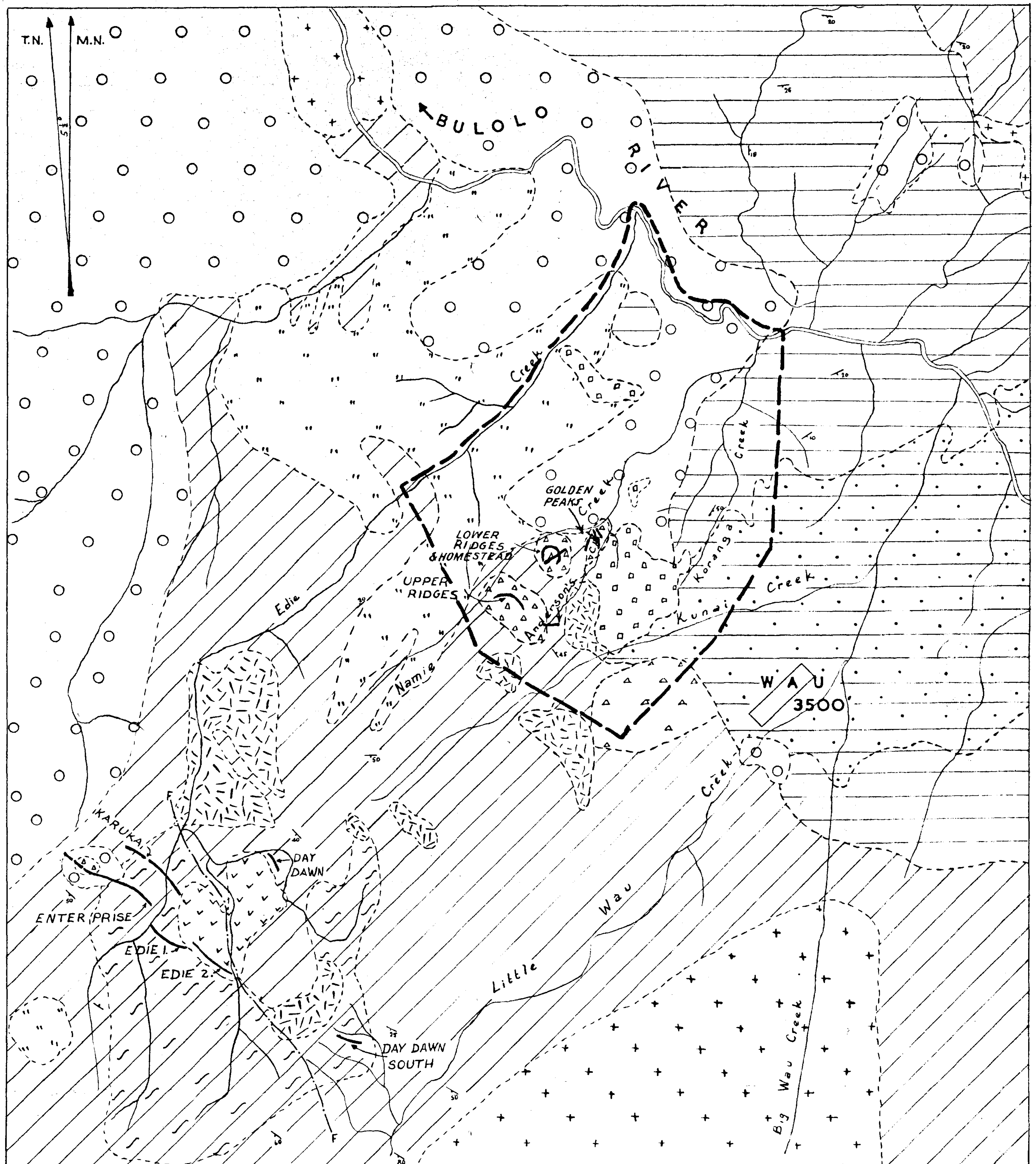
G. SIEDNER,
Bureau of Mineral Resources.

WAU,
October, 1957.

GEOLOGICAL MAP OF THE WAU-EDIE CK. AREA, MOROBE GOLDFIELD.

(AFTER N.H.FISHER, 1943.)

SCALE: 1inch = 1 mile.



LEGEND

RHYOLITE FLOWS & BRECCIA	RECENT
PIEDMONT DEPOSITS	
OTIBANDA LAKE DEPOSITS	PLEISTOCENE
EXPLOSION BRECCIA	PLIOCENE TO PLEISTOCENE
VOLCANIC AGGLOMERATE	
UPPER EDIE PORPHYRY	
UNCLASSIFIED PORPHYRY	
LOWER EDIE PORPHYRY	
GRANODIORITE	INTRUSIVE INTO KAINDI SERIES
PHYLLITE, SCHIST, RECRYSTALLIZED LIMESTONE ETC.	KAINDI METAMORPHICS: CRETACEOUS AND OLDER
CHLORITOID SCHIST ("MUDSTONE")	
LODES	
FAULT	
STRIKE & DIP	

PLATE 2

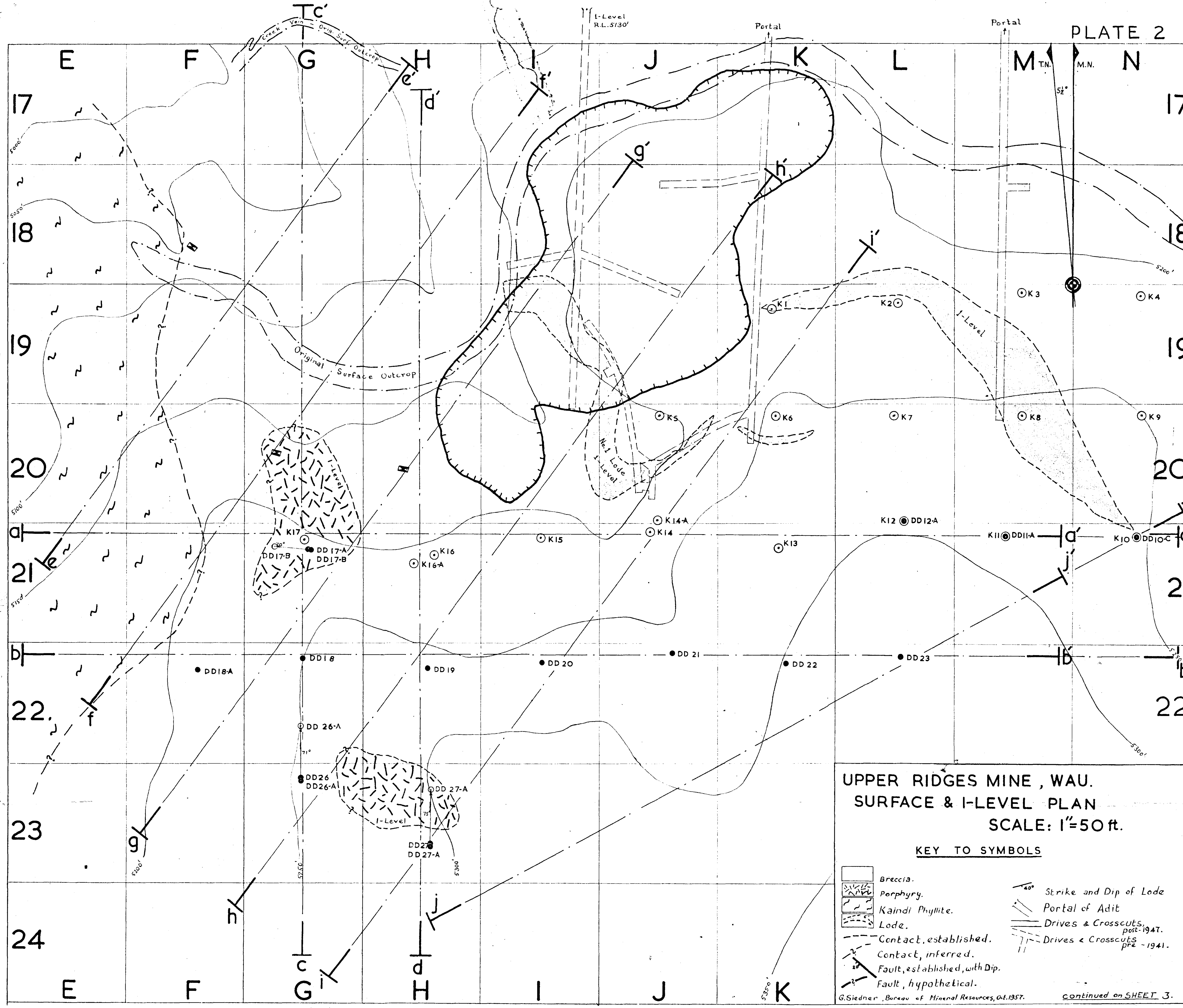
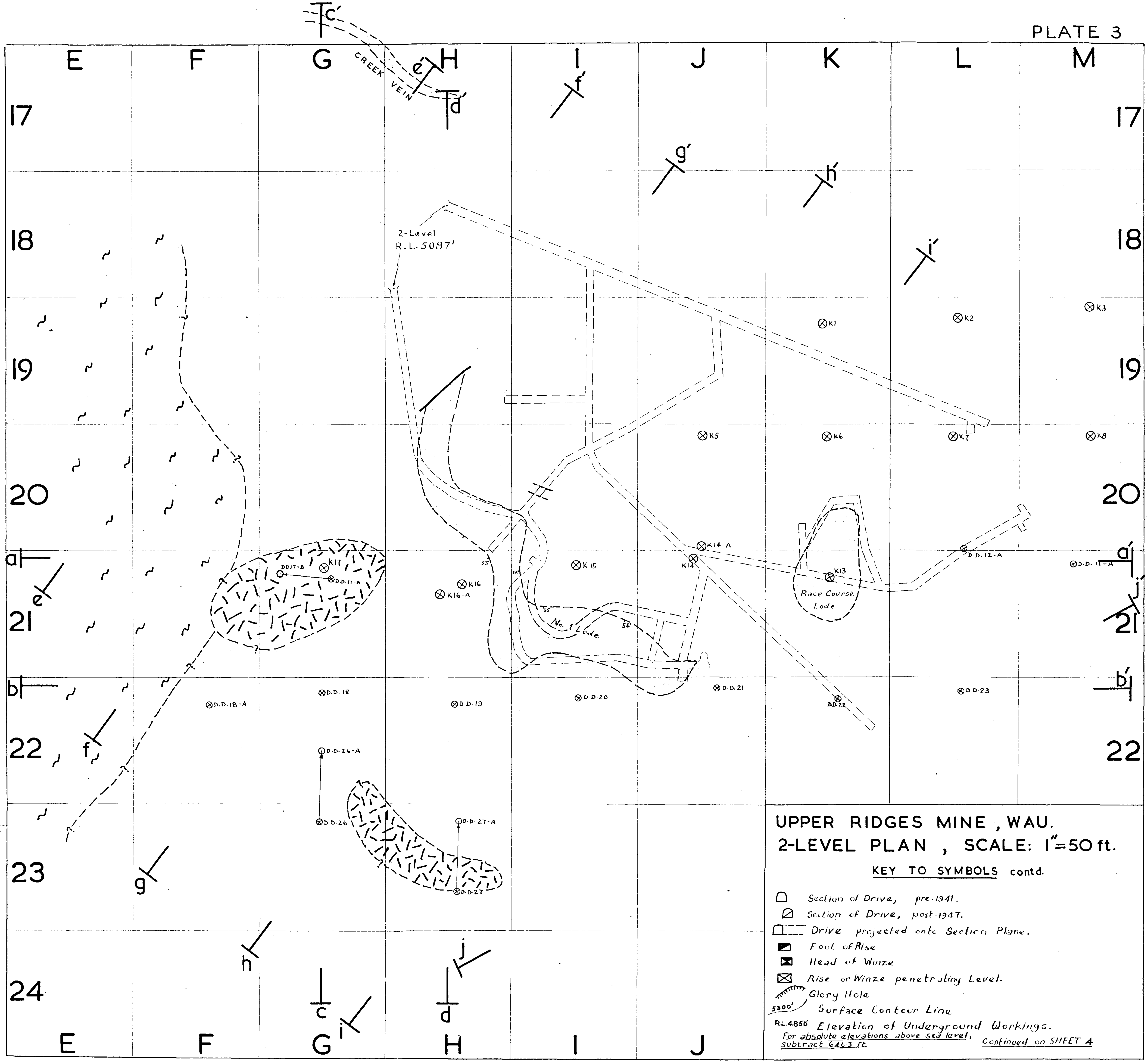
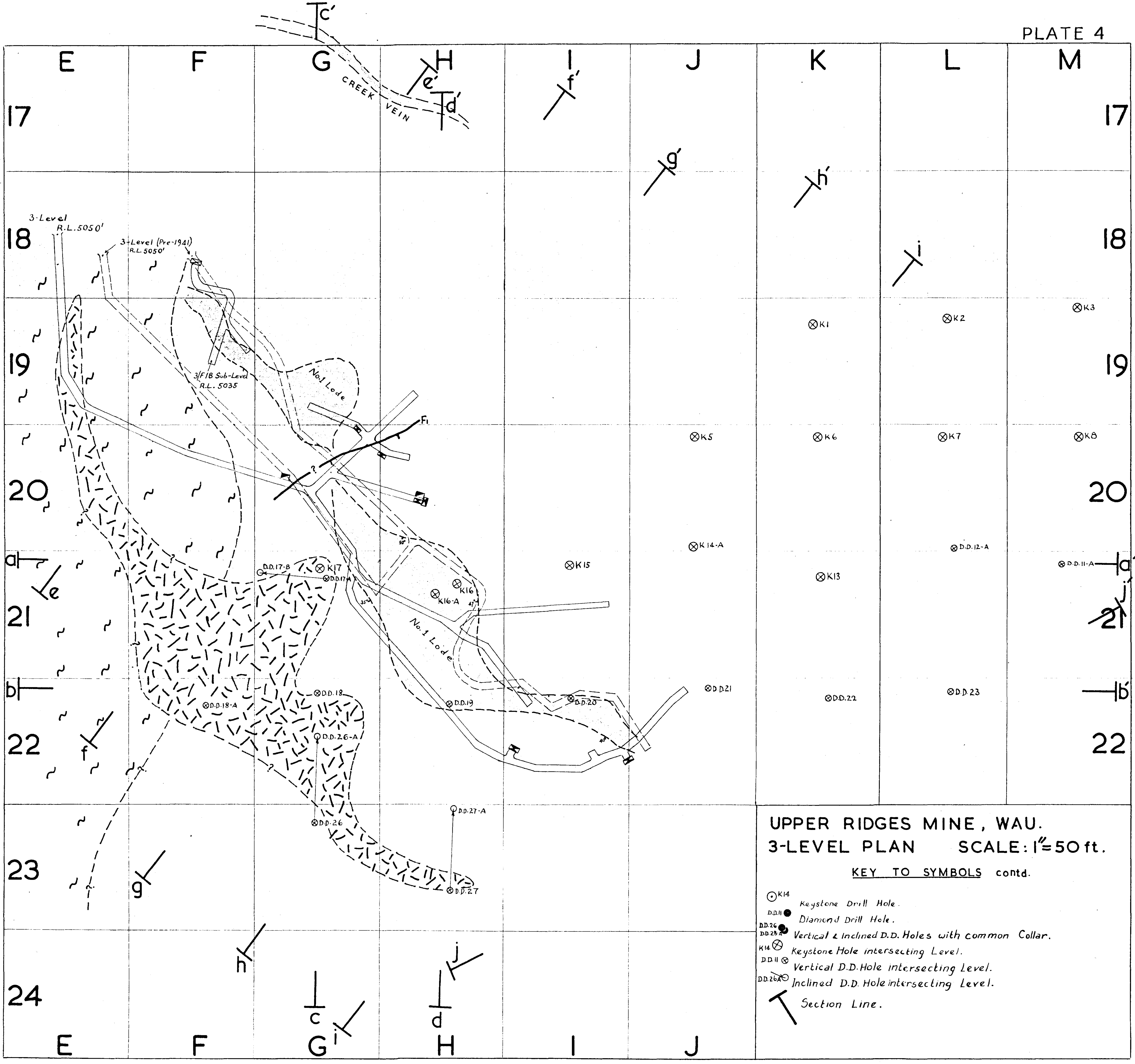

UPPER RIDGES MINE, WAU.
SURFACE & 1-LEVEL PLAN
SCALE: 1" = 50 ft.
KEY TO SYMBOLS
Breccia.
Porphyry.
Kaindi Phyllite.
Lode.
Contact, established.
Contact, inferred.
Fault, established, with Dip.
Fault, hypothetical.
Strike and Dip of Lode
Portal of Adit
Drives & Crosscuts, post-1947.
Drives & Crosscuts pre-1941.
G. Siedner, Bureau of Mineral Resources, Oct. 1957.
continued on SHEET 3.
Original Surface Outcrop
Creek Vein - Orig. Surf. Outcrop
1-Level R.L. 5130'
Portal
T.N.
M.N.
No. 1 Lode 1-Level
1-Level
K1
K2
K3
K4
K5
K6
K7
K8
K9
K10
DD10-C
K11
DD11-A
K12
DD12-A
K13
K14
K14-A
K15
K16
K16-A
K17
DD17-A
DD17-B
DD18
DD18-A
DD19
DD20
DD21
DD22
DD23
DD26
DD26-A
DD27
DD27-A
5000'
5050'
5100'
5150'
5200'
5250'
5300'
5350'

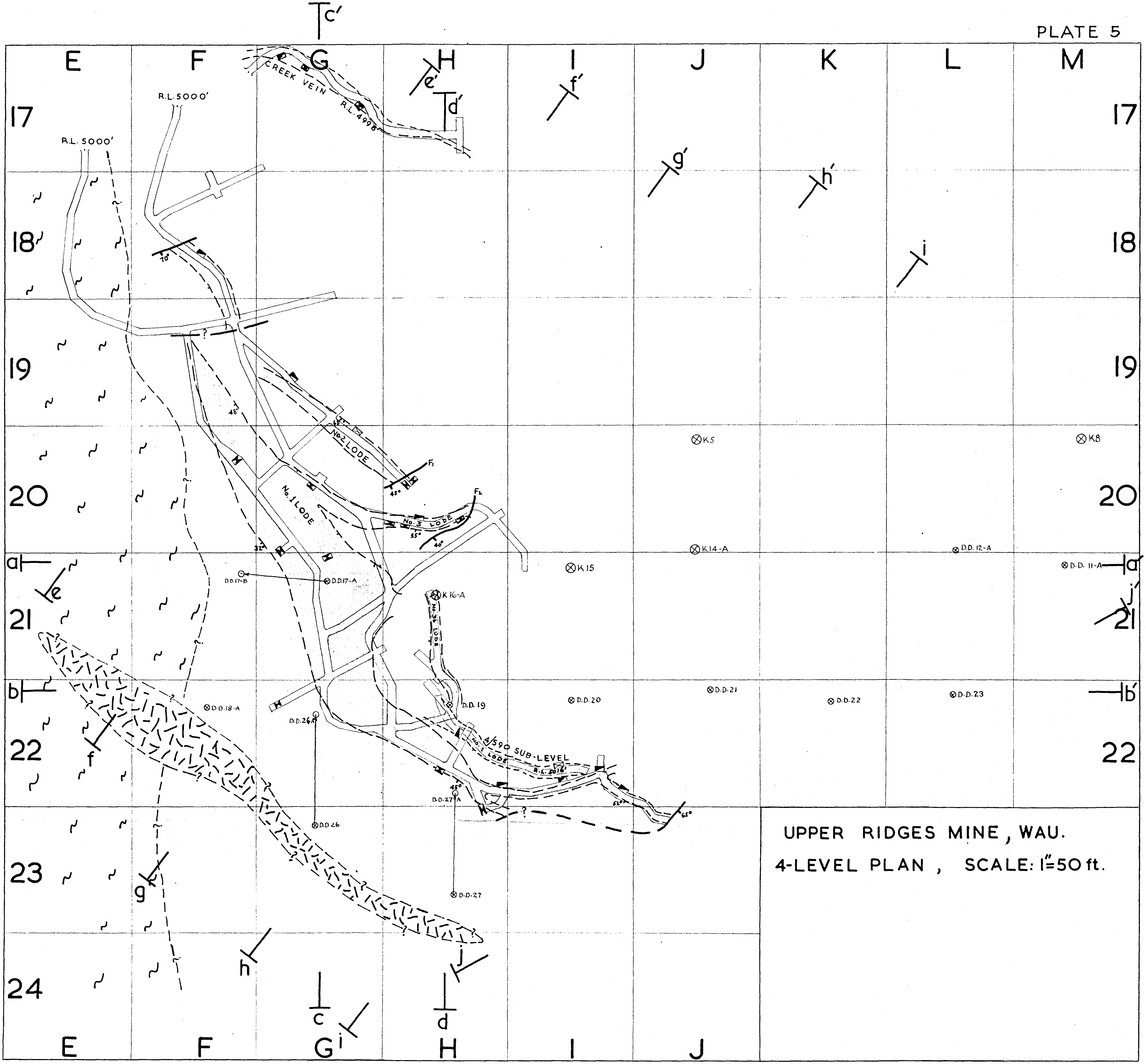
PLATE 3



CREEK VEIN
2-Level
R.L. 5087′
K1
K2
K3
K5
K6
K7
K8
K14-A
K14
K13
K15
K16
K16-A
K17
DDJ7-B
D.D.17-A
D.D.12-A
D.D.11-A
Race Course Lode
No. 1 Lode
D.D.18-A
D.D.18
D.D.19
D.D.20
D.D.21
D.D.22
D.D.23
D.D.26-A
D.D.26
D.D.27-A
D.D.27
UPPER RIDGES MINE , WAU.
2-LEVEL PLAN , SCALE: 1″=50 ft.
KEY TO SYMBOLS contd.
Section of Drive, pre-1941.
Section of Drive, post-1947.
Drive projected onto Section Plane.
Foot of Rise
Head of Winze
Rise or Winze penetrating Level.
Glory Hole
5300′
Surface Contour Line
RL.4850′
Elevation of Underground Workings.
For absolute elevations above sea level, subtract 646.3 ft.
Continued on SHEET 4

PLATE 4

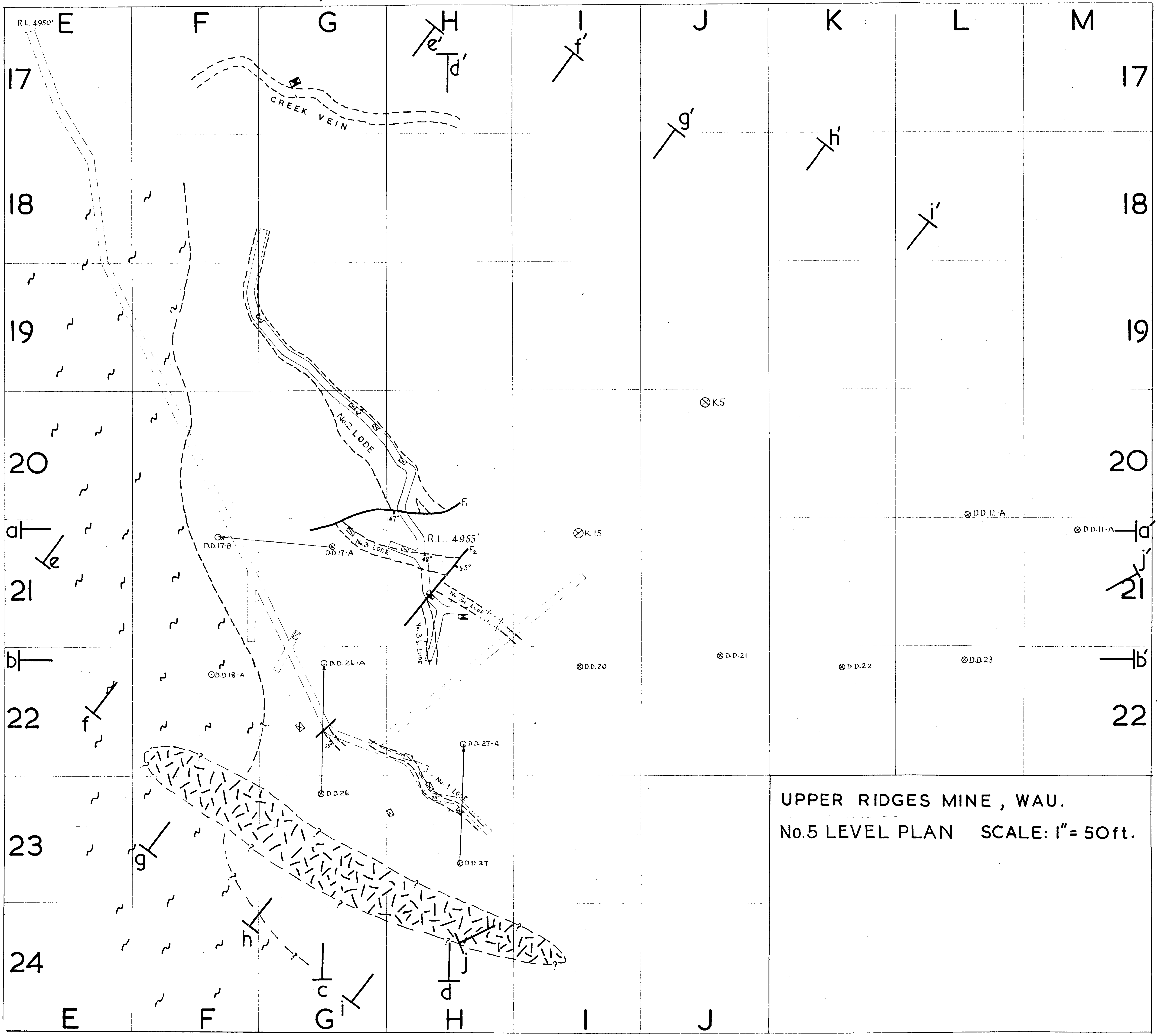

UPPER RIDGES MINE, WAU.
3-LEVEL PLAN SCALE: 1" = 50 ft.
KEY TO SYMBOLS contd.
Keystone Drill Hole.
Diamond Drill Hole.
Vertical & Inclined D.D. Holes with common Collar.
Keystone Hole intersecting Level.
Vertical D.D. Hole intersecting Level.
Inclined D.D. Hole intersecting Level.
Section Line.
3-Level R.L. 5050'
3-Level (Pre-1941) R.L. 5050'
3/F18 Sub-Level R.L. 5035
No. 1 Lode
No. 1 Lode
CREEK VEIN
F1
K1
K2
K3
K5
K6
K7
K8
K13
K14-A
K15
K16
K16-A
K17
D.D. 11-A
D.D. 12-A
D.D. 17-A
D.D. 17-B
D.D. 18
D.D. 18-A
D.D. 19
D.D. 20
D.D. 21
D.D. 22
D.D. 23
D.D. 26
D.D. 26-A
D.D. 27
D.D. 27-A
E F G H I J K L M
17 18 19 20 21 22 23 24



UPPER RIDGES MINE, WAU.

4-LEVEL PLAN, SCALE: 1"=50 ft.

PLATE 6



UPPER RIDGES MINE, WAU.

No.5 LEVEL PLAN SCALE: 1" = 50 ft.

PLATE 7

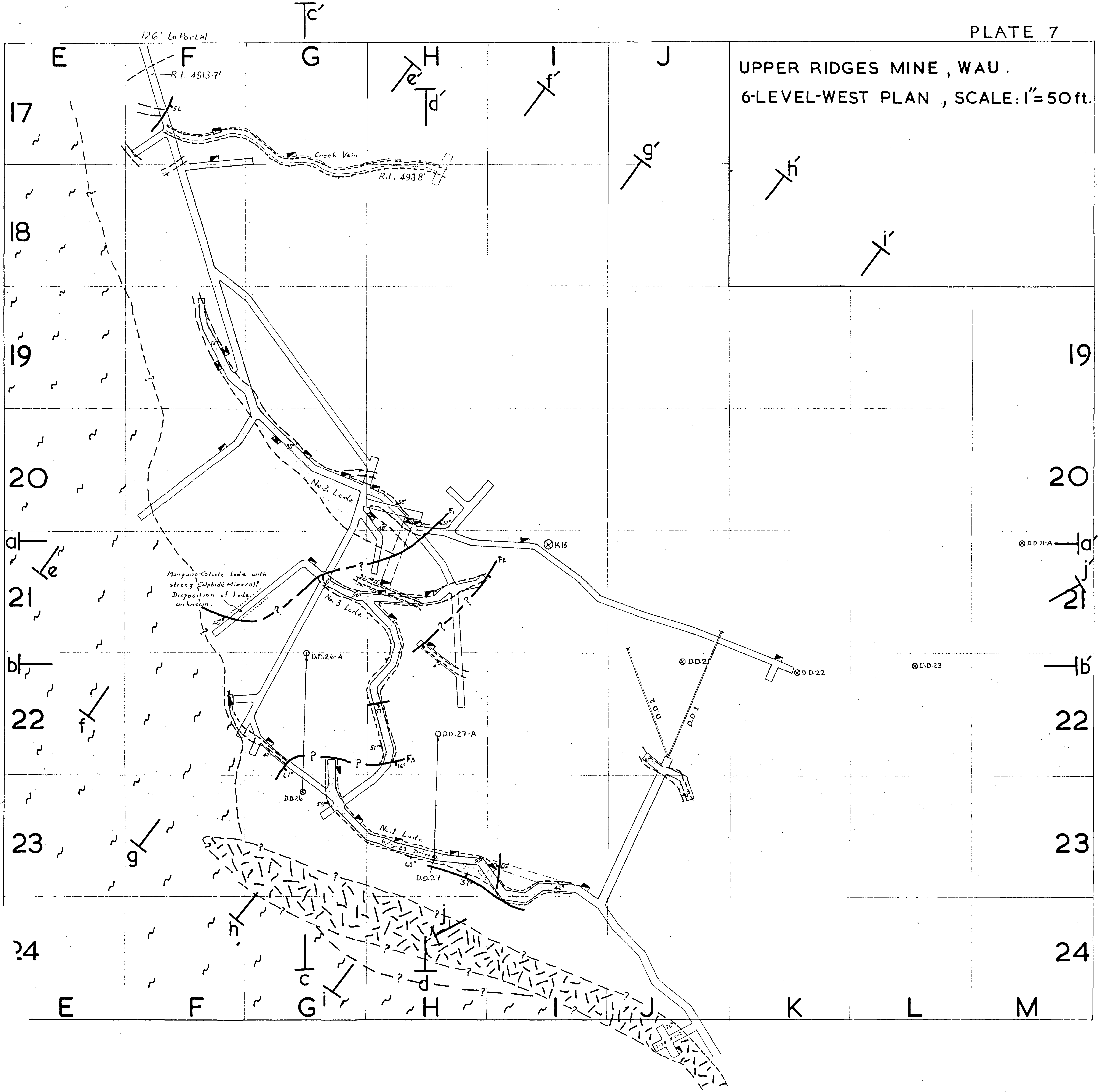
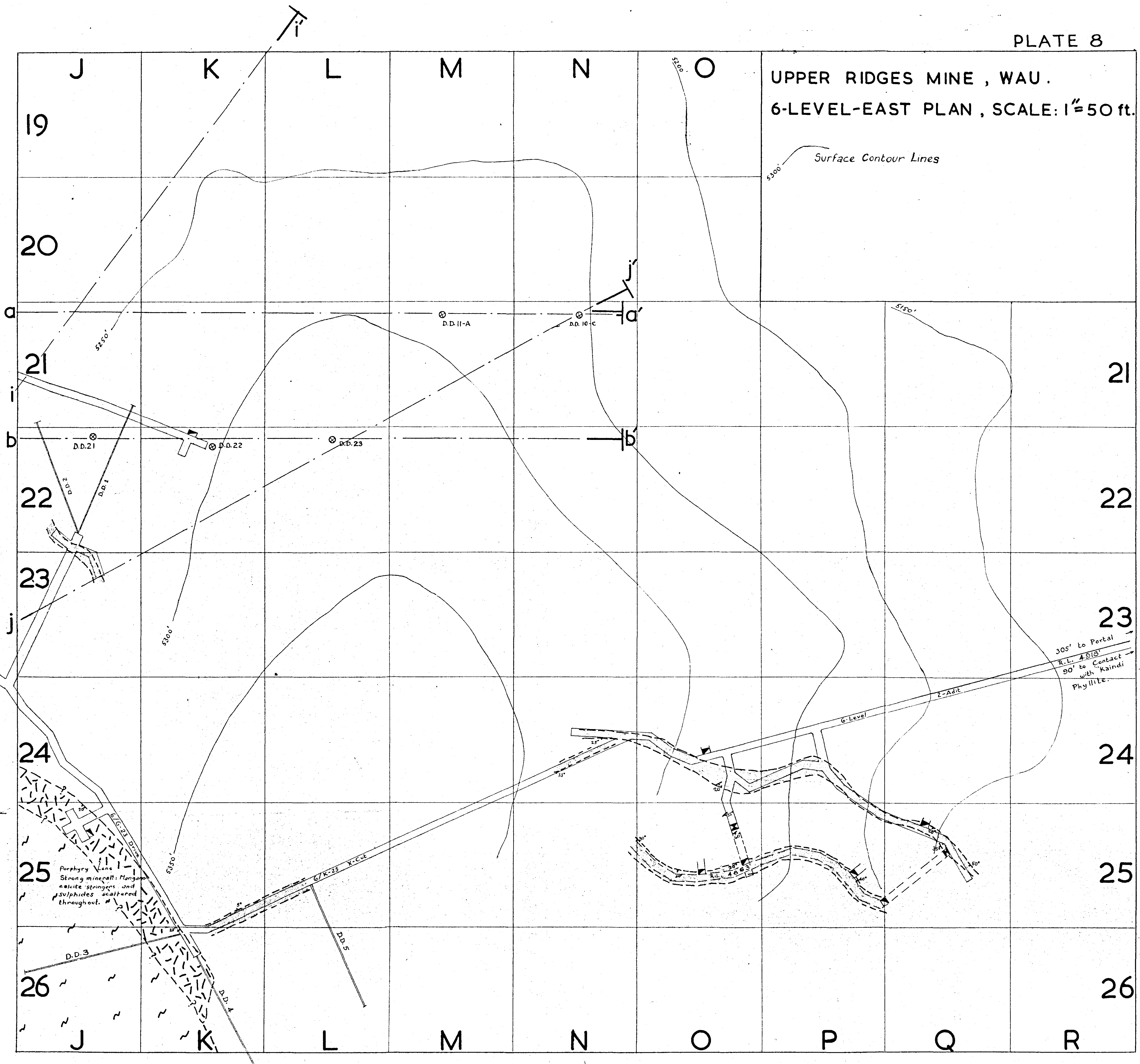
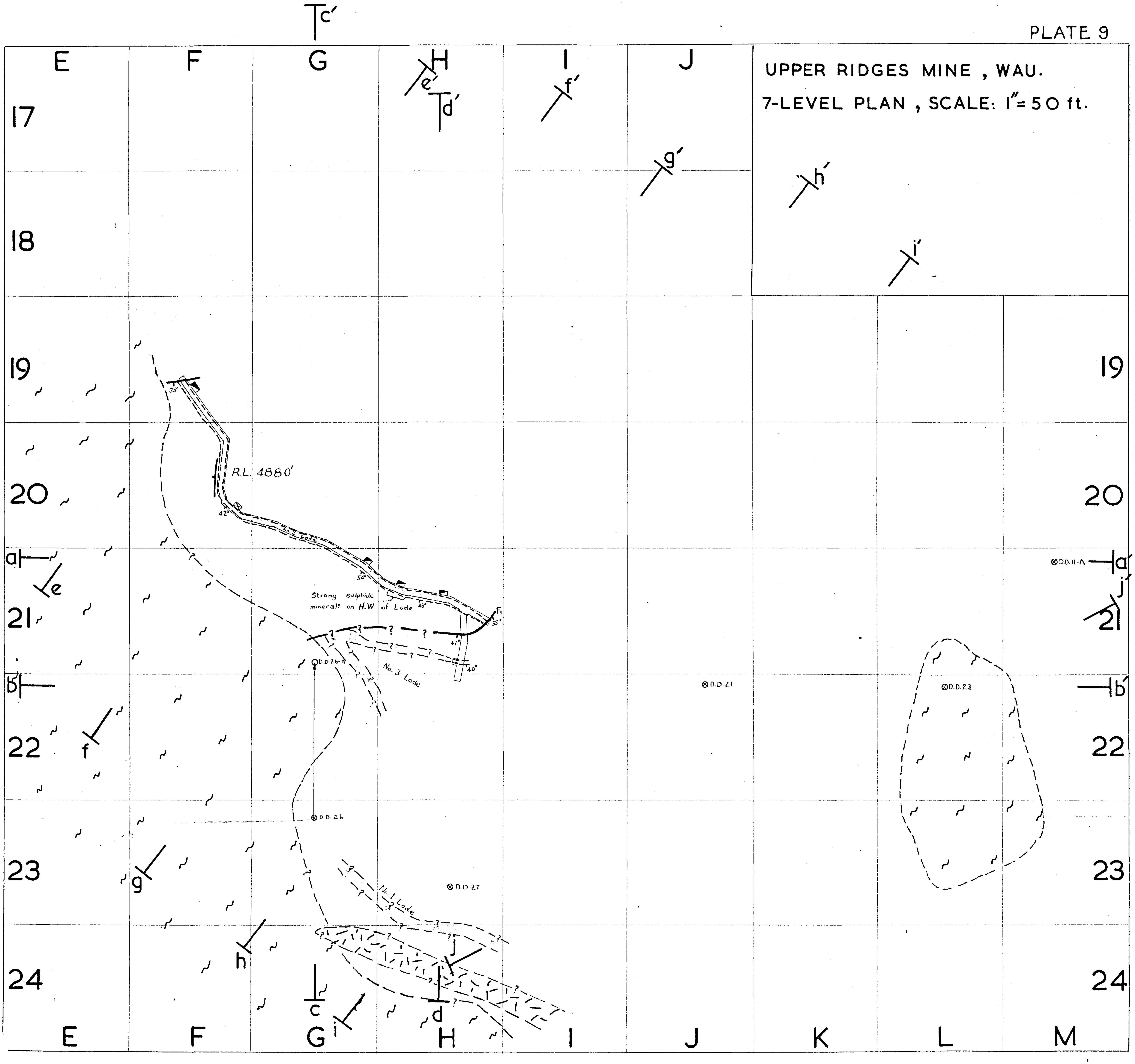
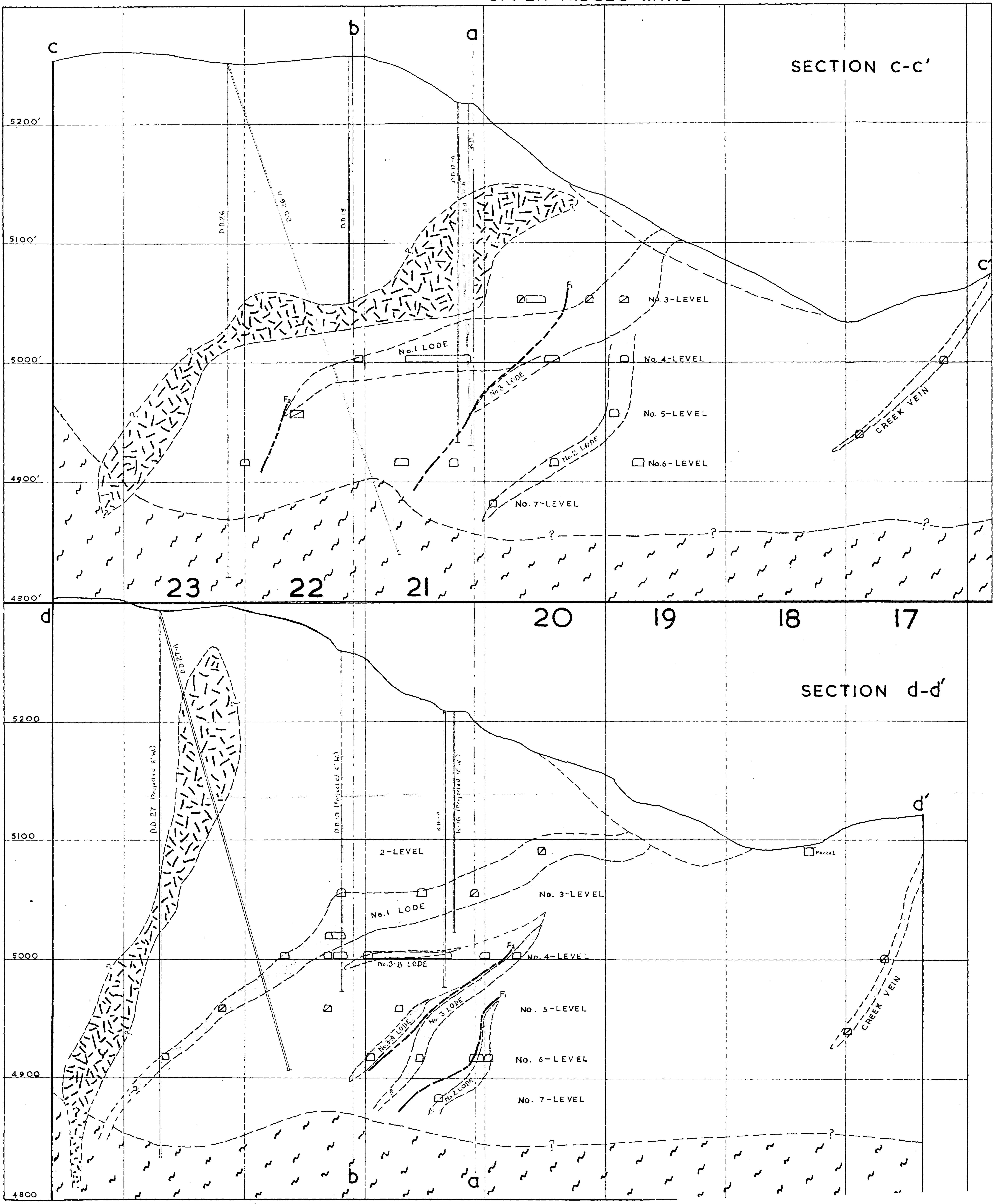

UPPER RIDGES MINE, WAU.
6-LEVEL-WEST PLAN, SCALE: 1"=50 ft.
126' to Portal
R.L. 4913·7'
Creek Vein
R.L. 4938'
No. 2 Lode
No. 3 Lode
No. 1 Lode
6/G-23 Drive
Mangano-Calcite Lode with strong Sulphide Mineral? Disposition of Lode unknown.
F1
F2
F3
K15
D.D. 26-A
D.D. 26
D.D. 27-A
D.D. 27
D.D. 21
D.D. 22
D.D. 23
D.D. 11-A
D.D. 1
D.D. 2
E F G H I J
E F G H I J K L M
17 18 19 20 21 22 23 24
19 20 21 22 23 24

PLATE 8

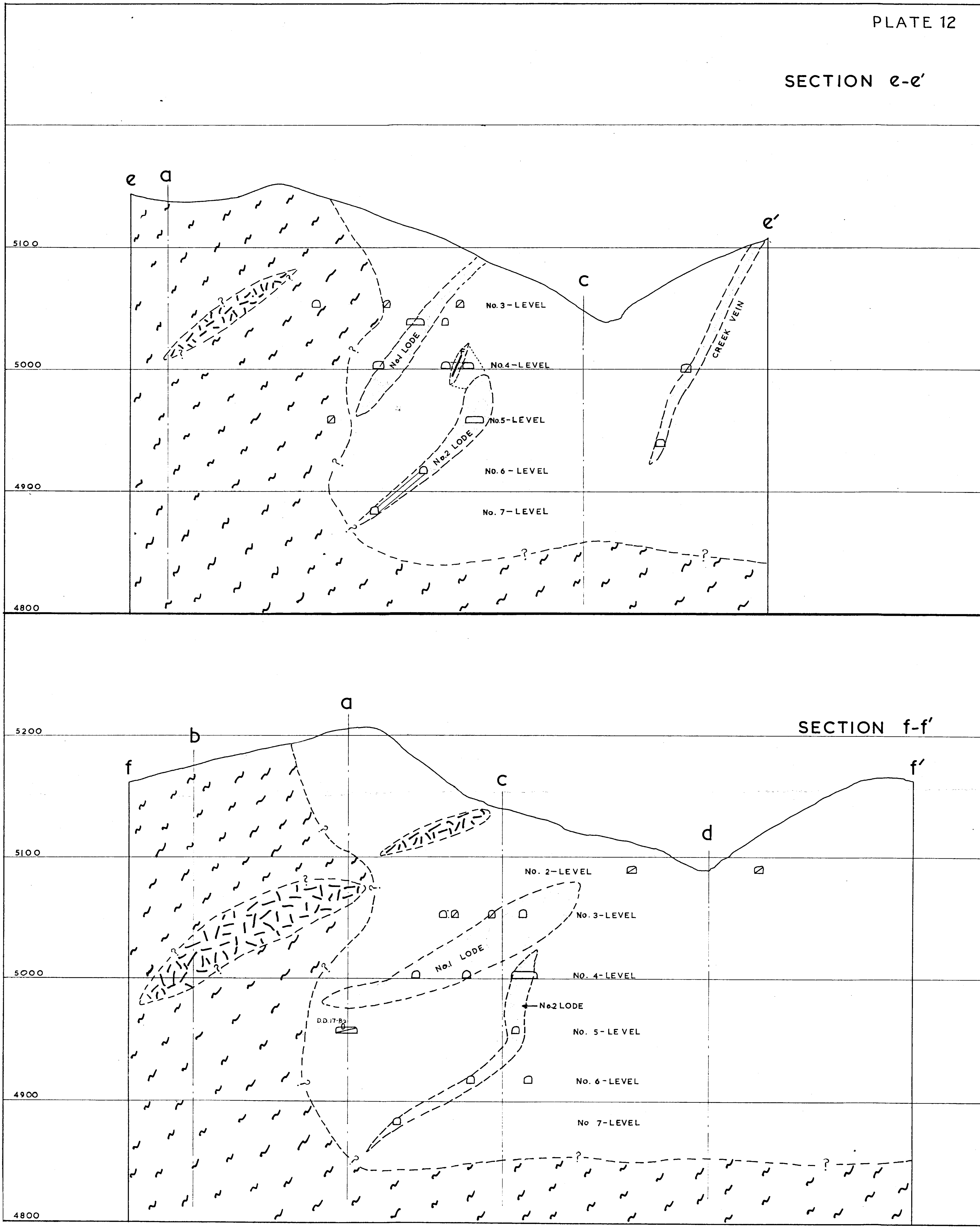

UPPER RIDGES MINE, WAU.
6-LEVEL-EAST PLAN, SCALE: 1" = 50 ft.
Surface Contour Lines
5300'
5250'
5200'
5150'
5350'
J K L M N O P Q R
19 20 21 22 23 24 25 26
a a'
b b'
i i'
j j'
D.D.11-A
D.D.10-C
D.D.21
D.D.22
D.D.23
D.D.1
D.D.2
D.D.3
D.D.4
D.D.5
305' to Portal
R.L. 4918'
90' to Contact with Kaindi Phyllite.
2-Adit
6-Level
6/K-25 X-Cut
6/G.23 Drive
Porphyry Lens
Strong mineral: Mangano calcite stringers and sulphides scattered throughout.


UPPER RIDGES MINE, WAU.
7-LEVEL PLAN, SCALE: 1" = 50 ft.
E
F
G
H
I
J
K
L
M
17
18
19
20
21
22
23
24
R.L. 4880'
No. 2 Lode
Strong sulphide mineral^n on H.W. of Lode
No. 3 Lode
No. 1 Lode
D.D. 26-A
D.D. 26
D.D. 27
D.D. 21
D.D. 23
D.D. 11-A
35°
42°
54°
43°
47°
40°

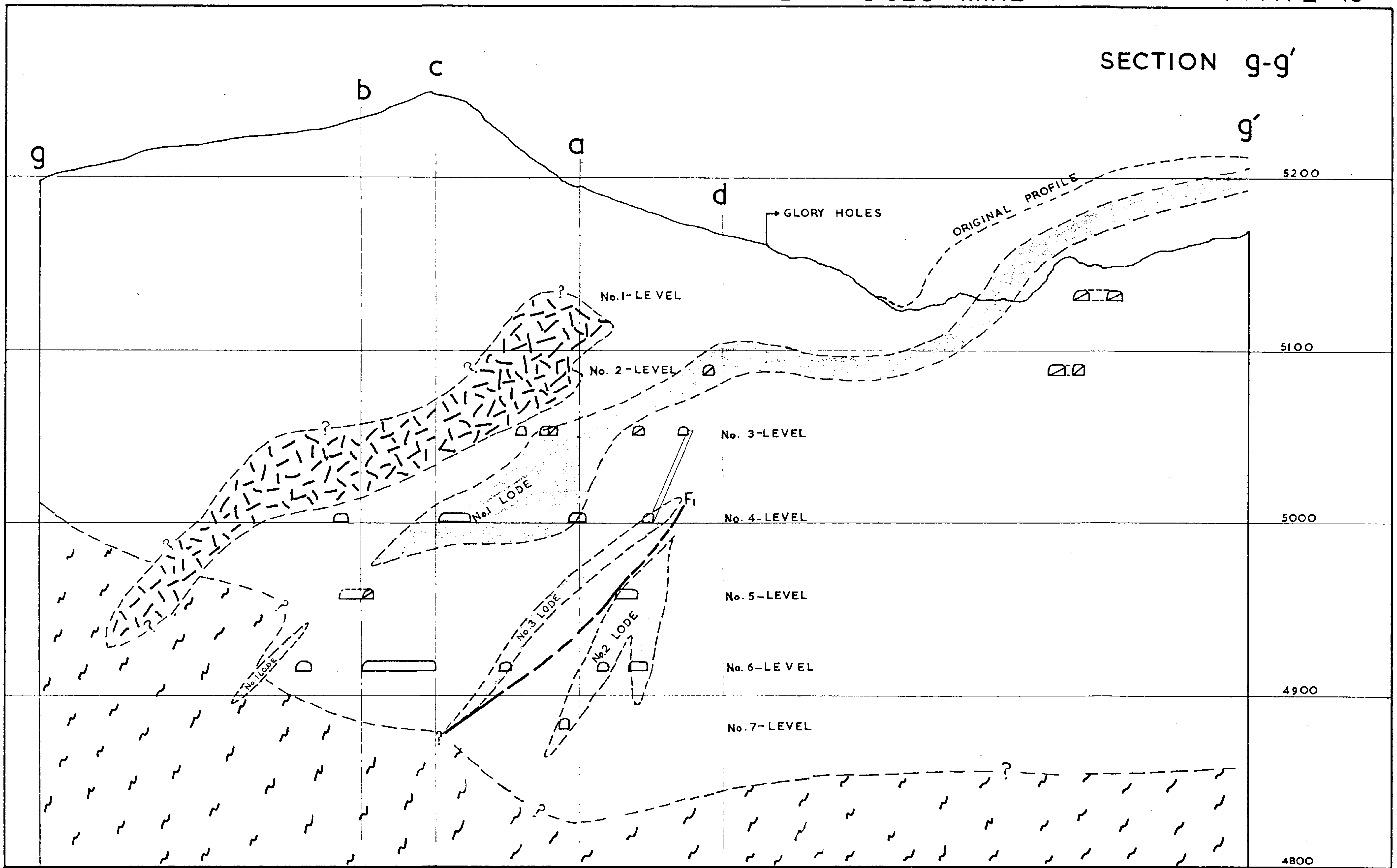

E F G H I J K L M N
SECTION a-a'
5300'
5200'
5100'
5000'
4900'
4800'
c d
a a'
D.D. 17-B
D.D. 17-A
K 17 (Projected 15' N)
K 16-A (Projected 25' N)
K 16 (Projected 15' N)
K 15
K 14
K 14-A (Projected 12' S)
K 13 (Projected 12' N)
D.D. 12-A (Projected 12' S)
K 12
D.D. 11-A
K 11
K 10
K 10-B
K 10-A
D.D. 10-C
No. 1-LEVEL
No. 2-LEVEL
No. 3-LEVEL
No. 4-LEVEL
No. 5-LEVEL
No. 6-LEVEL
No. 7-LEVEL
RACE COURSE LODE
No. 1 LODE
No. 3 LODE
No. 2 LODE
LOWER LODE
DRILL EVIDENCE ONLY
F1
F2
SECTION b-b'
5300'
5200'
5100'
5000'
4900'
4800'
b b'
D.D. 18-A (Projected 13' N)
D.D. 18
D.D. 19 (Projected 12' N)
D.D. 20 (Projected 7' N)
D.D. 21
D.D. 22 (Projected 7' N)
D.D. 23
No. 2-LEVEL
No. 3-LEVEL
No. 4-LEVEL
No. 5-LEVEL
No. 6-LEVEL
No. 7-LEVEL
No. 1 LODE
No. 3 LODE
No. 3-A LODE
LOWER LODE
D.D. 26-A
D.D. 2
D.D. 1
c d

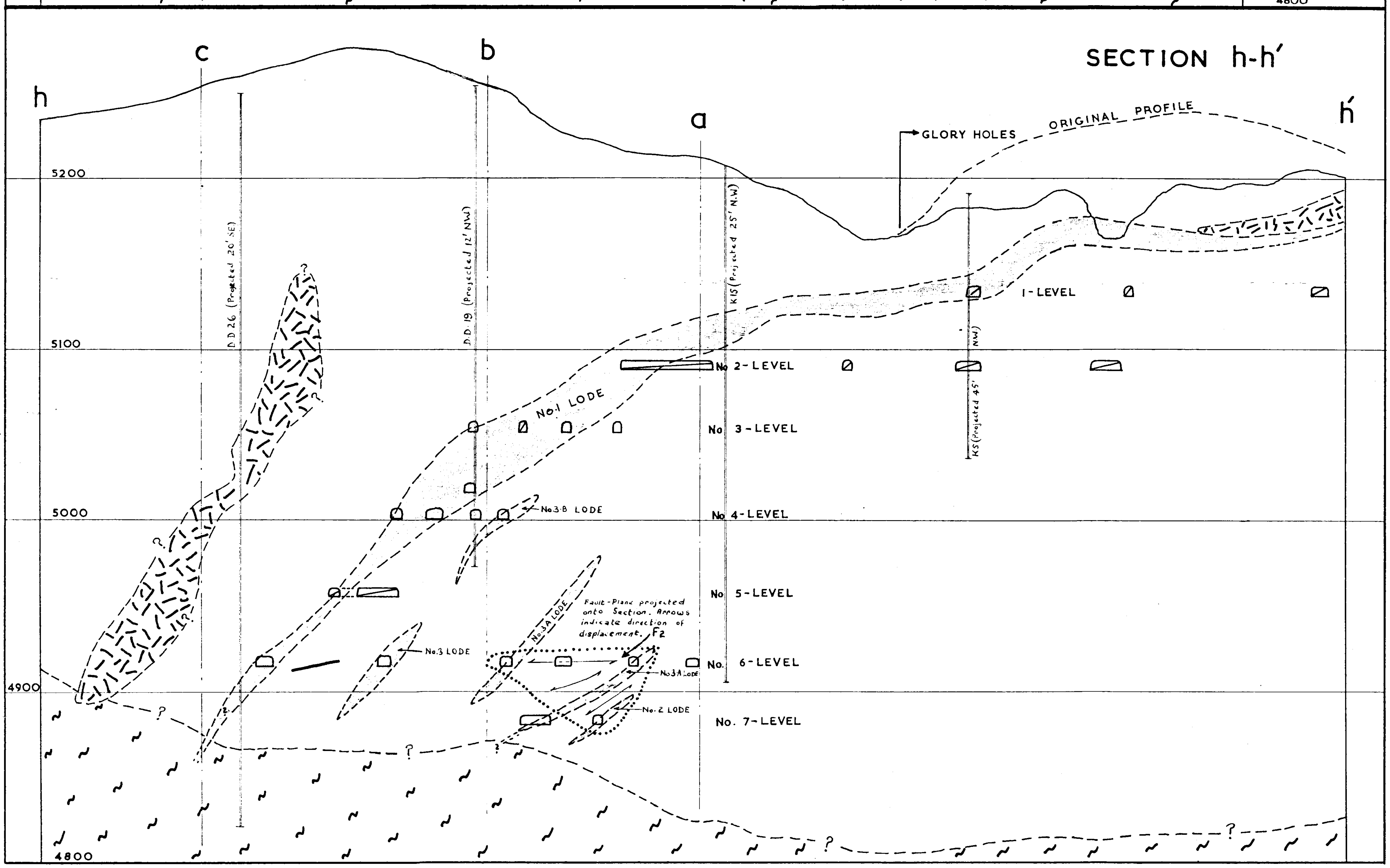

SECTION c-c'
c
c'
b
a
5200'
5100'
5000'
4900'
4800'
D.D.26
D.D.26-A
D.D.18
D.D.11-A
K.17
No. 1 LODE
No. 3 LODE
No. 2 LODE
No. 3-LEVEL
No. 4-LEVEL
No. 5-LEVEL
No. 6-LEVEL
No. 7-LEVEL
CREEK VEIN
F1
F2
23
22
21
20
19
18
17
SECTION d-d'
d
d'
5200
5100
5000
4900
4800
D.D.27 (Projected 8' W.)
D.D.27-A
D.D.19 (Projected 6' W.)
K.16-A
K.16 (Projected 12' W.)
2-LEVEL
No. 3-LEVEL
No. 1 LODE
No. 3-B LODE
No. 4-LEVEL
No. 5-LEVEL
No. 3A LODE
No. 3 LODE
No. 2 LODE
No. 6-LEVEL
No. 7-LEVEL
Portal
CREEK VEIN
F1
F2
b
a

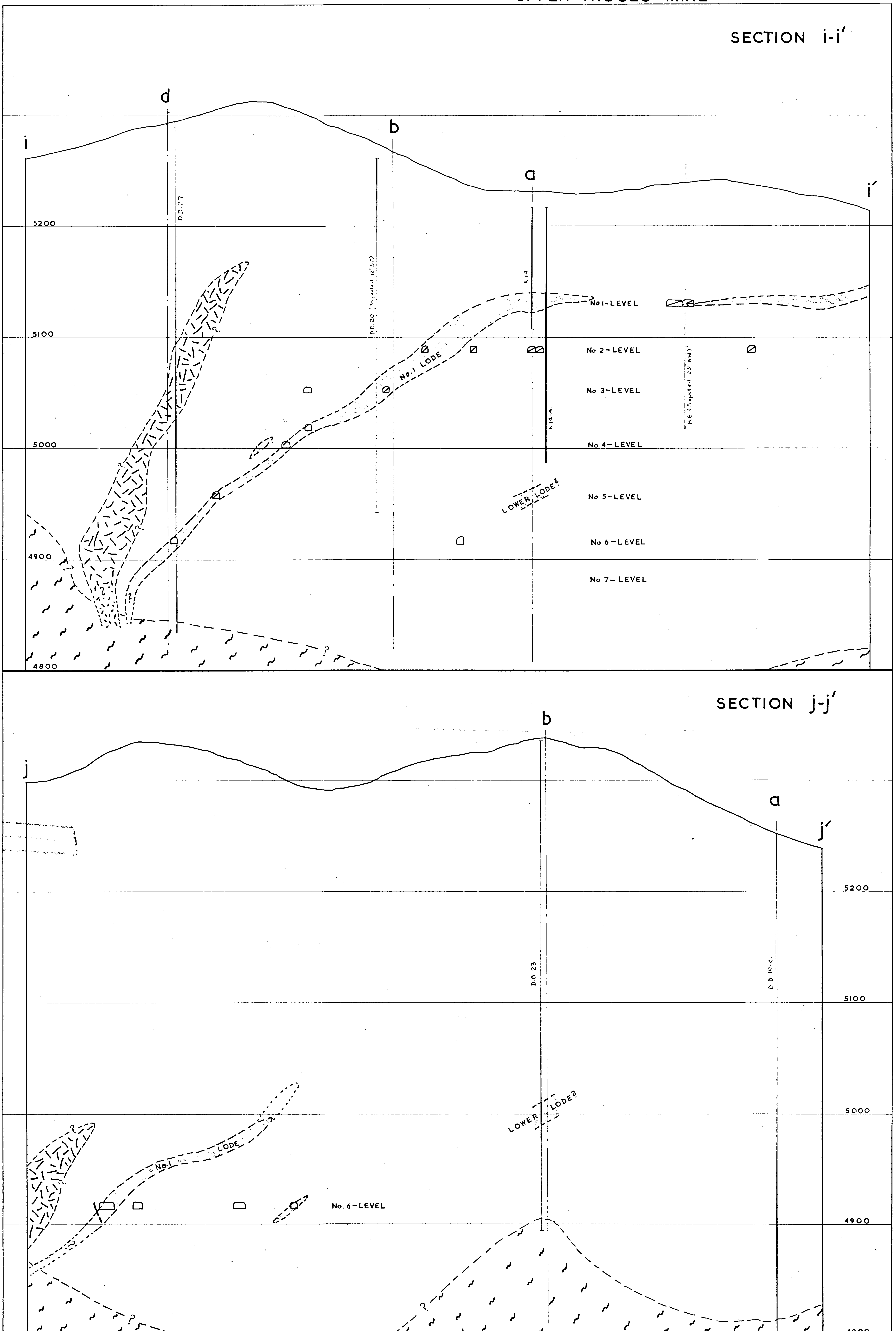
UPPER RIDGES MINE



UPPER RIDGES MINE PLATE 13







SECTION i-i'
d
b
a
i
i'
5200
5100
5000
4900
4800
D.D. 27
D.D. 20 (Projected 12' S.E.)
K 14
K 14-A
K 6 (Projected 23' N.W.)
No 1-LEVEL
No 2-LEVEL
No 3-LEVEL
No 4-LEVEL
No 5-LEVEL
No 6-LEVEL
No 7-LEVEL
No. 1 LODE
LOWER LODE?
SECTION j-j'
b
a
j
j'
D.D 23
D.D 10-C
LOWER LODE?
No 1 LODE
No. 6-LEVEL