

THE MINERALOGY OF POLLUCITE AND BERYL FROM THE TANCO
PEGMATITE AT BERNIC LAKE, MANITOBA

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of the Requirements for the Degree

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Frederick Simpson

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ABSTRACT

Pollucite and beryl are two of the economically and petrologically important minerals in the Tanco pegmatite, Bernic Lake, Manitoba.

One hundred and thirty six pollucite samples were collected from the eastern pollucite body and the isolated pods of pollucite in the western portion of the pegmatite. The refractive index (n) was measured on all samples. Samples were selected for partial or full chemical analysis on the basis of n and location. Three samples were chemically analysed in full and their density and unit cell dimensions were determined. The pollucite from the Tanco pegmatite was found to fit the previously established positive correlations between n , density and wt.% Cs_2O . It was noted that the samples from the western isolated pods of pollucite had, in general, a higher n than those from the eastern pollucite body indicating they are richer in Cs_2O . Alteration products of pollucite occur as thin veins and spherical masses, and consist of spodumene, mica and clay minerals.

One hundred and thirteen beryl samples were collected from the wall zone, lower intermediate zone, central intermediate zone and the lepidolite zone of the pegmatite. The refractive index (ω) of each sample was measured, and on the basis of ω and location samples were selected for full or partial chemical analysis. Densities and unit cell dimensions were measured for the three samples which were chemically analysed in full. Beryls from the Tanco pegmatite appear to fit the established positive correlations between density and $\Sigma \text{R}_2\text{O}$. Zoning in the beryl crystals was checked by systematically measuring ω from the center to the outermost edge of the crystal.

In many cases the crystals were found to be intensely zoned. Zoning of beryl with respect to ΣR_2O and ω was also noted in the pegmatite and it appears, in general, that the ΣR_2O and ω increase towards the center of the pegmatite.

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Specimen collecting within the Tanco mine was made possible through the assistance of Mr. C. T. Williams, Mine Manager, and Mr. R. A. Crouse, resident geologist of the Tantalum Mining Corporation of Canada.

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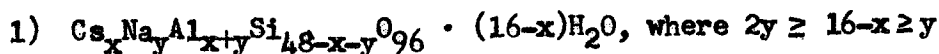
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CHAPTER I INTRODUCTION

(a) General Introduction

This study deals with the mineralogical description of pollucite (ideally $\text{CsAlSi}_2\text{O}_6$ for pure synthetic pollucite) and beryl (ideally $\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$) from the Tanco pegmatite, Bernic Lake, south-eastern Manitoba.

A solid solution series exists between analcime ($\text{NaAlSi}_2\text{O}_6 \cdot \text{H}_2\text{O}$) and pollucite (Cs end member). The general formula for pollucite as stated by Beger (1969) is



or



The limitations of $2y \geq 16-x \geq y$ for formula 1 may be complemented by the empirical restriction of $x+y=90$ (Černý, 1974). Table I states some of the physical and crystallographic characteristics of pollucite. According to Beger (1969),

"Pollucite has the analcime framework with the cesium atoms occupying the large voids in the framework, as initially suggested by Naray-Szabo. The water molecules occupy the large voids of this same set which are not occupied by the cesium atoms. The sodium atoms are located in equipoint 24c, at $\frac{1}{4}, 1/8, 0$, in the positions between the water molecules. The water molecules and the sodium atoms occupy the same positions as they do in analcime, but they occur only in randomly distributed clusters of atoms whose outer members are restricted to water molecules."

Figure 1 shows the aluminosilicate framework of pollucite projected on (001). The aluminosilicate framework is composed of 4-, 6- and 8-membered loops of tetrahedra which are normal to $\bar{4}$, $\bar{3}$ and the two-fold rotation axis, respectively. Figures 2 and 3 show the location

TABLE I Physical and Crystallographic Characteristics of Pollucite
(after Deer et al., 1962).

Cubic

$$n = 1.5172 - 1.5238$$

$$D \ 2.8914 - 2.9093$$

$$H \ 5\frac{1}{2}$$

Cleavage: $\{001\}$ very poor.

Twinning: $\{001\}$, $\{110\}$ lamellar.

Colour: White, pink, gray or colourless.

Unit cell: $a = 13.7\text{\AA}$

$Z = 16$. Space group $Ia\bar{3}d$.

TABLE II Physical and Crystallographic Characteristics of Beryl
(after Deer et al., 1962)

Hexagonal (-)

$$\xi = 1.565 - 1.590$$

$$\omega = 1.567 - 1.598$$

$$\gamma = 0.004 - 0.008$$

Dispersion: Weak. $D \ 2.66 - 2.83$ $H \ 7\frac{1}{2}-8$

Cleavage: $\{0001\}$ imperfect.

Twinning: Rare; on $\{31\bar{4}1\}$, $\{11\bar{2}0\}$ and $\{40\bar{4}1\}$ (?).

Colour: Colourless, white, bluish green greenish yellow, yellow, blue, rose; usually colourless in thin section.

Pleochroism: In thick sections, weakly pleochroic: e.g. emerald may show ω yellowish green, ξ sea green.

Unit cell: $a \ 9.188\text{\AA}$, $c \ 9 \ 189\text{\AA}$, $c/a \ 1.0001\text{\AA}$

$Z = 2$. Space group $C6/mcc$.

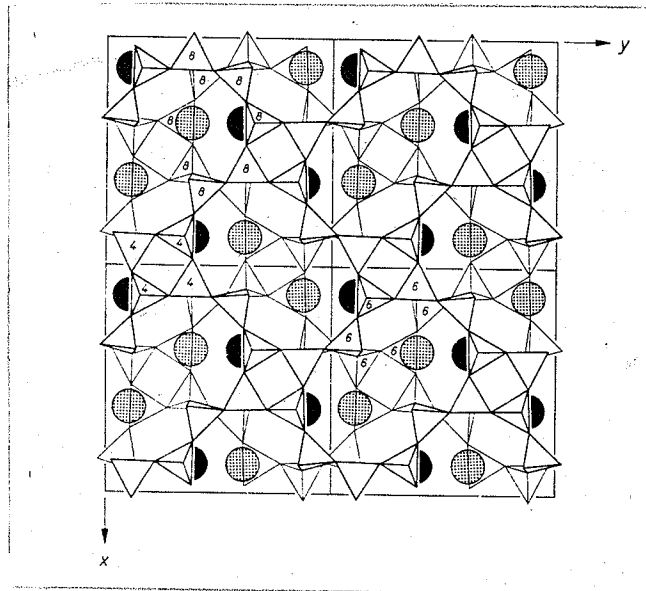


Figure 1. Projection on (001) of the aluminosilicate framework and Cs and H₂O positions in pollucite. The lower halves of four cells are shown. Cs and H₂O are represented by solid circles at 1/8c and stippled circles at 3/8c (Beger, 1969).

of the Cs and H_2O , and Na atoms in pollucite respectively. In pollucite the 16 large voids filled by Cs and H_2O are each framed by two 6-membered loops of tetrahedra centred on the three-fold axis and by three 8-membered loops related by the three-fold rotation (Beger, 1969).

Pollucite is of particular interest as it is one of the major known economic sources of cesium. With recent developments in the use of Cs as an energy source (magnetohydrodynamics), cesium has become a very important element.

The pollucite zone of the Tanco pegmatite represents the world's largest known pollucite deposit.

The general formula of beryl may be stated as $R_n^{+1}Be_{3-1/2n}Al_2(Si_6O_{18}) \cdot pH_2O$, where $n = 0-1$ and $p = 0.2-0.8$ (Ginzburg in Deer et al., 1962). Table II states some of the physical and crystallographic characteristics of beryl. The beryl structure is made up of hexagonal rings of 6 SiO_4 tetrahedra (Figure 4). These rings are stacked one above another having their centers on the hexad axis. Within the rings two of the oxygen atoms in each SiO_4 group are shared by SiO_4 on each side thus giving the metasilicate ratio (Si:O=1:3). Mirror planes in the unit cell are at 0, $c/2$, c and the hexagonal rings lie with the silicon and shared oxygen atoms on these planes; between them lie the Al and Be atoms, each Al coordinated with an octahedral group of 6 oxygen atoms and each Be atom surrounded by 4 oxygen atoms in a distorted tetrahedron. Cations such as Na^{+1} , Cs^{+1} , Li^{+1} , K^{+1} , Rb^{+1} , Ca^{+2} and H_2O molecules may substitute into the hollow channels. Vorma et al. (1965) showed that the cations and H_2O molecules in the channels lie in the plane of the Al and Be atoms and that Li may substitute for Be in the tetrahedral sites. Substitutions of alkalis, especially the large Cs cation into the channel causes an increase in

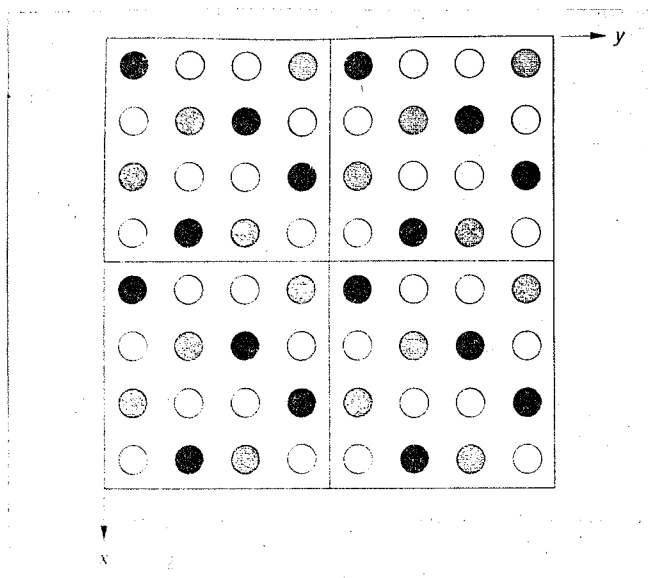


Figure 2. Projection on (001) of the Cs atoms and H_2O molecules of pollucite showing four cells. Solid black circles at $1/8c$, heavy stippled circles at $3/8c$, light stippled circles at $5/8c$ and open circles at $7/8c$ (Beger, 1969).

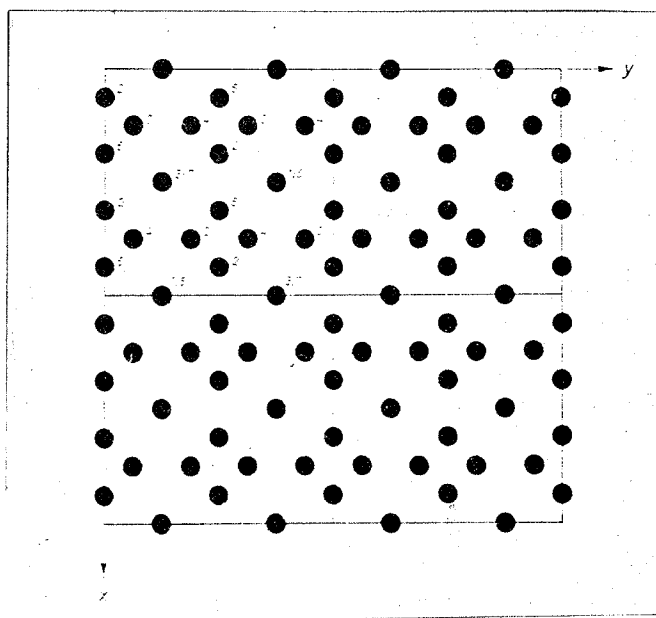


Figure 3. Projection on (001) of the Na atoms in pollucite. Four cells are shown. Z coordinates are in eighths (e.g. 5 signifies $5/8c$). (Beger, 1969).

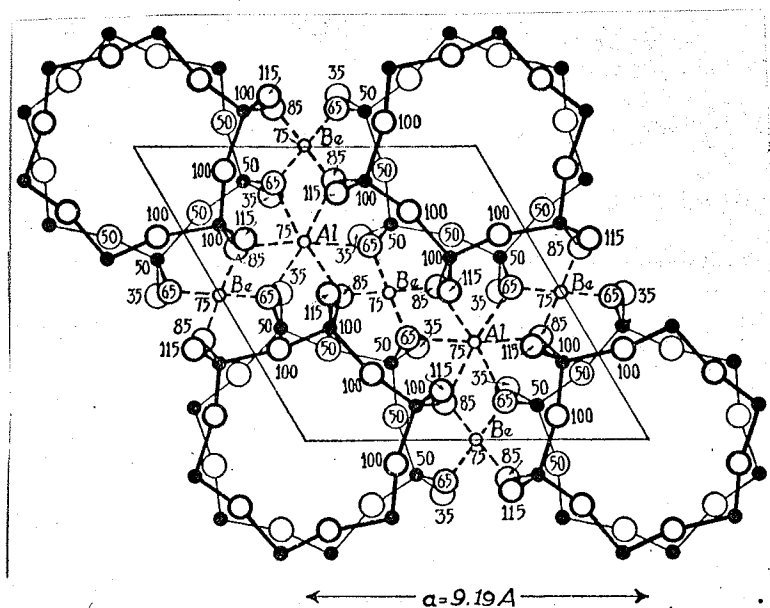


Figure 4. The structure of beryl ($\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$). Reflection planes are at heights 0, 50, 100. (Bragg et al., 1965).

the c dimension, the a dimension not being affected. Bakakin et al. (1969) confirmed that Li may substitute directly for Be in the tetrahedral sites. This isomorphous substitution of Li for Be in the tetrahedral site increases parameter c, (Bakakin et al., 1970). Beryls showing substitutions of Li for Be are called t-beryls (i.e. beryls with tetrahedral substitutions). Bakakin et al. (1970) also note the existence of o-beryls (i.e. beryls with octahedral substitutions) in which Al is partially replaced by Fe, Mg, Mn, Sc, etc.. Such substitutions for Al in o-beryls increases parameter a.

The beryl from the Tanco pegmatite is of interest since little mineralogical work has been done on it and since the beryl may be extracted economically as a future byproduct of the present tantalum oxide concentration.

(b) History

The Tanco (Bernic Lake) pegmatite is located on the north shore of the west part of Bernic Lake, about 110 miles northeast of Winnipeg (Figure 5). In 1929, claims were staked on the northwest shore of Bernic Lake, by Jack Nutt Tin Mines Limited, on the basis of small surface outcroppings containing cassiterite. The Tanco pegmatite, being unexposed, was discovered accidentally during drilling by Consolidated Tin Mines Co. Ltd. in 1929. The property was later taken over, in 1954, by Montgary Explorations Limited, now Chemalloy Minerals Limited. Chemalloy stockpiled various minerals and marketed minor amounts of quartz. The mine was abandoned in 1962 and allowed to flood. In 1967 Tantalum Mining Corporation of Canada Ltd. (Tanco) reopened the mine and began mining and concentrating tantalum oxide minerals. At present the Tantalum Mining Corporation is concentrating 550 tons of tantalum oxide minerals

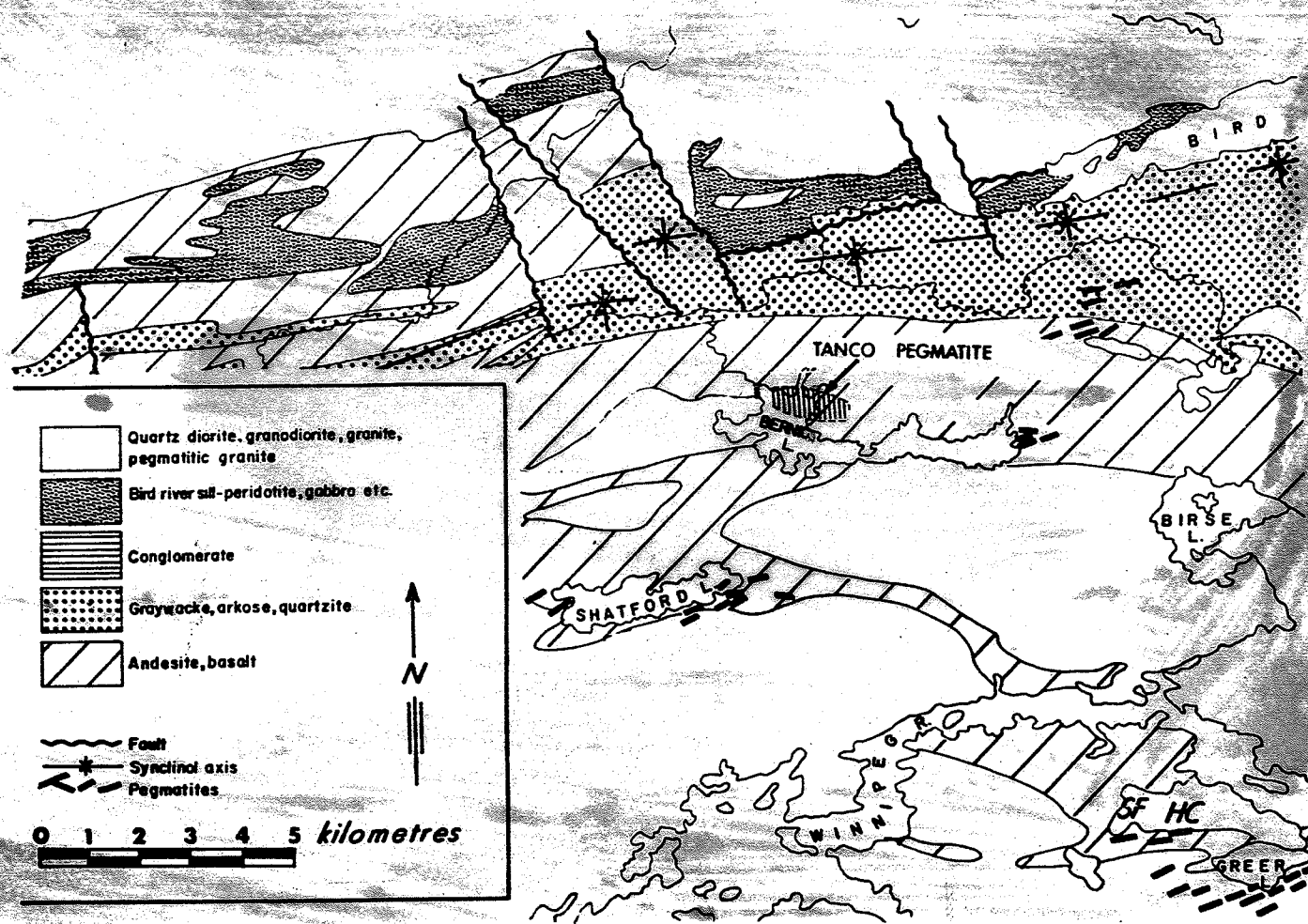


Figure 5. Geological map of Bird Lake - Bernic Lake - Winnipeg River Area (after Davies et al., 1962).

a day, has mined and is considering the economic aspects of concentrating beryl, spodumene and amblygonite as byproducts. Present studies are being done on the possibility of the economic recovery of gallium.

(c) General Geology

The Tanco pegmatite lies near the southwestern edge of the Superior Province in Manitoba. The broader neighbourhood of the pegmatite is underlain by an east-west trending belt of metasediments and metavolcanics of the Rice Lake Group (Davies, 1955; Davies et al., 1962). According to Penner and Clark (1971), the Tanco pegmatite is approximately 2.6 by. old. The pegmatite bodies north and south of the belt (Figure 5) are also approximately 2.6 by. old. The Tanco pegmatite fills a subhorizontal fracture which crosscuts the schistosity of the amphibolite country rocks. The flat-lying tabular pegmatite ranges in thickness from 60 to 280 feet, has an east-west strike, and a low angle of dip to the north. The total dimensions of the pegmatite have not yet been determined, but it is at least 1300 feet wide and 4000 feet long.

The pegmatite is composed of nine zones (Crouse and Černý, 1972) (Figure 6b):

Border zone (1) - is composed mainly of fine-grained albite and quartz with abundant tourmaline. This zone forms an outer shell a few inches thick around the inner zones.

Wall zone (2) - is an albite, quartz, microcline-perthite zone with abundant tourmaline. The zone is shell-like in shape and contains large (up to one foot across) microcline-perthite crystals in fine-grained albite and quartz.

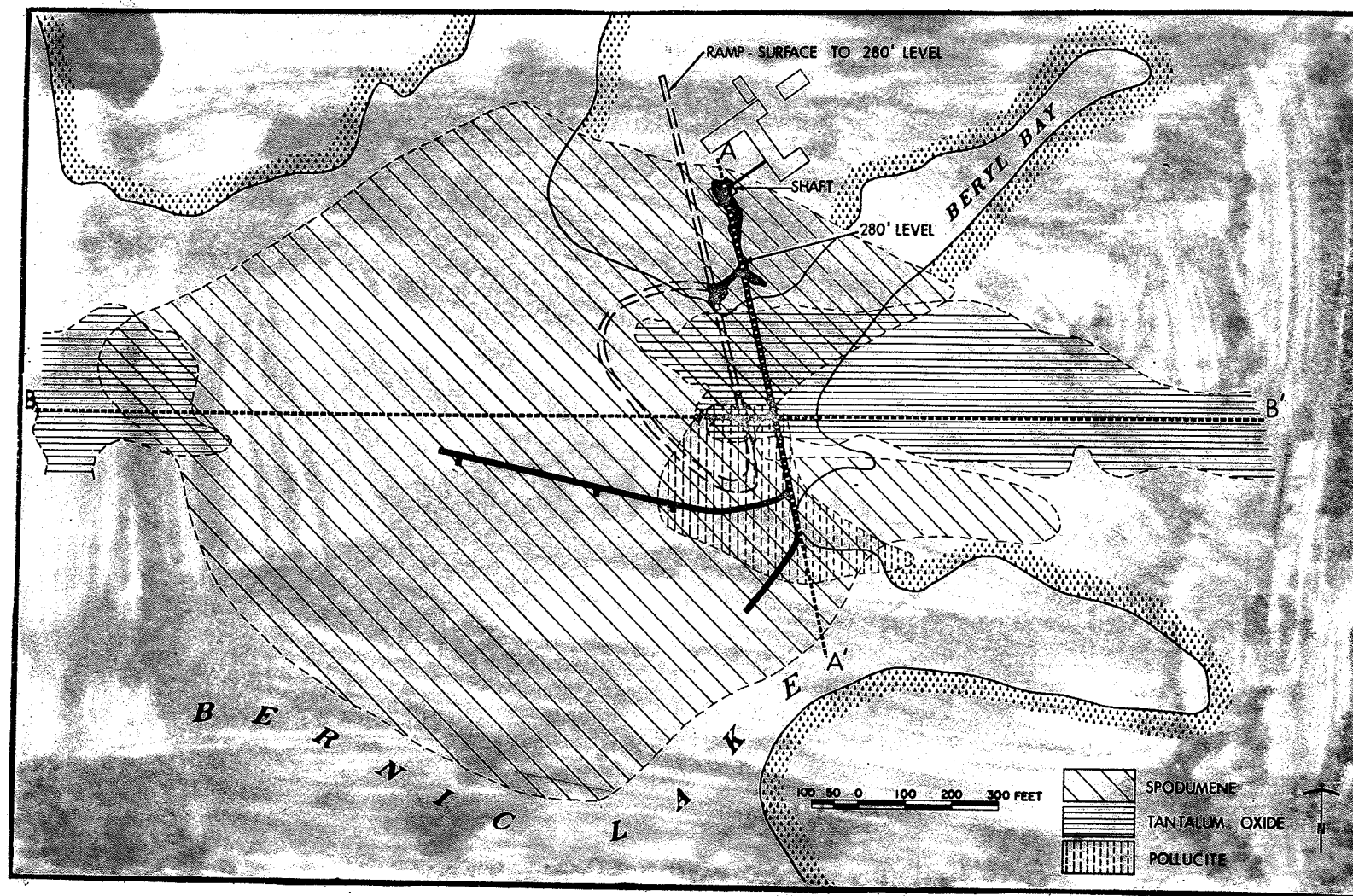


Figure 6a. Plan of the Tanco mine showing the position of cross-section A-A' (after Crouse and Černý, 1972).

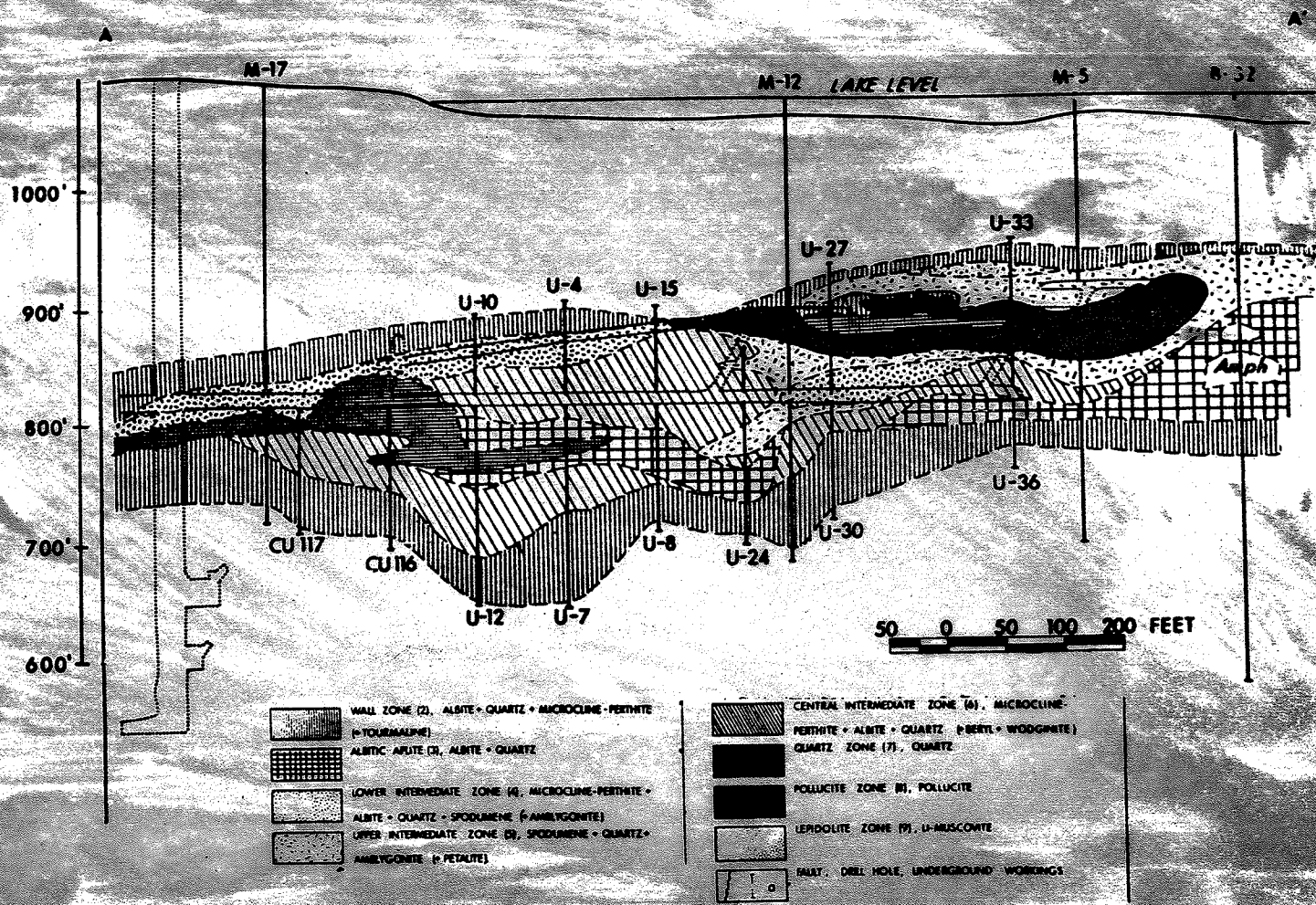


Figure 6b. A N-S (A-A') section of the Tanco pegmatite. The border zone (1) is omitted (after Crouse and Černý, 1972).

Albitic aplite zone (3) - an albite and quartz zone (60 feet thick) appearing as thin folded layers and as small discontinuous bodies located along the contact of the footwall portion of the wall zone (2) with the overlying intermediate zones or along the contacts of the lower (4) and the upper (5) intermediate zones.

Lower intermediate zone (4) - a microcline-perthite, albite, quartz, spodumene zone with abundant amblygonite. The zone is composed of two mineral assemblages: 1) large microcline-perthite crystals in medium-grained albite and quartz with mica and spodumene + quartz intergrowths; 2) large quartz pods with amblygonite and spodumene + quartz aggregates.

Upper intermediate zone (5) - a spodumene, quartz, amblygonite zone with petalite. This zone is texturally and compositionally homogeneous. It contains spodumene as tabular crystals or as quartz + spodumene intergrowths after petalite.

Central intermediate zone (6) - a microcline-perthite, albite, quartz zone with abundant beryl and wodginite (< 5%) (Crouse and Cerny, 1972) and is made up of three assemblages:

1) medium- to coarse-grained microcline-perthite with minor quartz, beryl, spodumene, albite, muscovite and wodginite; 2) rounded patches and waves of bluish albitic aplite and disseminated tantalum oxides; 3) grayish to smoky quartz pods with white to bluish beryl accumulated along its contacts with feldspar-rich assemblages. Beryl-bearing pods are most abundant in the upper parts of this zone.

Quartz zone (7) - does not form a central core as in most pegmatites but appears as several lens-shaped bodies disseminated at random in different locations.

Pollucite zone (8) - is composed of lenticular or globular bodies of massive pollucite in the upper parts of the pegmatite - in the upper intermediate zone (5) and between the central intermediate (6) and the hanging wall of the border (1) and wall (2) zones.

Lepidolite zone (9) - is composed of Li-muscovite and appears as two flat-lying east-west trending elongated sheets and as several smaller bodies all in the central intermediate zone.

The Tanco pegmatite is a product of advanced differentiation of a granitic magma, and is accompanied by minor introductions of K, Li, F, B, P, and H_2O into the amphibolite country rock (Wright, 1963). According to Černý and Crouse (1972) zones (1), (2) and part of (4) may have formed by initial magmatic crystallization. Černý and Crouse (1972) also state that resurgent boiling took place during the formation of zones (4)

and (6). Resurgent boiling during the formation of zone (4) formed a sodic residual magma which crystallized as albitic aplite (3) in the lower part and a Li, K, Si-rich super-critical fluid which gave rise to the coarse-grained upper intermediate zone (5). The pollucite zone may represent a monomineralic separation in the upper intermediate zone (5). The lepidolite zone is a metasomatic zone which formed at the expense of the central intermediate zone (6).

(d) Previous work

Detailed work has been done on pollucite and beryl from many localities. The work done on the Tanco pollucite and beryl is, however, negligible with the exception of a recent paper by Dr. P. Černý (1974) on "The Present Status of the Analcime-Pollucite Series". That paper supports the views presented by Beger (1969) in his report on "The Crystal Structure and Chemical Composition of Pollucite". Other papers dealing with the crystal structure, physical properties and cation exchanges in pollucite and analcime include those by: Barrer et al. (1951), Ames (1966), Beger and Buerger (1967) and Newnham (1967). Quensel (1956) in his paper on the Varuträsk pegmatite reports on the pollucite and beryl from that pegmatite. Ginsberg (1946) and Melentyev (1961) respectively report on the pollucite from the Kalbin Range (Eastern Kazakustan) and from the granite pegmatites of Sayan Mountains.

Significant work was done on the cation and water molecule positions in the channels of beryl by Vorma et al. (1965); they also suggested the possible substitution of Li for Be. Bakakin et al. (1969) confirmed the substitution of Li for Be and proposed that Li substituted directly into the tetrahedral Be sites. A later paper by Bakakin et al. (1970) pointed out the existence of six types of beryl.

Several papers have been published in the last few years dealing with the minerals of the Tanco pegmatite (Can. Min., Vol. 11, part 3, 1972). These papers deal with the general geology and parageneses of the pegmatite, the Ta oxide minerals, amblygonite-montebrazite, petalite and spodumene, K feldspars, Li-Rb-Cs micas, eucryptite, and secondary minerals from the spodumene rich zone (including secondary cesian-beryl and cesian-analcime).

(e) Present Study

The present study of pollucite and beryl from the Tanco pegmatite was begun in May, 1972. Samples were collected from sections of drill cores at the mine and from areas in the mine. Many of the underground pollucite samples had been collected by Dr. Cerny, R. Good and the writer in the summer of 1971. A more detailed description of the pollucite and beryl samples will be found in the following chapters dealing specifically with each of these minerals.

(f) Experimental Methods

The refractive indices were measured first on all samples. Samples were then selected for partial chemical analysis on the basis of their refractive indices and their location in the pegmatite. Three samples of pollucite and three samples of beryl were selected for complete chemical analysis and a detailed mineralogical study on the basis of their refractive indices. These samples were selected to represent one sample of high, low, and average refractive index.

Refractive index

The refractive indices of all the pollucite and beryl samples were measured by the immersion method, using a monochromatic yellow light

filter in a darkened room. Immersion liquids were mixed to obtain a series of liquids with increments of 0.001 (e.g. 1.520, 1.521, 1.522, etc.). The fourth decimal place was estimated from the degree of movement of the Becke line.

Most Tanco pollucite consists of clear glassy eyelets embedded in a braided white matrix. The refractive index of each pollucite sample was measured on the clear eyelets except where only milky material was available. The homogeneity of the pollucite was tested on four samples by selecting several clear eyelets from each and measuring their refractive indices.

The ω refractive index was measured for the beryl samples. Zoning in beryl was checked by measuring the ω of a series of grains separated along centre-to-surface traverses on suitable crystals. These traverses were oriented parallel and perpendicular to the c axis of the crystal.

Sample separation

Clear eyelets of pollucite were obtained for refractive index study by picking them out with a dissecting pin. Material for chemical analyses and mineralogical study was separated by hand, under the binocular microscope, from crushed portions of the samples. Grains of beryl were separated for chemical and mineralogical studies in a similar way.

Density

The densities of the three pollucite and the three beryl samples were measured using the Berman balance with toluene as the displacement liquid. Three to four separate grains were taken from each sample and two or three weighings were made on each of these grains. The density of the sample was found first by finding the average density of the two or three

weighings on each grain and then averaging the densities of the three to five grains from that sample. The refractive index of each sample was checked, by the immersion method, on a mixture of crushed material from the three to five grains used in the density determination.

Unit cell dimensions

Portions of the three pollucite and the three beryl samples for which the densities had already been measured were ground in an agate mortar. CaF_2 was added as an internal standard and glass slide mounts were run on the x-ray powder diffractometer using Cu/Ni radiation. The pollucite samples were run at $\frac{1}{4}^\circ 2\theta/\text{min.}$, 1000/4/0. The beryl samples were run at $\frac{1}{4}^\circ 2\theta/\text{min.}$, 1000/8/0 changing to 400/8/0 at $34^\circ 2\theta$ in order to resolve the high 2θ peaks. Each sample was x-rayed three times rotating the slide in the sample holder instead of remounting the powder. The 2θ values of the pollucite and beryl reflections were corrected according to the variation in the CaF_2 reflections with the values stated in powder diffraction file. The readings from the three records of each sample were then averaged. Using average values of 2θ the unit cell dimensions were refined using the self-indexing least-squares program by Evans et al. (1963) modified by D. E. Appleman.

Chemistry

Twenty-nine pollucite and nineteen beryl samples were selected for partial chemical analysis on the basis of their refractive indices and their location in the pegmatite. Partial chemical analysis of the pollucite and beryl samples was done by atomic absorption spectroscopy for CaO , K_2O , Na_2O , Li_2O , Rb_2O , and Cs_2O . Three pollucite and three beryl samples selected on the basis of their refractive indices to represent an average as well as the extreme high and the extreme low values of the

observed indices, were analysed in full. The methods used to analyse for the various oxides were:

X-ray fluorescence spectrography	SiO_2 , Al_2O_3 , Fe_2O_3
Atomic absorption spectroscopy	Li_2O , Na_2O , K_2O , Rb_2O , Cs_2O , CaO , MgO , MnO , BeO , total Fe as Fe_2O_3
Gravimetry	H_2O^- , H_2O^+

Chemical analyses were performed by x-ray fluorescence, atomic absorption spectroscopy and gravimetry in the chemical analysis laboratory of the Department of Earth Sciences, University of Manitoba.

Thin sections

Six of the pollucite samples, collected underground, were selected for thin section study of the alteration products of pollucite. Two thin sections of each sample were made: one of 30 μ . and one of approximately 60 μ ..

X-ray diffraction of alteration products

Four pollucite samples were collected from the mine dumps for a study of the alteration products of the pollucites. These samples were thinly sliced and the veins of alteration products were separated from the slices using pliers and a dissecting pin. The material was then ground in an agate mortar and run on the x-ray powder diffractometer using Cu/Ni radiation at $\frac{1}{2}^\circ 2\theta$ /min., 1000/4/0. Standard diffractograms of spodumene, pollucite and quartz were prepared to aid in the identification of the alteration products.

CHAPTER II POLLUCITE

(a) Introduction

Pollucite occurs in two general locations in the Tanco pegmatite: a) blebs of pollucite in zone (5) and b) zone (8) which consists of a large eastern pollucite body and isolated pods of pollucite in the western part of the pegmatite. These components of zone (8) are located between the central intermediate zone (6) and the hanging wall portion of the border (1) and wall (2) zones. The majority of the samples studied were collected from the eastern pollucite body either by underground sampling or by sampling of drill cores. Samples from the western pods of pollucite were collected mostly from drill cores with the exception of a few samples collected from the western tantalum ore zone ramp, late in the winter of 1973, by Dr. Cerny.

A total of 90 pollucite samples were collected from drill cores. Table III and Figure 7 (in map pocket) show the elevation of the core samples and the drill hole collars respectively. Forty-six additional samples were collected underground by Dr. Cerny, R. Good and the writer from the eastern pollucite body. These forty-six samples were collected in vertical profiles through the eastern pollucite (Table III). Four samples were collected from the mine dumps by Dr. Cerny for the study of the alteration products of the pollucite. One sample was collected by Dr. Cerny from an isolated pod of pollucite in the western tantalum ore zone ramp.

The secondary cesian-analcimes that occur in the Tanco pegmatite were not included as part of the present study. A brief review of these secondary cesian-analcimes is given, however, in a later section of this chapter.

TABLE III

Refractive Indices and Footage in Feet of Pollucite Samples

Eastern Pollucite Body									
<u>U39</u>		<u>B34</u>		<u>B12</u>		<u>M5</u>		<u>M4</u>	
Foot.	<u>n</u>	Foot.	<u>n</u>	Foot.	<u>n</u>	Foot.	<u>n</u>	Foot.	<u>n</u>
62.0	1.5180	147.5	1.5185	207.2	1.5236	189.0	1.5190	163.5	1.5218
62.5	1.5185	149.5	1.5205	208.0	1.5235	192.0	1.5180	164.0	1.5208
63.0	1.5192	152.0	1.5202	209.1	1.5228	196.0	1.5182	164.5	1.5212
65.7	1.5200	157.5	1.5205	210.4	1.5205	202.5	1.5200	165.0	1.5212
66.0	1.5202	162.5	1.5205	212.6	1.5205	205.5	1.5202	165.5	1.5206
66.6	1.5200	167.5	1.5220	215.0	1.5206	206.5	1.5205	166.0	1.5202
67.0	-	172.5	1.5212	217.0	1.5208	213.8	1.5206	230.8	1.5208
74.2	1.5200	177.5	1.5202	218.0	1.5216	217.0	1.5205	231.0	1.5208
75.5	1.5204	183.0	1.5208	219.0	1.5202	221.3	1.5200	231.8	1.5212
77.0	1.5198	187.0	1.5212	220.0	1.5214	224.0	1.5202	232.3	1.5210
81.0	-	187.5	1.5220	221.9	1.5209	225.6	1.5205	232.5	1.5208
84.0	1.5200	195.0	1.5204	223.0	1.5212	226.5	1.5208		
87.2	1.5192	195.5	1.5200	224.9	1.5202				
88.5	1.5192	202.0	1.5204	226.2	1.5210				
92.0	1.5195	205.0	1.5180	226.9	1.5210				
93.5	1.5205	206.6	1.5202	227.9	1.5208				
95.0	1.5172	219.0	1.5214						
95.8	1.5172								
Western Isolated Pods of Pollucite									
<u>M20</u>		<u>G</u>		<u>H</u>		<u>J</u>		<u>U</u>	
Foot.	<u>n</u>	Foot.	<u>n</u>	Foot.	<u>n</u>	Foot.	<u>n</u>	Foot.	<u>n</u>
177.5	1.5200	202.0	1.5202	184.0	1.5200	264.0	1.5200	204.3	1.5120
178.0	1.5220	202.5	1.5200					205.8	1.5206
178.9	1.5238	203.0	1.5205					207.5	1.5228
179.5	1.5238							207.8	1.5208
180.5	1.5236							209.0	1.5205
181.2	1.5206								
183.5	1.5222								
184.0	1.5232								
Samples Collected Underground									
<u>P-1</u>		<u>P-2</u>		<u>P-3</u>		<u>P-4</u>		<u>R-1</u>	
#1	1.5200	#1	-	#1	1.5200	#1	1.5180	#1	1.51850
#2	1.5200	#2	1.5200	#2	1.5198	#2	1.5195	#2	1.5220
#3	1.5200	#3	1.5200	#3	1.5200	#3	1.5200	#3	1.5205
#4	1.5206	#4	1.5205	#4	1.5215	#4	1.5192	#4	1.5200
#5	1.5214	#5	1.5205	#5	1.5208	#5	1.5200	#5	1.5200
		#6	1.5208	#6	1.5200	#6	1.5205	#6	1.5190
				#7	1.5200				
<u>R-2</u>		<u>R-3</u>		<u>R-4</u>					
#1	1.5204	#1	1.5200	#1	1.5200				
#2	1.5195	#2	-	#2	1.5200				
#3	1.5190	#3	1.5215	#3	1.5200				
#4	1.5194	#4	1.5220	#4	1.5220				
#5	1.5200	#5	1.5210	#5	1.5200				
#6	1.5220	#6	1.5190	#6	1.5194				

(b) General Study

Physical and optical properties

The pollucite samples collected from the eastern pollucite body are massive and have a braided (augen) texture formed by tiny eyelets (2 - 10 mm., averaging about 3 mm. in length) of clear pollucite in a milky white matrix usually contaminated by other minerals (see page 35). Pollucite samples collected from the isolated pods in the western part of the pegmatite show no or very poorly developed eyelets of clear pollucite and are generally of a grayish or milky white colour.

In plane polarized light the eyelets are clear and the matrix is cloudy. Both the eyelets and the matrix are, however, isotropic. Refractive indices were measured on the clear eyelets of all the pollucite samples and n was found to vary from 1.5172 to 1.5238, the average being 1.5204. Figure 8 shows the values of n for the various samples as well as the profiles of the variations in n within the various drill holes. These profiles show that the variation in n in the vertical profiles is relatively small and that the eastern pollucite body itself is not noticeably zoned. In some drill holes (U 39, M 5 and B 34) there appears to be only a slight increase of n toward the center of the body.

Figure 9 shows a histogram of the number of samples collected versus the value of n , for the whole pegmatite, the eastern pollucite body and the isolated pods from the western part of the pegmatite. From Figure 9 we can see that most of the pollucite samples have n in the range of 1.520 to 1.521. Figure 9 also shows that the pollucite samples from the eastern pollucite body show a similar relationship (i.e. n for most samples is in the range of 1.520 to 1.521), and that for the pollucite from the

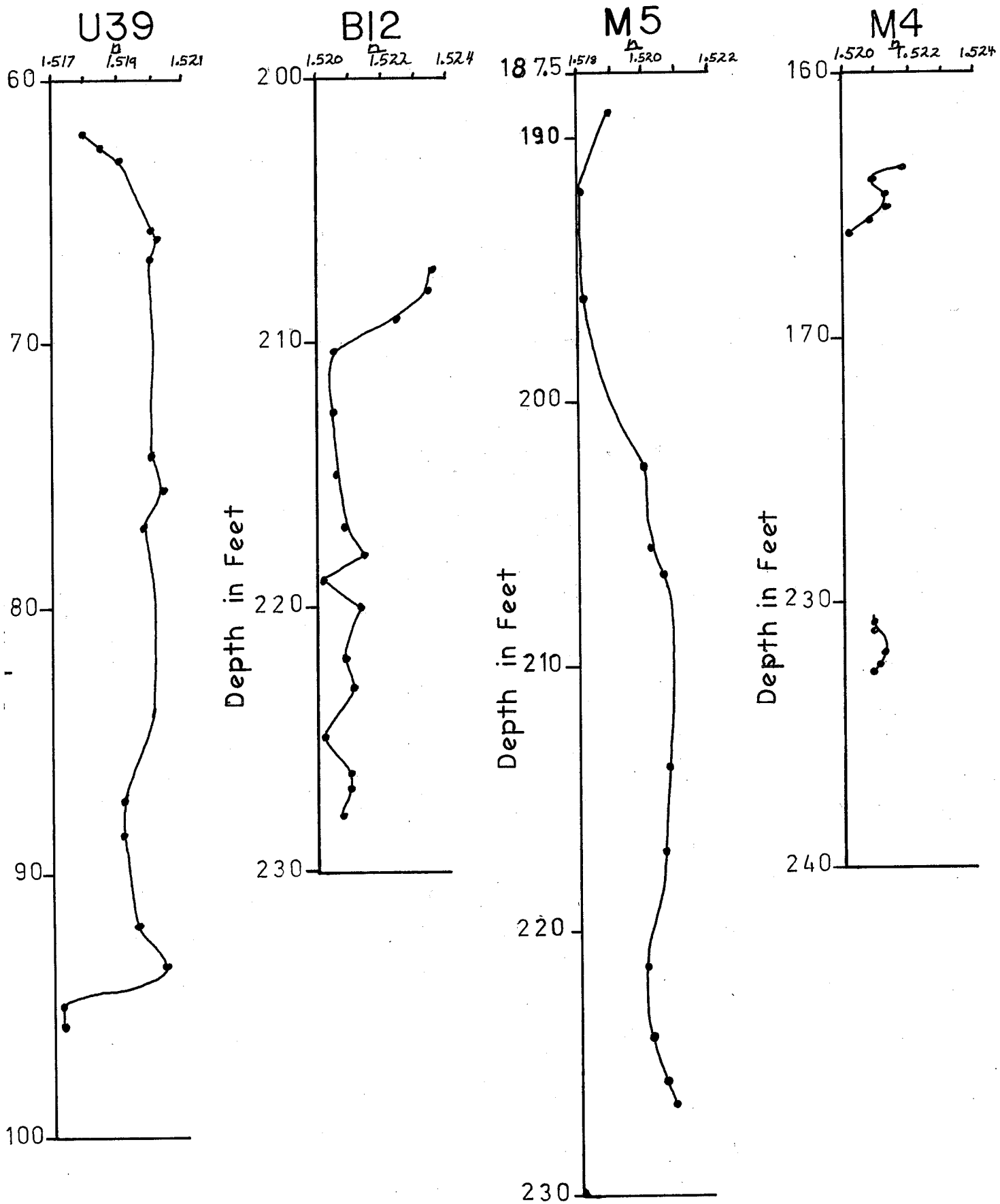


Figure 8. To be continued.

F8

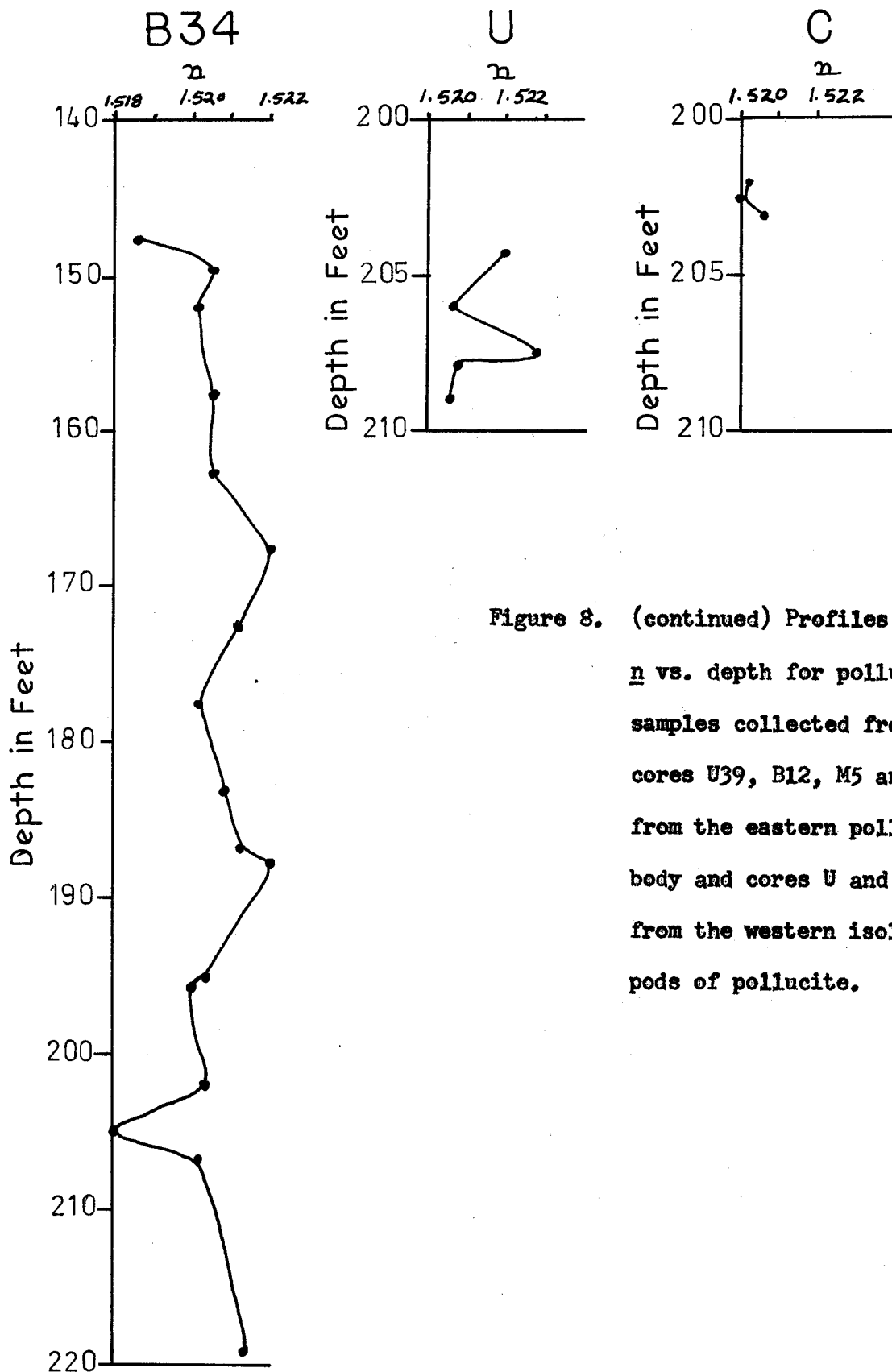


Figure 8. (continued) Profiles of n vs. depth for pollucite samples collected from drill cores U39, B12, M5 and B34 from the eastern pollucite body and cores U and C from the western isolated pods of pollucite.

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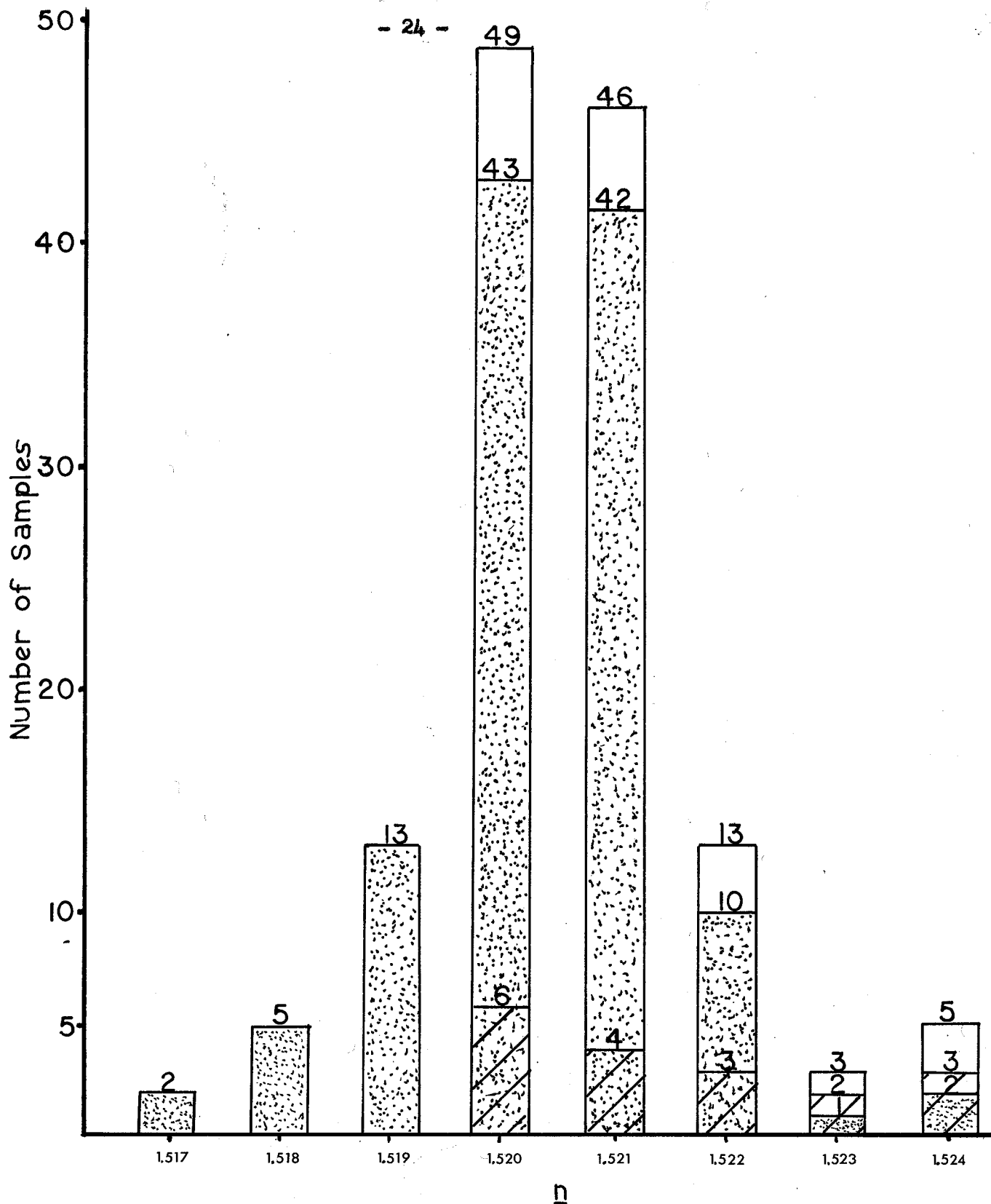


Figure 9. Histogram showing the variation of $\bar{n}$ in 135 pollucite samples. The stippled areas indicate the samples from the eastern pollucite body, the areas marked by diagonal lines indicate the samples from the western isolated pods of pollucite, and the outlines indicate the total number of samples within a given range of $\bar{n}$. E. g. for samples with $\bar{n}=1.5175-1.5185$ a total of 5 samples were collected, all were from the eastern pollucite body.

TABLE IV

Homogeneity Test on Pollucite by Refractive Index

(estimated error $\pm .0004$)

Sample Grain # #	P 3 6	R 4 5	B 12 218.0	U39 77.0
Grain #1	1.5198	1.5206	1.5214	1.5198
Grain #2	1.5200	1.5204	1.5218	1.5195
Grain #3	1.5200	1.5208	1.5215	1.5202
Grain #4	1.5202	1.5208	-	-
Grain #5	1.5208	1.5205	-	-

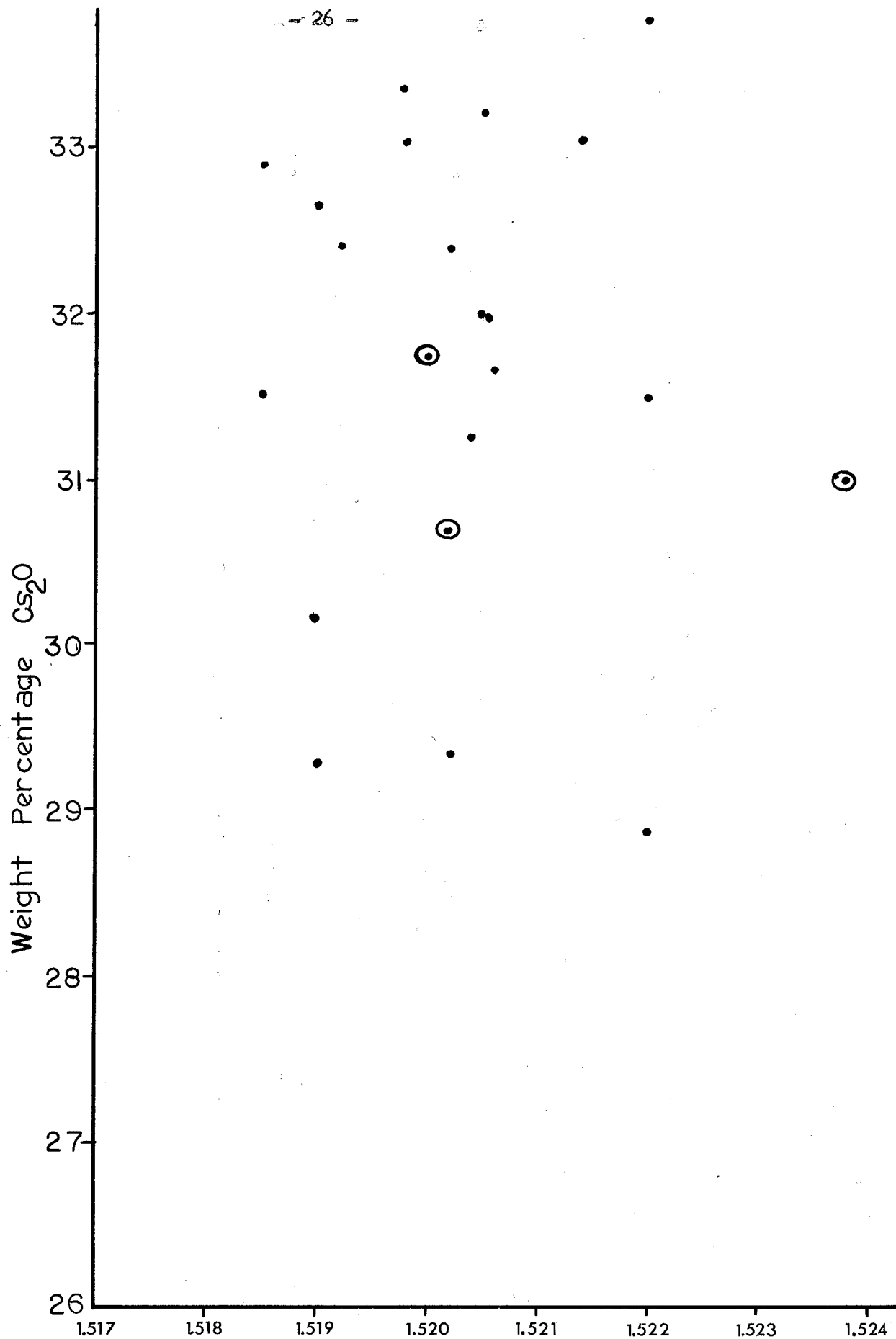


Figure 10. Weight percentage of Cs_2O vs. $\bar{n}$ for pollucite from the Tanco pegmatite. Dots in circles represent the samples from the Western isolated pods.

western pods no sample has $\bar{n}$ lower than 1.520. These western pods contain three of the five samples with $\bar{n}$ in the range of 1.524 and two of the three samples with $\bar{n}$ in the range of 1.523 (Figure 9).

The number of specimens examined from the western pods is much smaller than that from the eastern pollucite body. Nevertheless it seems to be large enough to conclude that the western pollucite pods show a distinctly higher average value of $\bar{n}$.

Four samples were selected for a homogeneity test and were found to be of fairly constant $\bar{n}$ throughout the sample. Table IV shows the results of the homogeneity test.

Partial chemical analysis

Samples for partial chemical analysis were separated on the basis of $\bar{n}$ and location. Samples were selected to represent high, low and average values of $\bar{n}$ as well as to represent both the eastern pollucite body and the western isolated pods of pollucite. The samples were analysed for Cs_2O , Na_2O , K_2O , Rb_2O , Li_2O and CaO . The results of the analyses are shown on Table V which also shows the value of $\bar{n}$ for the samples analysed. Figure 10 shows the direct relationship between $\bar{n}$ and the cesium content of pollucite.

In general it can be seen, from Table V and Figure 10, that the samples from the western isolated pods have a slightly lower cesium content (29.36 wt.% Cs_2O on the average) compared to that of the samples from the eastern pollucite body (31.29 wt.% Cs_2O on the average). This is not what one would expect from the average value of $\bar{n}$ which is the same ($\bar{n} = 1.5204$) for both the analyzed pollucite samples from both the eastern pollucite body and the western isolated pods of pollucite. One can also see that the cesium content of the pollucite is fairly constant throughout the eastern pollucite body.

TABLE V
Partial Chemical Analysis for Pollucite*

	Sample Number	Wt.% of Oxides Analysed						<u>n</u>
		Li ₂ O	Na ₂ O	K ₂ O	Rb ₂ O	Cs ₂ O	CaO	
Eastern Pollucite Body	R1 - 6	0.076	1.85	1.21	1.07	30.15	0.024	1.5190
	R1 - 1	0.088	1.88	0.12	0.71	32.90	0.046	1.5185
	R2 - 3	0.058	1.70	0.52	0.94	32.65	0.074	1.5190
	R2 - 6	0.151	1.68	0.37	0.86	31.50	0.084	1.5220
	R3 - 4	0.112	1.65	0.09	0.79	34.10	0.043	1.5220
	R4 - 2	0.090	1.85	0.05	0.89	33.35	0.018	1.5198
	P1 - 5	0.189	1.64	0.11	0.97	33.04	0.055	1.5214
	P2 - 4	0.116	1.87	0.15	0.88	33.20	0.029	1.5205
	P3 - 2	0.084	1.72	0.07	0.72	33.04	0.025	1.5198
	P4 - 1 [†]	0.847	1.56	0.47	0.42	26.80	0.045	1.5180
	P4 - 4	0.151	1.73	0.15	0.85	32.40	0.029	1.5192
	P4 - 6	0.235	1.63	0.19	0.74	32.00	0.034	1.5205
	B34 - 147.5	0.178	1.84	0.08	0.80	31.52	0.061	1.5185
	B34 - 157.5	0.197	1.76	0.10	1.10	32.00	0.028	1.5205
	B34 - 187.5	0.519	1.47	0.23	0.54	28.87	0.060	1.5220
	B34 - 206.6	0.091	1.68	0.10	0.73	32.40	0.076	1.5202
	M5 - 192.0	0.379	1.40	0.49	0.77	29.28	0.037	1.5190
	M5 - 205.5	0.227	1.33	0.17	0.75	29.33	0.058	1.5202
	M5 - 226.5 ^{††}	0.686	2.00	0.45	0.40	28.10	0.127	1.5208
	M4 - 163.5	0.645	1.30	0.18	0.78	30.53	0.049	1.5218
	M4 - 165.5	0.565	1.43	0.20	0.80	31.67	0.041	1.5206
	U39 - 62.6 ^{††}	0.667	1.96	0.18	0.44	29.67	0.100	1.5180
	U39 - 75.5 [†]	0.717	1.73	0.23	0.86	31.27	0.070	1.5204
Western Isolated Peds	M20 - 179.5	0.533	1.45	0.24	0.77	31.00	0.026	1.5238
	M20 - 181.2	0.412	1.58	0.35	0.83	30.70	0.033	1.5202
	U - 205.8 ^{†††}	0.365	1.57	0.75	0.75	28.67	0.082	1.5206
	U - 209.0 ^{††††}	0.710	1.76	1.39	0.43	28.13	0.114	1.5205
	J - 264.0 ^{††††}	1.080	1.52	0.82	0.51	26.40	0.170	1.5200
	C - 202.5	0.560	1.45	0.15	0.67	31.75	0.074	1.5200

* Analyses done by R. Hill, R. Chapman and K. Ramlal, chemists; Dept. of Earth Sciences, University of Manitoba.

[†] Contaminated with spodumene.

^{††} Contaminated with albite.

^{†††} Contaminated with K-feldspar.

Table V indicates that there is no regular change in Na content of the pollucite with location; only local irregular variations are evident. The high Na contents are reflected by low values of $\underline{n}$ and low cesium contents for those samples. The high Na contents of some samples may be due to the presence of impurities such as Na feldspars. The presence of such feldspars was confirmed by x-ray powder diffraction.

Samples P4-1, U39-62.5, U39-75.5, U-209.0, B34-187.5, M5-226.5, M4-165.5 and M4-163.5 (with anomalously high Li contents) were checked by x-ray powder diffraction. The samples were found to be slightly contaminated with spodumene.

(c) Full Mineralogical Study

The three samples (B12-226.2, B12-207.2 and U39-95.8) destined for full mineralogical study were selected to represent specimens with high, low and average values of $\underline{n}$; the location of the samples was not considered.

Density and refractive index

The densities of the samples varied from 2.903 to 2.909 g/cm³. as can be seen from Table VI which also shows the values of $\underline{n}$ for the samples. It has been proven by previous researchers (such as Černý, 1974) that the density of pollucite is directly proportional to $\underline{n}$. It is concluded that there are not sufficient samples present to accurately draw a graph of density vs. $\underline{n}$ when one considers the large error in measuring density of very small grains (7-12mg.) on the Eberman balance. Figure 11 shows the graph of density vs. $\underline{n}$ (Černý, 1974) with the three samples from the present study superimposed. Table VI shows the values of $\underline{n}$ measured on a mixture of grains used to measure the density.

TABLE VI

Full Chemical Analyses for Pollucite

Sample Wt. % oxide	B12 226.2	B12 207.2	U39 95.8	1	2	3
SiO ₂	42.20	44.05	42.30	46.28	43.51	44.28
Al ₂ O ₃	14.83	15.02	14.53	16.71	16.30	16.32
Fe ₂ O ₃	0.012	0.0129	0.008	0.01	-	-
Li ₂ O	0.43	0.59	0.28	0.25	0.05	-
Na ₂ O	1.74	1.50	1.88	1.87	1.68	1.59
K ₂ O	0.16	0.89	0.17	0.51	0.48	0.38
Rb ₂ O	0.74	0.67	0.77	1.60	-	-
Cs ₂ O	32.04	30.20	32.40	30.77	36.10	35.83
BeO	nil	nil	nil	-	-	-
MgO	0.003	0.011	0.003	0.00	-	-
CaO	0.010	0.060	0.037	0.00	0.22	0.13
MnO	-	-	-	0.00	-	-
H ₂ O ⁺	1.73	1.67	1.91	1.80	1.50	1.62
H ₂ O ⁻	0.04	0.04	0.04	0.00	-	-
F	-	-	-	0.03	-	-
P ₂ O ₅	-	-	-	0.25	-	-
Total	93.94	94.71	94.33	100.08	99.84	100.15
Density	2.9093	2.9037	2.9028			
<u>n</u>	1.5210	1.5236	1.5172			
Check on <u>n</u>	1.5204	1.5230- 1.5234	1.5170			
U.C.D.	13.672 ±.001	13.672 [†] ±.001	13.674 ±.001			

1. Varutrask pegmatite (Quensel, 1956) 2. Hebron, Maine (Beger, 1969)

3. Tamminen quarry, Maine (Beger, 1969)

†. A check on n for one of the five grains used to determine the density of B12-207.2 showed n = 1.5222 - 1.5224. This grain also showed a lower density to the rest of the grains.

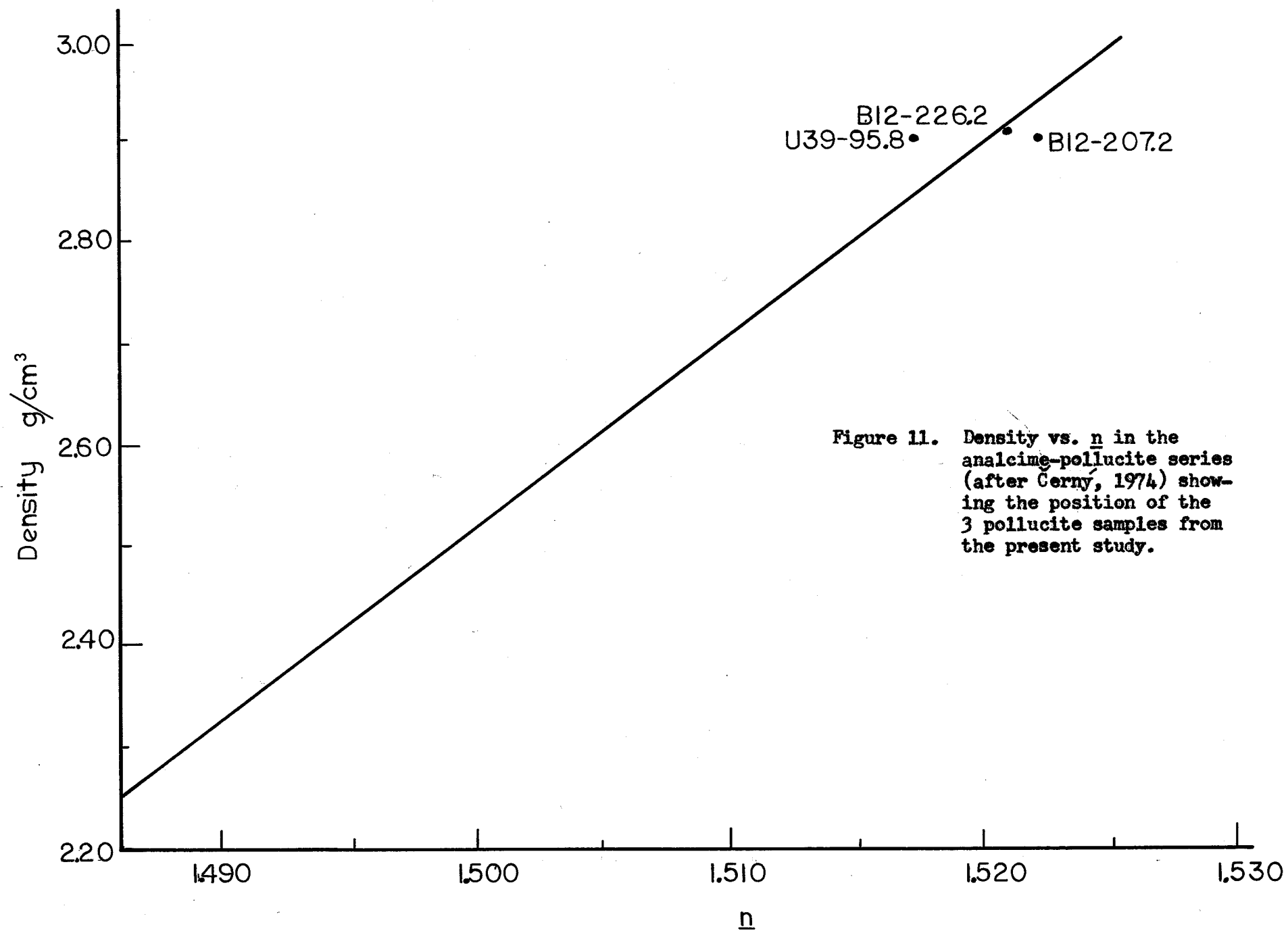


Figure 11. Density vs. n in the analcime-pollucite series (after Cerny, 1974) showing the position of the 3 pollucite samples from the present study.

Unit cell dimensions

The unit cell dimensions of the three pollucite samples chemically analysed in full (see Table VI) were found to lie within the previously established range of $a = 13.64 - 13.71 \text{ \AA}$ (Černý, 1974).

Discrepancies in the full chemical analyses

The results of the full chemical analyses to date were very inaccurate and did not total 100 wt.%. The problem is most probably due to the silica and alumina contents which seem low for all three samples. The discrepancy in the silica and alumina contents which are fairly constant for pollucite indicate that the samples may be contaminated with other minerals and that the alkali contents are not to be trusted. Table VI shows the results for the samples from the Tanco pegmatite as well as the results of analyses of the pollucites from other pegmatites. It will be noted that in all other pollucites the silica and alumina contents are higher than those of the pollucites from the Tanco pegmatite.

(d) Secondary Cesian-analcimes

Although secondary cesian-analcimes were not a part of the present study, a brief account of the findings of Dr. P. Černý (1972) will now be presented. The cesian-analcimes present in zone (5) of the pegmatite are the result of the alteration of spodumene and quartz intergrowths which also yielded other rare minerals in unusual assemblages: cesian beryl and lithiophosphate in various combinations with cookeite, adularia, albite, apatite, calcite, quartz and clay minerals. Figure 12 shows the sequences of crystallization of the four cesian-analcime bearing assemblages. All these sequences were found in close neighbourhood of the pollucite zone (8). Table VII shows the chemical composition and physical properties

TABLE VII

Chemical Composition and Physical Properties of Cesian Alalcime*

	1	2	2 - 1	2 - 2	3	63568
SiO ₂	54.85	52.10	52.93	n.d.	-	n.d.
Al ₂ O ₃	20.36	17.60	19.27	n.d.	-	n.d.
CaO	0.05	0.13	0.06	0.27	-	n.d.
Na ₂ O	10.30	6.46	9.29	4.91	-	7.5
K ₂ O	0.40	0.19	0.19	1.84	-	0.2
Rb ₂ O	0.01	0.06	n.d.	0.11	-	0.01
Cs ₂ O	6.00	18.00	10.50	14.90	-	7.9
H ₂ O ⁺	7.51	4.45	7.76	n.d.	-	n.d.
H ₂ O ⁻	0.41	0.14	-	n.d.	-	n.d.
	99.89	99.13	100.00	-	-	-
n _m	1.492	1.500- 1.509	1.496- 1.497	1.505	1.505	1.493- 1.496
a(Å)	13.694 ±.001	13.693 ±.003	-	13.684 ±.001	13.685 ±.003	-
Sp.						
Sp.gr.	2.35	2.63	-	2.60	-	-

* After Černý (1972).

Analysts: sample 635 - Dr. Jun Ito (Harvard University); other specimens - K. Ramlal and R. M. Hill (Dept. of Earth Sciences, University of Manitoba).

Sample 2 - 1 calculated from the mixture with eucryptite 32 quoted by Černý (1972a), assuming the Al_{0.9}Si_{2.1} tetrahedral content as found in samples 1 and 2.

Sample 2 - 2 slightly contaminated by quartz.

Sample 63568 slightly contaminated by quartz and by a phase insoluble in hot HNO₃+HF.

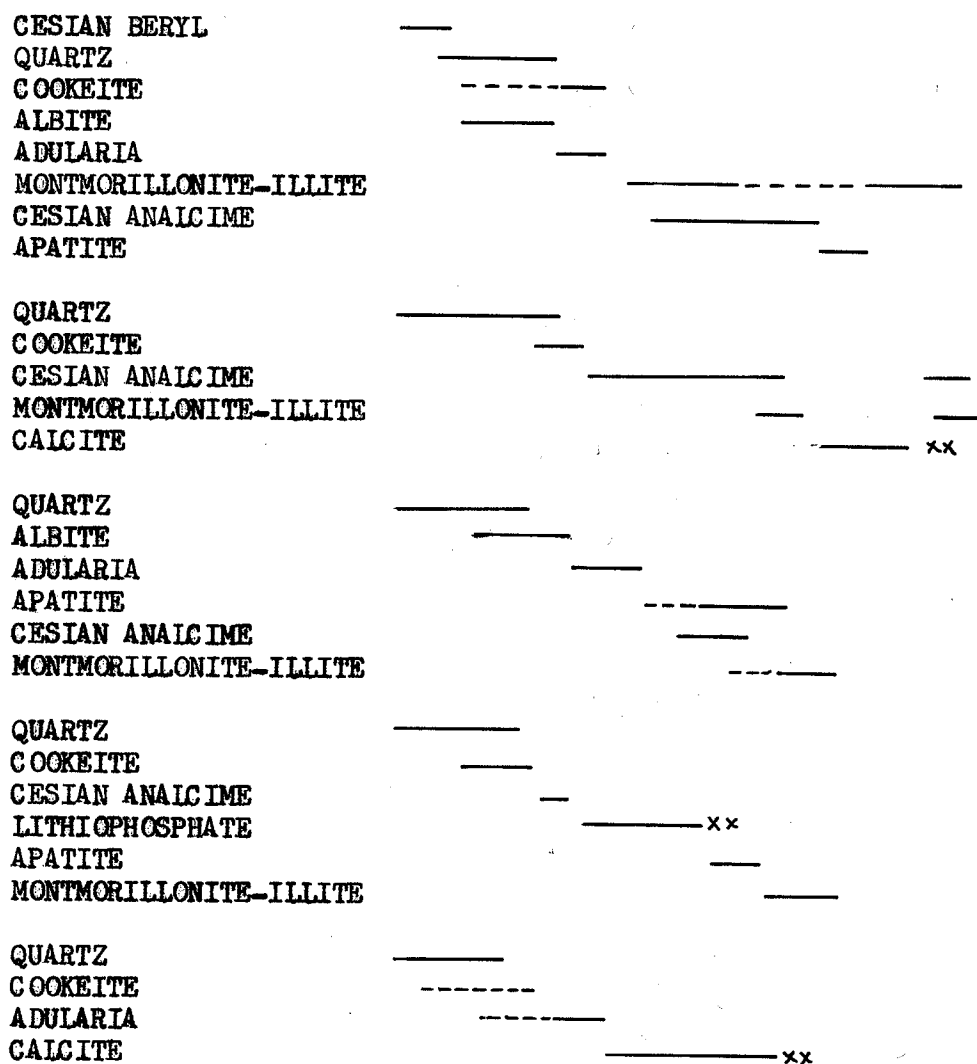


Figure 12. Paragenetic sequences of secondary minerals in five hydrothermal assemblages from the upper intermediate zone (5) of the Tanco pegmatite; dashed line - crystallization of small amounts concurrent with predipitation of another major phase; xx - etching and corrosion (after Cerny, 1972).

of five samples. According to Černý (1972),

The chemical composition of samples 1, 2 and 2 - 1 shows a good correlation with the general pollucite formulae proposed by Nel (1944) and Neuvonen and Vesasalo (1960), when recalculated to 6 oxygens per anhydrous formula:

sample 1 $(\text{Na}_{.76}\text{Cs}_{.10}\text{K}_{.02}) (\text{Al}_{1.91}\text{Si}_{2.09})\text{O}_6 \cdot 0.95 \text{H}_2\text{O}$

sample 2 $(\text{Na}_{.51}\text{Cs}_{.32}\text{K}_{.01}) (\text{Al}_{1.85}\text{Si}_{2.15})\text{O}_6 \cdot 0.61 \text{H}_2\text{O}$

sample 3 $(\text{Na}_{.72}\text{Cs}_{.18}) (\text{Al}_{1.90}\text{Si}_{2.10})\text{O}_6 \cdot 1.0 \text{H}_2\text{O}$

It was also noted by Černý (1972) that the refractive index and density of these secondary cesian-analcimes are intermediate between those of pollucite and analcime and show positive correlation with the Cs-content. The crystals are zoned (refractive index increasing towards the center of the crystal) and anisotropic, consisting of several radial sectors with uniform extinction.

These secondary cesian-analcimes lie in the analcime-rich gap in the pollucite-analcime series.

(e) Alteration Products

There are two basic types of alteration of the Tanco pollucites. The first type occurs as coarse veins (0.5 to 1.5 cm. thick) of albite, microcline, quartz, spodumene and pollucite. These coarse veins cut the pollucite in a polygonal mesh.

The second type of alteration appears as fine veinlets (< 1 mm. to 2 mm. thick) and small spherical masses (approximately 1 to 3 mm. in diameter) in the milky pollucite matrix. The veins and spherical masses were found to be mostly spodumene often rimmed with fine-grained colourless mica. Most of the veins contain some pollucite and minor amounts of quartz with the spodumene. Other veins appeared to be completely made up of fine-grained colourless mica. Clay minerals were present in some of the

spherical masses of alteration products of the pollucite. Traces of similar clay minerals were also noted intermittently throughout the pollucite matrix.

CHAPTER III BERYL

(a) Introduction

Samples of beryl collected underground and from drill cores in the eastern part of the pegmatite are all from the central intermediate zone (6). In zone (6) the beryl crystals appear along the contacts of the bluish albitic aplite with gray-smoky quartz pods or in a medium- to coarse-grained microcline-perthite. Core samples of beryl from the western portion of the pegmatite are from the lower intermediate zone (4) and the wall zone (2). Core samples from the central portion of the pegmatite are mostly from the wall zone (2) with some from the lower intermediate zone (4). One sample was collected from the lepidolite zone (9).

Seventy-seven core samples of beryl were collected. Table VIII shows the refractive indices (ω) and the footage of the samples within each drill hole. Figure 7 (in map pocket) shows the location of the drill holes. Ten samples all from the central intermediate zone (6) were collected underground. Early in 1974 Dr. Cerny collected another 20 samples from underground (3 from the lepidolite zone (9) and 17 from the western central intermediate zone (6)). Figure 13 (in map pocket) shows the sample location for the beryls collected underground from the eastern central intermediate zone (6). An additional 13 samples were provided by Dr. Cerny.

Secondary cesian beryls that occur in the Tanco pegmatite were not included as part of the present study. A brief review of the finds of Dr. Cerny (1972) in a previous study of these cesian beryls is given in a later portion of this chapter.

(b) General Study

Physical and optical properties

Beryl from the Tanco pegmatite occurs as irregular shaped grains

TABLE VIII

REFRACTIVE INDICES FOR BERYL SAMPLES

Footage	W	Footage	W	Footage	W	Footage	W
C 62		U 12		L 9		M 9	
400.0'	1.5880	1.1'	1.5927	383.2'	1.5927	257.5'	1.5816
405.0	1.5930	2.0	1.5928	388.4	1.5929	284.4	1.5814
C 13		5.8	1.5928	390.5	1.5927	289.0	1.5930
385.2	1.5932	22.0	1.5937	391.5	1.5925	290.0	1.5814
C 32		27.1	1.5933	392.3	1.5930	291.0	1.5816
347.5	1.5930	30.0	1.5934	393.3	1.5930	294.6	1.5929
348.7	1.5930	35.1	1.5937	395.0	1.5922	T	
U 10		36.8	1.5935	398.0	1.5927	243.5	1.5936
5.7	1.5930	47.5	1.5926	398.1	1.5927	244.0	1.5958
8.5	1.5940	54.5	1.5920	398.5	1.5928	244.4	1.5870
10.6	1.5930	57.0	1.5924	399.0	1.5930	245.1	1.5925
11.5	1.5859	65.5	1.5924	399.2	1.5928	245.8	1.5929
12.9	1.5936	71.9	1.5928	L 13		246.8	1.5925
13.6	1.5910	A		365.4	1.5890	247.7	1.5930
20.0	1.5932	228.2	1.5896	555.9	1.5800	L 19	
U 24		229.2	1.5892	L 6		397.5	1.5884
46.4	1.5940	230.0	1.5900	347.3	1.585-1.589	398.6	1.5878
U 21		L 6		349.4	1.5884	414.5	
2.0	1.5928	503.2	1.5932	354.0	1.5801-1.5806	1.5930	
21.0	1.5930	504.0	1.5932	B		495.2	1.5864
21.6	1.5930	509.5	1.5934	188.8		506.8	1.5926
M 20		512.0	1.5930	1.5940		510.5	1.5926
313.7	1.5912	514.5	1.5932	L 11		518.4	1.5930
314.2	1.5925	709.0		1.5886			

TABLE VIII - continued

	Sample #	W		Sample #	W
	Underground samples			Černý Samples	
Central Intermediate Zone (6) (east)	1		Central Intermediate Zone (6) (east)	BLM-1A (white)	1.5925
	2	1.5872		BLM - 1	1.5910
	3	1.5890		BLM-1C (white)	1.5925
	4	1.5926		BLM-2A (pink)	1.5922
	5	1.5932		BLM-2B	1.5850
	6	1.5906		BLM-2	1.5928
	7			APL	1.5924
	8a	1.5918		???	1.5928
	8b	1.5912		Zone (6)	1.5931
	9a	1.5914		XX	1.5924
Lepidolite (9)	9b	1.5912	Central Intermediate Zone (6) (east)	E. Ta. Body	1.5930
	9c	1.5924		Zone (6) (Contact)	1.5931
	10	1.5938			
	11	1.5934			
Lepidolite (9)	12	1.5920	Border (1)	Dumps	1.5926
Central Intermediate Zone (6) (west)	13	1.5915			
	14	1.5918			
	15	1.5922			
	16	1.5918			
	17	1.5920			
	18	1.5916			
	19	1.5924			
	20	1.5904			
	21	1.5912			
	22	1.5920			
	23	1.5918			
	24	1.5914			
	25	1.5920			
	26	1.5922			
	27	1.5924			
	28	1.5912			
	29	1.5925			

as well as well-formed crystals (the largest, to date, measuring $5\frac{1}{2}$ inches in diameter). The crystals show well developed hexagonal prisms, basal pinacoids and rarely pyramidal facets. Many of the crystals are stout stump-like prismatic crystals or thick tabular crystals parallel to $\{0001\}$. One sample collected by Dr. Cerny showed beryl in the form of a massive vein. The colour of the Tanco beryl is generally white or milky although pale greenish and pinkish as well as colourless beryls are present. The majority of the beryl samples studied were found to contain very fine grained inclusions of mica oriented parallel to the basal parting in the beryl crystals.

The refractive index (ω) was measured for all the beryl samples, on chips separated from the surfaces of the grains and crystals, and was found to vary from 1.5800 - 1.5958 (Table VIII).

Figure 14 (a - c) shows histograms of the number of samples versus ω for the beryl samples from the various zones. Figure 14 c shows the histogram for all the beryl samples collected. From Figure 14 (a and b) we can see that zones (4) and (6) (east) show a maximum of samples with $\omega = 1.593$ whereas the maximum of samples from zone (6) (west) show $\omega = 1.592$. All the samples examined from the lower intermediate zone (4) have $\omega = 1.593$ * (Figure 14a). Beryls from zone (2) are subdivided into pink and gray according to the colour of the host feldspar. Those samples, referred to as zone (2) (pink) were found associated with quartz, prismatic tourmaline crystals and a fine-grained granular pink albitic feldspar. The samples referred to as zone (2) (gray) were found associated with a dark gray coarse-

* The number of samples collected from zone (4) is small (six). Therefore, the apparent $\omega = 1.593$ for all samples may be greatly reduced if more samples were available.

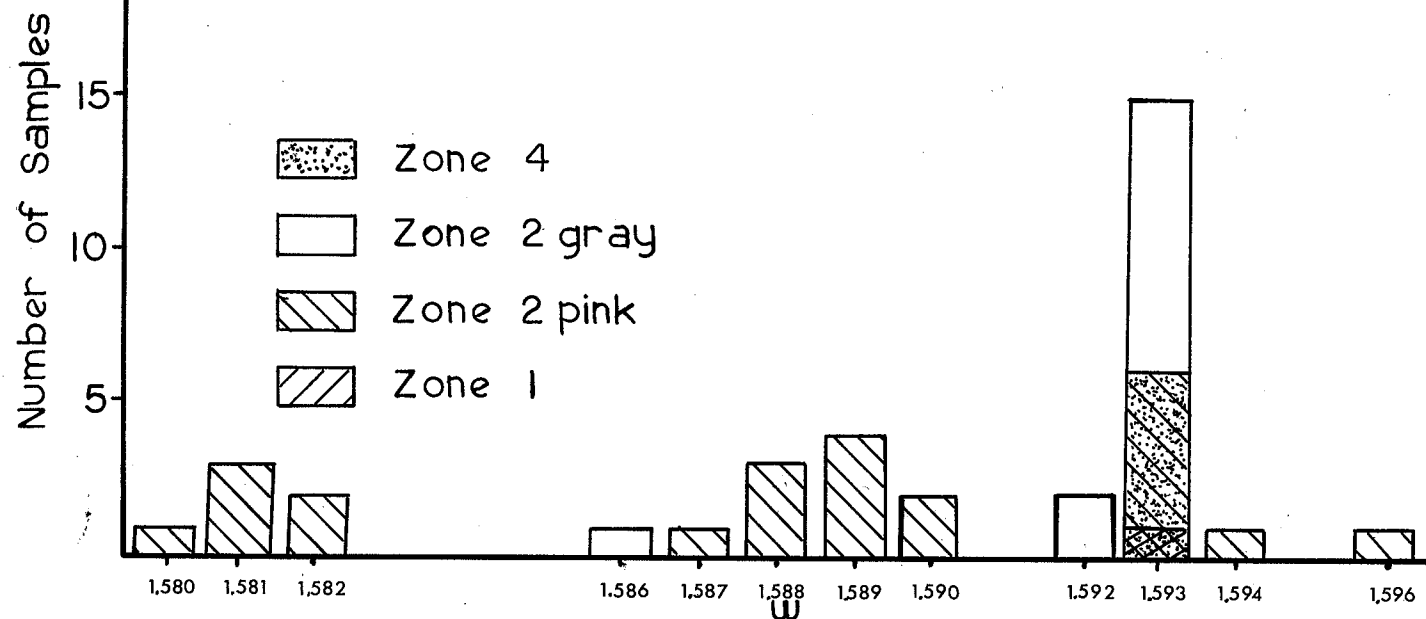


Figure 14a. Histogram showing the variation of ω in 43 beryl samples from zone (4), zone (2) (pink), zone (2) (gray), and zone (1).

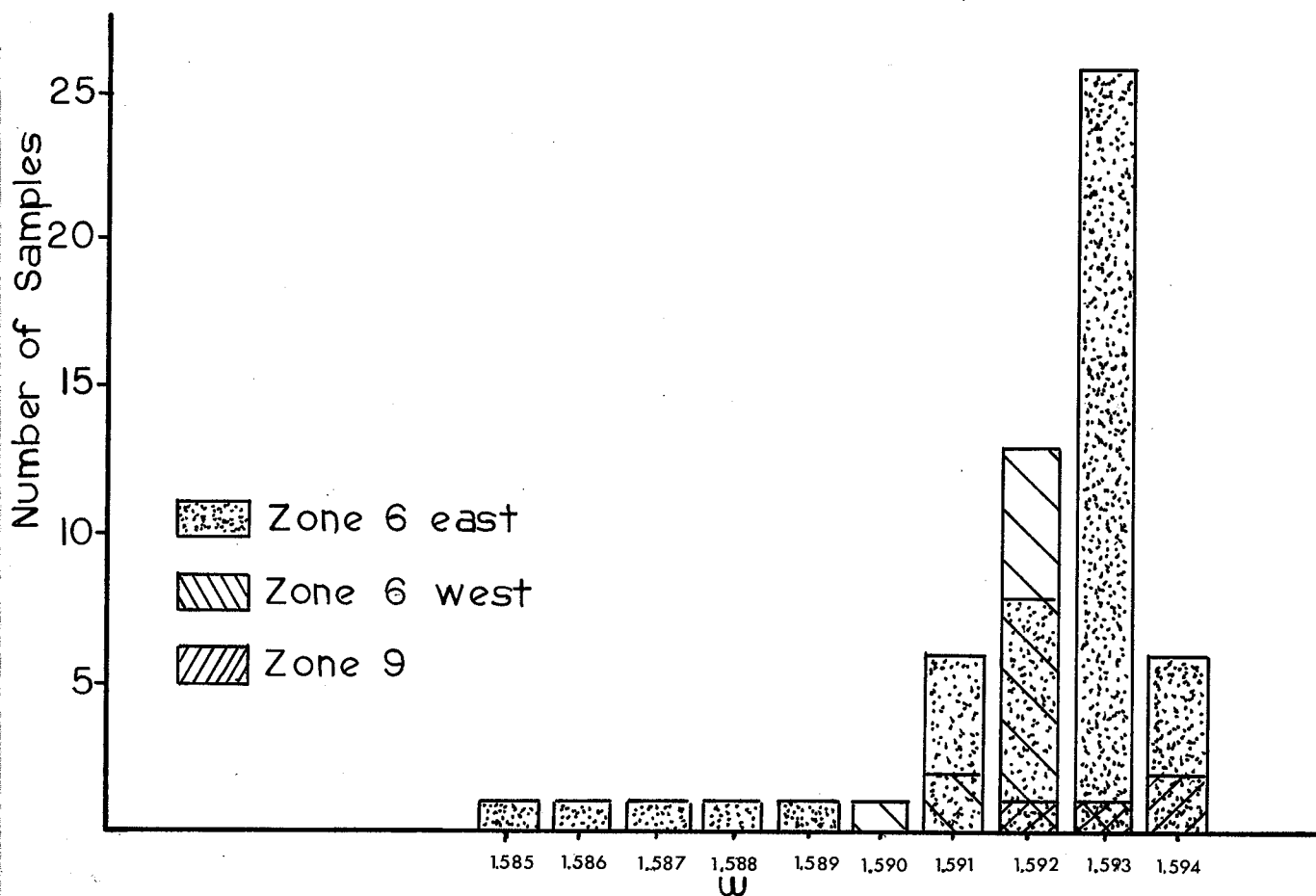


Figure 14b. Histogram showing the variation of ω in 81 beryl samples from zone (6) (east), zone (6) (west) and zone (9).

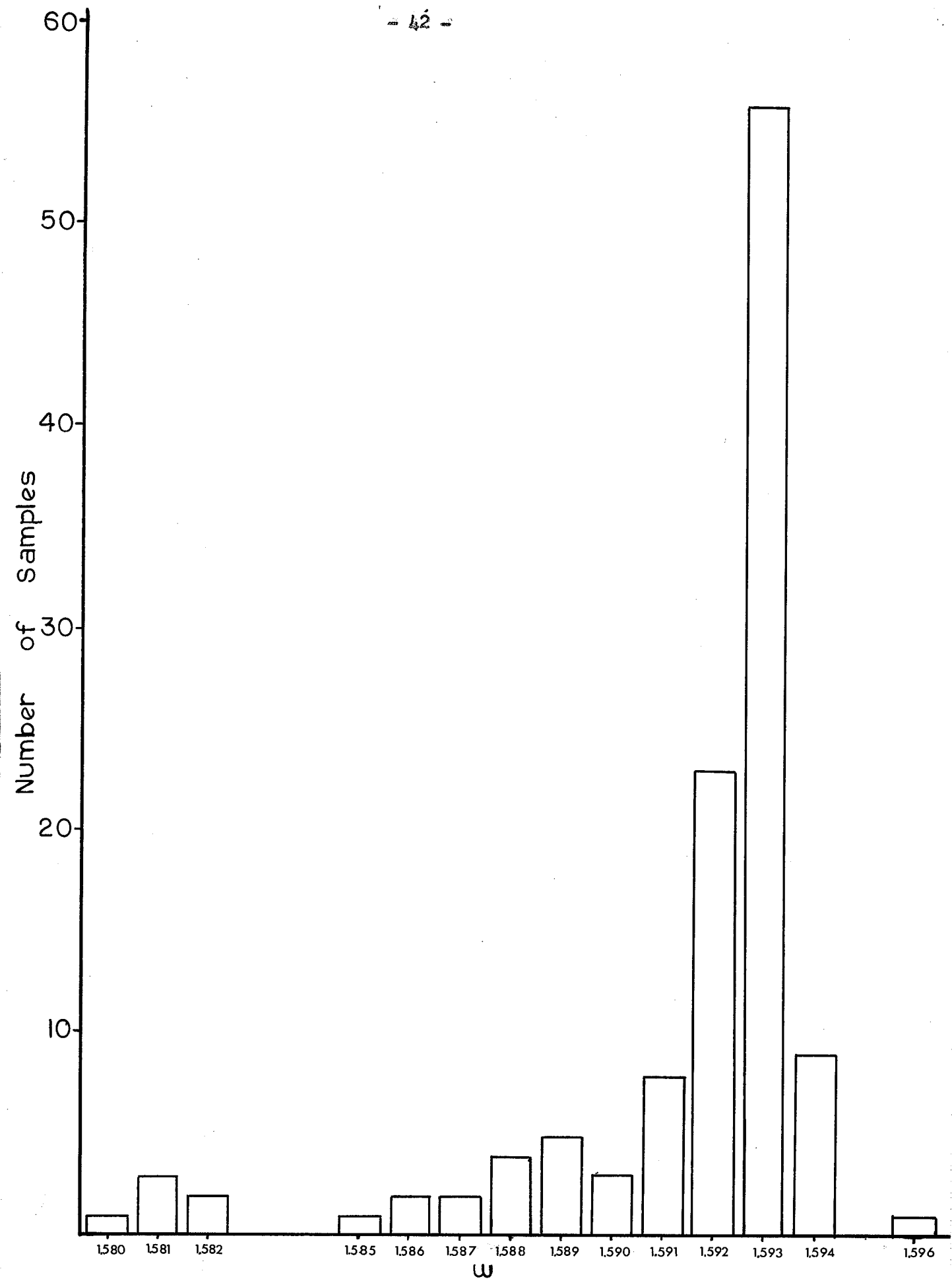


Figure 14c. Histogram of the number of samples vs. ω for all the 120 beryl samples collected from the Tanco pegmatite.

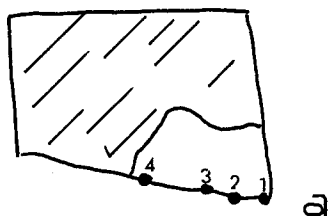
grained albite (cleavelandite) and very fine needlelike tourmaline crystals. The majority of the gray samples have $\omega \cong 1.5930$. The samples from zone (2) can also be divided according to their position in that zone i.e. whether they came from the hanging wall or footwall portion. All the samples from the hanging wall are pink while those from the footwall are pink or gray.

The average ω was calculated from each zone:

Zone (2) (pink)	1.5879
Zone (2) (gray)	1.5923
Zone (4)	1.5923
Zone (6) (east)	1.5921
Zone (6) (west)	1.5918
Zone (9)	1.5934

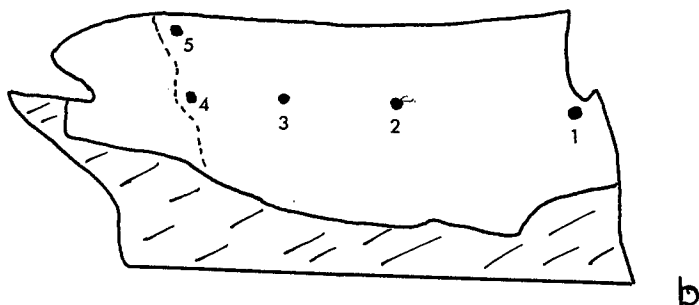
There appears to be an increase in ω from zone (2) to zone (9) or from the outermost zone sampled to the innermost zone sampled (bearing in mind the error concerned with the average ω for zone (4) and assuming the high average $\omega \cong 1.5923$ for zone (2) (gray) to be due to localized conditions in the pegmatite).

Correlation of ω with zonation in the pegmatite is complicated, however, by the intense zoning within the crystals. The refractive index (ω) was checked in cross-sections of 11 suitable crystals. It was found that the value of ω increased from the center of the crystal to its surface. In one extreme case ω varied from 1.5859 at the center of the crystal to 1.5931 on the outermost edge of the crystal (a distance of 45 mm.). In another sample ω varied from 1.5895 near its center to 1.5922 on the outer edge (a distance of 17 mm.). Figure 15 (a - g) shows sketches of some of the crystals studied for zoning.



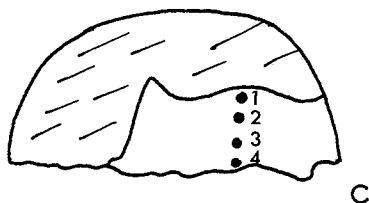
L19-398.6

	1	1.5842
5 mm.	2	1.5850
3 mm.	3	1.5852
8 mm.	4	1.5876



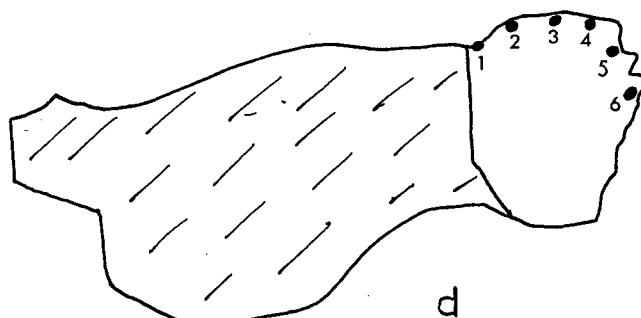
U10-11.5

	1	1.5931
13 mm.	2	1.5928
9 mm.	3	1.5884
8 mm.	4	1.5862
8 mm.	5	1.5859



A-229.2

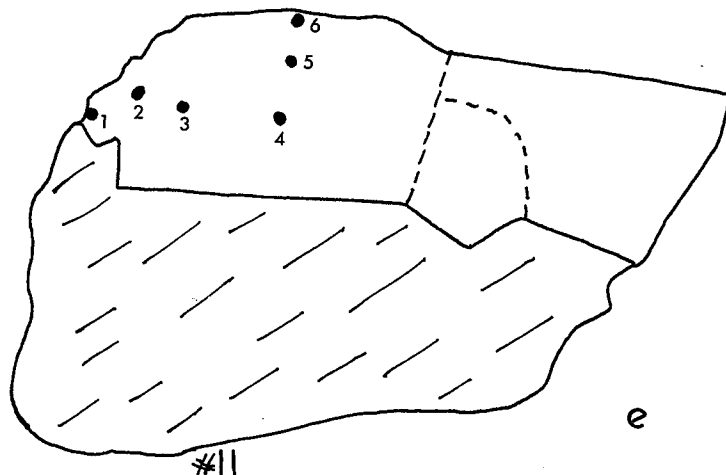
	1	1.5842
3 mm.	2	1.5865
2 mm.	3	1.5860
3 mm.	4	1.5860



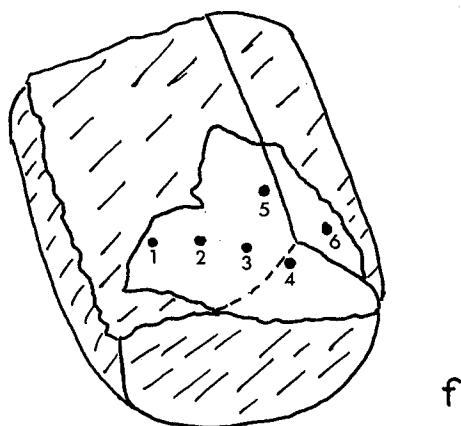
BLM-2

	1	1.5934
8 mm.	2	1.5932
8 mm.	3	1.5920
6 mm.	4	1.5902
7 mm.	5	1.5922
7 mm.	6	1.5930

Figure 15a-g. Sketches of beryl crystals studied for zoning showing the change of ω through the crystal over a measured distance. To be continued.

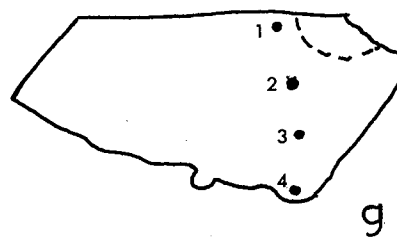


- #11
- | | |
|---|--------|
| 1 | 1.5930 |
| 2 | 1.5928 |
| 3 | 1.5924 |
| 4 | 1.5914 |
| 5 | 1.5928 |
| 6 | 1.5934 |



L19-4952

- | | |
|---|--------|
| 1 | 1.5928 |
| 2 | 1.5922 |
| 3 | 1.5882 |
| 4 | 1.5864 |
| 5 | 1.5918 |
| 6 | 1.5920 |



BLM 2A pink

- | | |
|---------|--------|
| 1 | 1.5922 |
| 7 mm. 2 | 1.5902 |
| 5 mm. 3 | 1.5900 |
| 5 mm. 4 | 1.5895 |

Figure 15a-g. - continued.

As a result of the zoning within the crystals, care was taken to take grains for refractive index measurement from the outer edge of the crystals so that comparison of ω for beryls from different zones would make sense. (i.e. would not involve changes in ω due to crystal zoning). It was, however, difficult to tell in some cases if a given surface on an irregular shaped grain in a core sample was, in fact, the outermost surface of that grain. The average values of ω mentioned earlier may have been slightly affected by zoning.

Partial chemical analysis

Samples of high, low and average values of ω were selected for partial chemical analysis. The samples were also selected to represent zones (2), (4), and (6). Material for analysis was taken from the area immediately around the point where ω had been measured in an attempt to keep the effects of zoning to a minimum. Table IX shows the results of the analyses as well as the value of ω for each sample.

The value of ΣR_2O is proportional to ω (Figure 16). The increase in ω from the outer zones towards the inner zones of the pegmatite is paralleled, therefore, by a similar increase in ΣR_2O as can be seen from Table IX and Figure 16. Low or high values of ΣR_2O in a given zone may be due to crystal zoning. In general ΣR_2O increases towards the center of the pegmatite as can be seen from the following average* values (in wt.%) of ΣR_2O : wall zone (2) 4.82, lower intermediate zone (4) 4.77, central intermediate zone (6) 5.10 and lepidolite zone (9) 6.48. Within the central intermediate zone (6)

* Average values of ΣR_2O include ΣR_2O of those samples fully analysed (Table X).

TABLE IX

Partial Chemical Analyses and ω for Beryl Samples

Sample Number	Zone	Oxides in Wt. %						ΣR_2O + CaO	ω
		CaO	K ₂ O	Na ₂ O	Li ₂ O	Rb ₂ O	Cs ₂ O		
T - 244.4	Wall (2)	0.078	0.022	1.76	1.13	0.044	2.38	6.116	1.5870
M20 - 314.2	Wall (2)	0.050	0.049	1.63	1.10	0.056	2.23	5.115	1.5925
L13 - 555.9	Wall (2)	0.035	0.067	1.62	0.29	0.025	0.18	2.217	1.5800
L9 - 399.0	Wall (2)	0.034	0.032	1.53	1.07	0.057	2.66	5.383	1.5930
L9 - 388.4	Wall (2)	0.057	0.057	1.89	1.18	0.061	2.91	6.155	1.5929
L9 - 393.0	Wall (2)	0.109	0.037	1.58	1.02	0.053	2.53	5.329	1.5930
L19 - 398.6	Wall (2)	0.013	0.024	1.26	0.68	0.034	0.45	2.416	1.5878
L19 - 510.5	Wall (2)	0.018	0.034	1.92	1.08	0.058	2.71	5.820	1.5926
L19 - 495.2	L. Inter. (4)	0.023	0.043	1.84	1.19	0.056	2.53	5.682	1.5864
L16 - 512.0	L. Inter. (4)	0.135	0.149	1.86	1.09	0.065	2.67	5.969	1.5930
A - 229.2	Wall (2)	0.035	0.029	1.32	0.70	0.036	0.55	2.670	1.5892
M9 - 284.4	Wall (2)	0.030	0.052	1.30	0.69	0.036	0.47	2.578	1.5814
M9 - 257.5	Wall (2)	0.028	0.031	1.48	0.72	0.035	0.50	2.794	1.5816
U21 - 2.0	C. Inter. (6)	0.015	0.270	1.46	1.27	0.104	3.06	6.179	1.5928
U10 - 5.7	C. Inter. (6)	0.015	0.029	1.26	1.06	0.070	2.83	5.264	1.5930
C62 - 405.0	C. Inter. (6)	0.045	0.050	1.60	1.05	0.066	2.86	5.671	1.5930
#5	C. Inter. (6)	0.015	0.038	1.20	0.95	0.068	2.60	4.871	1.5932
Zone(6) Contact	C. Inter. (6)	0.675	0.034	2.02	1.21	0.054	3.00	6.993	1.5931
Vein	C. Inter. (6)	0.040	0.031	1.52	1.17	0.061	2.78	5.602	1.5930

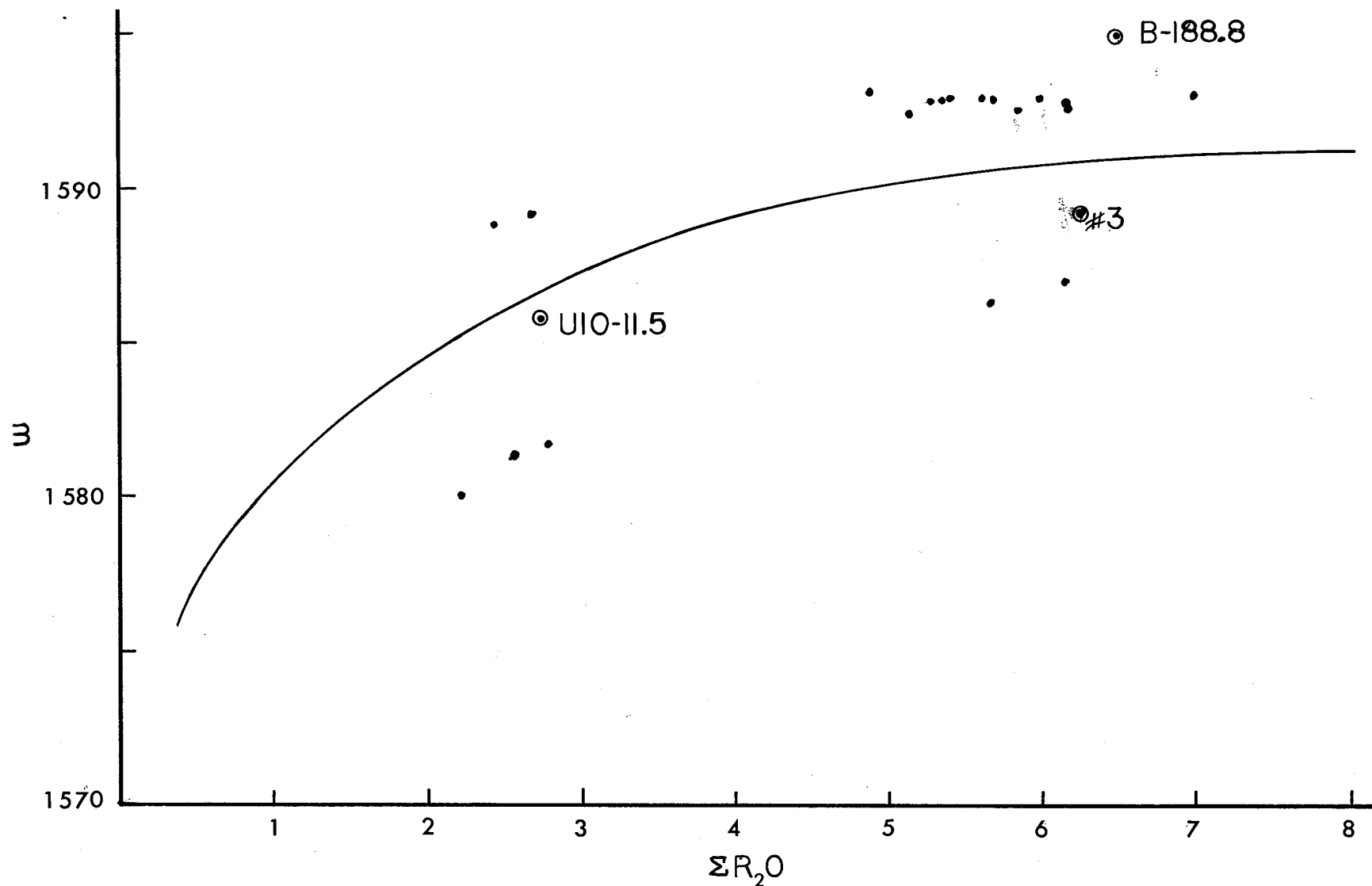


Figure 16. Refractive index (ω) vs. ΣR_2O for beryl (after Feklitchev, 1964) with positions of the beryls from the present study superimposed. Samples in circles are those that were chemically analysed in full.

TABLE X

Full Chemical Analyses for Beryl from the Tanco Pegmatite and Other Pegmatites

Oxide Wt. %	Sample #	U10 11.5	B 188.8	#3*	1	2	4
SiO ₂		62.35	62.00	62.078	61.28	62.97	62.17
Al ₂ O ₃		17.50	17.71	17.505	17.25	17.45	17.90
Fe ₂ O ₃		0.0269	0.0183	0.0784	0.12	Tr.	0.08
Li ₂ O		0.98	1.13	1.395	1.33	1.18	1.33
Na ₂ O		1.38	1.68	1.742	1.86	0.86	1.28
K ₂ O		0.046	0.266	0.073	0.65	0.16	0.19
Rb ₂ O		0.0715	0.1089	0.0642	0.17	-	0.05
Cs ₂ O		2.47	3.27	3.045	4.09	3.01	4.60
BeO		11.66	11.32	11.704	10.47	11.56	10.88
MgO		0.001	0.017	0.003	-	-	0.05
CaO		0.007	0.030	0.121	0.10	0.12	0.03
MnO		0.0014	0.0043	0.0005	0.03	0.01	0.01
H ₂ O ⁺		1.96	2.06	2.192	-	2.22	1.84
H ₂ O ⁻		0.08	0.07	0.052	-	-	-
TiO ₂		-	-	-	-	-	0.01
Ign. Loss		-	-	-	2.72	-	-
Total		98.53	99.68	99.70	99.97	99.86	100.02
Zone		C.I. (6)	Lep. (9)	C.I. (6)			
Density		2.7402	2.7812	2.7744			
ω		1.5859	1.5940	1.5890			
ω check		1.5865- 1.5867	1.5930- 1.5938	1.5892			
U.C.D. a		9.2116 ±.0009	9.2107 ±.0013	9.2149 ±.0009			
c		9.2237 ±.005	9.2162 ±.005	9.2488 ±.0088			

To be continued.

TABLE X - continued

1. Magaritra, Madagascar (Bakakin et al., 1970).
 2. Morganite, Zambezia, Mozambique (Bakakin et al., 1970).
 4. Yellowish transparent beryl, Kola Pen. (Bakakin et al., 1970).
- * Wt.%'s of sample #3 are those corrected for contamination by quartz
(see Table XIV).

one can see, from Table IX, that the beryl is fairly homogenous with reference to ΣR_2O and ω with only the odd irregular variation, probably due to crystal zoning.

The intense zoning within the crystals makes an accurate correlation of ΣR_2O and ω difficult. The value of ΣR_2O probably represents the average of two or more zones rather than only the one zone represented by the value of ω . The problem of crystal zoning complicates the apparent zoning in ΣR_2O contents of the beryls in the pegmatite since it is difficult to be sure that the same zone from crystal to crystal is being compared.

(c) Full Mineralogical Study

Three samples were selected for full mineralogical study: one of high ω (B188.8), one of low ω (U10-11.5), and one of average ω (#3).

Density and refractive index

The density as measured on the three samples was found to vary from 2.7402 to 2.7812 as can be seen from Table X which also lists the ω for each sample. Table X shows the values of ω obtained on a mixture of the grains used to measure the density.

The density of beryl is proportional to ω (Figure 17). Again, however, we run into the problem of crystal zoning. Since the density is directly proportional to ω , the density will increase towards the outer edges of the crystal. Since the densities shown in Table X and used in Figure 17 are averages of the densities of several grains, an error is introduced into the correlation of ω and density for it is difficult to say if all the grains used to measure the density came

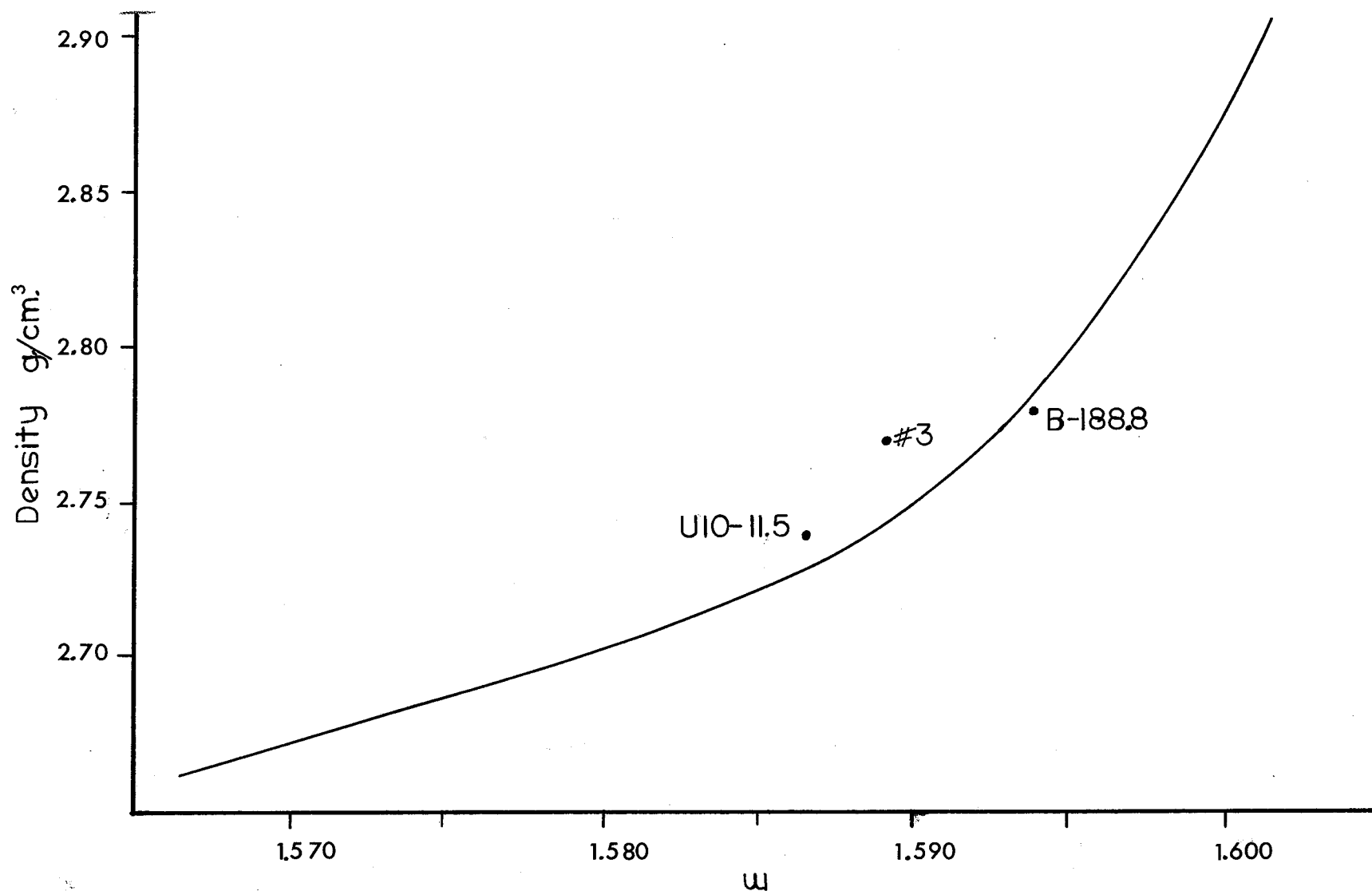


Figure 17. Density vs. ω for beryl (after Beus, 1960) with the samples from the present study superimposed.

from the zone of that particular ω . Examination of Table X will show that the mixture of grains used to measure the density was not homogeneous for samples U10-11.5 and B-188.8 and that for sample #3 the mixture was not from the zone of the crystal for which the original ω was measured.

Unit cell dimensions

The unit cell dimensions of the three beryl samples chemically analysed in full are listed in Table X. It is difficult to correlate the increase in the c dimension and ΣR_2O since the large amount (approximately 3 grams) of sample needed for full chemical analysis obviously represents a mixture of more than one zone in the beryl crystal.

Full chemical analysis

The results of the full chemical analyses of the Tanco beryls as well as the analyses of beryls from other pegmatites are shown in Table X. Table XI shows the calculation of the cation contents of the three Tanco beryls on the basis of 36 oxygens per unit cell. Table XII shows a further correction of the cation contents of Table XI based on 6 or 12 silicons since it is assumed that the silica content of beryl is constant and ideal.

Cations such as Na, Cs, Li, K, Rb and Ca, and molecules of H_2O enter the hollow channels in the beryl structure. Some Li may substitute for Be in the tetrahedral Be sites (Bakakin et al., 1969). The substitution of a univalent cation into the Be sites balances the charge introduced by the entry of univalent and divalent cations into the hollow channels. Aluminum may be partially replaced to a minor degree by Fe, Mg and Mn. Table XIII shows the formulas derived for the three Tanco beryls with the various cations in their respective

TABLE XI

Calculation of Cation Contents of Beryl Based on 36 Oxygens per Unit Cell

U10 - 11.5						
Oxide	Wt. %	Molec. Wt.	Mol. Ratio x 100	At. Ratio x100	At. Ratio Cat. x 100	Cation Content
SiO ₂	63.28	60.04	105.31	210.62	105.31	11.967
Al ₂ O ₃	17.76	101.96	17.42	52.25	34.84	3.959
Fe ₂ O ₃	0.027	159.70	0.016	0.048	0.03	0.004
Li ₂ O	0.994	29.88	3.33	3.33	6.65	0.756
Na ₂ O	1.400	61.98	2.26	2.26	4.52	0.513
K ₂ O	0.046	94.20	0.048	0.048	0.096	0.011
Rb ₂ O	0.072	186.96	0.038	0.038	0.076	0.009
Cs ₂ O	2.506	281.181	0.89	0.89	1.78	0.202
BeO	11.833	25.01	47.31	47.31	47.31	5.376
MgO	0.001	40.31	0.002	0.002	0.002	0.0002
CaO	0.007	56.08	0.012	0.012	0.012	0.001
MnO	0.0014	70.94	0.001	0.001	0.001	0.0001
H ₂ O ⁺	1.989	18.02	(11.04)	(11.04)	22.07	2.508
H ₂ O ⁻	0.081	18.02	(0.45)	(0.45)	0.898	0.102
	$\frac{36}{316.81} = .1136345$			316.81		

To be continued.

TABLE XII

Calculation of Cation Contents Based on Si

	U10 - 11.5				B - 188.8				#3			
Oxide	Cation Content	Back Calc. on 12Si	Cation Content 2	Back Calc. on 6 Si	Cation Content	Back Calc. on 12Si	Cation Content 2	Back Calc. on 6 Si	Cation Content	Back Calc. on 12Si	Cation Content 2	Back Calc. on 6 Si
SiO ₂	11.967	11.9999	5.9835	5.99995	11.911	11.99997	5.9555	5.9998	12.106	11.99995	6.0530	5.99997
Al ₂ O ₃	3.959	3.9699	1.9795	1.9849	4.010	4.03995	2.0050	2.01997	3.777	3.7439	1.8885	1.87195
Fe ₂ O ₃	0.004	0.0040	0.0020	0.0020	0.003	0.0030	0.0015	0.0015	0.010	0.0099	0.0050	0.00495
Li ₂ O	0.756	0.7581	0.3780	0.3790	0.873	0.8795	0.4365	0.4398	0.991	0.9823	0.4955	0.4912
Na ₂ O	0.513	0.5144	0.2565	0.2572	0.626	0.6307	0.3130	0.3153	0.618	0.6126	0.3405	0.3375
K ₂ O	0.011	0.0110	0.0055	0.0055	0.065	0.06548	0.0325	0.0327	0.017	0.0169	0.0085	0.0034
Rb ₂ O	0.009	0.0090	0.0045	0.0045	0.013	0.0131	0.0065	0.0065	0.008	0.0079	0.0040	0.00396
Cs ₂ O	0.202	0.2026	0.1010	0.1013	0.268	0.2700	0.1340	0.1350	0.238	0.2359	0.1190	0.11795
BeO	5.376	5.3908	2.6880	2.6954	5.225	5.2640	2.6125	2.6320	5.147	5.1019	2.5735	2.55095
MgO	0.0002	0.0002	0.0001	0.0001	0.005	0.0050	0.0025	0.0025	0.001	0.00099	0.0005	0.00049
CaO	0.001	0.0010	0.0005	0.0005	0.006	0.0060	0.0030	0.0030	0.023	0.0238	0.0120	0.0119
MnO	0.0001	0.0001	0.00005	0.00005	0.001	0.0010	0.0050	0.0005	0.0001	0.00009	0.00005	0.00004
H ₂ O ⁺	2.508	2.5149	1.2540	1.2574	2.639	2.6587	1.3195	1.3294	2.676	2.6526	1.3380	1.3263
H ₂ O ⁻	0.102	0.1023	0.0510	0.0511	0.089	0.0897	0.0445	0.0448	0.063	0.0624	0.0315	0.0312
	$\frac{12}{11.967} = 1.00275$		$\frac{6}{5.9835} = 1.00275$		$\frac{12}{11.911} = 1.00747$		$\frac{6}{5.9555} = 1.00747$		$\frac{12}{12.016} = 0.99124$		$\frac{6}{6.0530} = 0.99124$	

TABLE XIII

Unit Cell Content and Site Population of the Tanco Beryls Following the Crystallochemical Interpretation of Bakakin
et al. (1970)

Sample Number	O ₂	T ₃	T ₆ X ₁₈	R _n
U10 11.5	Al Fe Mg Mn 3.959 0.004 0.0002 0.0001	Be Li 5.376 0.624	Si O 11.976 36	Na Cs Li K Rb Ca H ₂ O 0.513 0.202 0.132 0.011 0.009 0.001 1.254
B 188.8	Al Fe Mg Mn 4.010 0.003 0.005 0.001	Be Li 5.225 0.775	Si O 11.911 36	Na Cs Li K Rb Ca H ₂ O 0.626 0.268 0.098 0.065 0.013 0.006 1.319
#3	Al Fe Mg Mn 3.988 0.011 0.001 0.0001	Be Li 5.435 0.565	Si O 12.00 36	Na Cs Li K Rb Ca H ₂ O 0.653 0.251 .481 0.018 0.008 0.025 1.413
U10 11.5	Al Fe Mg Mn 1.985 0.002 0.0001 0.00005	Be Li 2.695 0.305	Si O 6 18	Na Cs Li K Rb Ca H ₂ O 0.257 0.101 0.074 0.006 0.005 0.0005 0.629
B 188.8	Al Fe Mg Mn 2.02 0.002 0.003 0.0005	Be Li 2.632 0.368	Si O 6 18	Na Cs Li K Rb Ca H ₂ O 0.315 0.135 0.072 0.033 0.007 0.003 0.665
#3	Al Fe Mg Mn 1.999 0.006 0.0005 0.00005	Be Li 2.718 0.282	Si O 6.00 18	Na Cs Li K Rb Ca H ₂ O 0.326 0.126 0.241 0.009 0.004 0.013 0.707

TABLE XIV

Correction of Cation Content for Beryl #3 for Quartz Contamination by Setting Si 4 and the Content of the Octahedral Al Sites to 4.

Oxide	Cation Content	Corrected Cat. Cont. x 4 3.788	Atomic wt. of Cations	Molec. wt. of Cations	Molec. wt. of Oxygens	Molec. wt. of Oxide	Wt.% Oxide Corrected to 100 wt.%
Al_2O_3	3.777	3.988	26.982	107.604	995.706	203.310	17.505
Fe_2O_3	0.010	0.011	55.847	0.014	0.262	0.876	0.784
MgO	0.001	0.001	24.312	0.024	0.015	0.039	0.003
MnO	0.0001	0.0001	54.938	0.005	0.001	0.006	0.0005
BeO	5.147	5.435	9.012	48.980	86.954	135.934	11.704
Li_2O	0.991	1.046	6.939	7.258	8.367	15.625	1.345
SiO_2	12.106	12.000	28.086	337.032	383.976	721.008	62.078
Na_2O	0.618	0.653	22.990	15.012	5.223	20.235	1.742
Cs_2O	0.238	0.251	132.905	33.359	2.007	35.366	3.045
K_2O	0.017	0.018	39.102	0.703	0.143	0.846	0.073
Rb_2O	0.008	0.008	85.47	0.683	0.063	0.746	0.064
CaO	0.024	0.025	40.08	1.002	0.399	1.401	0.121
H_2O^+	2.676	2.826	1.008	2.848	22.606	25.454	2.192
H_2O^-	0.063	0.067	1.008	0.067	0.535	0.602	0.052
						1161.448	100.7085

positions with reference to the beryl structure.

Examination of the silicon content of sample #3 (Table XI) suggests this sample may be contaminated by quartz. The contamination of sample #3 by quartz was confirmed by the appearance of small quartz peaks on powder diffraction patterns run on the sample. The sample was corrected for quartz contamination by setting the cation content of silicon equal to 12 and then setting the cation content of the octahedral aluminum sites equal to 4 instead of 3.788 as it is in Table XI. The other cations were adjusted proportionally to the increase in the aluminum content. Table XIV shows the results of this correction for quartz contamination.

Both density and ω are proportional to ΣR_2O (Beus, 1960). Figure 18 shows a plot of density versus ΣR_2O for the three fully analysed Tanco beryls. Figure 16 (ΣR_2O versus ω for the partially analysed beryls) also shows the values of ΣR_2O for the fully analysed samples.

(d) Secondary Cesian Beryls

The following are the results of research done by Dr. P. Černý (1972). The occurrence of cesian beryl is rare, the beryl being found only in assemblage 1 of zone (5) (see Figure 12 in Chapter II). According to Černý (1972),

"It forms either larger crystals (up to 4 x 12 mm.) with colourless core overgrown by a pale pink zone, or small colourless prisms (up to 1.5 x 6 mm.) that seem to have crystallized later than the larger crystals. Both types of beryl are deeply corroded, and the etching grooves and crosscutting fractures are usually filled with clay minerals."

The pink outer zone of the larger crystals shows higher refractive indices than the colourless core and the colourless prisms

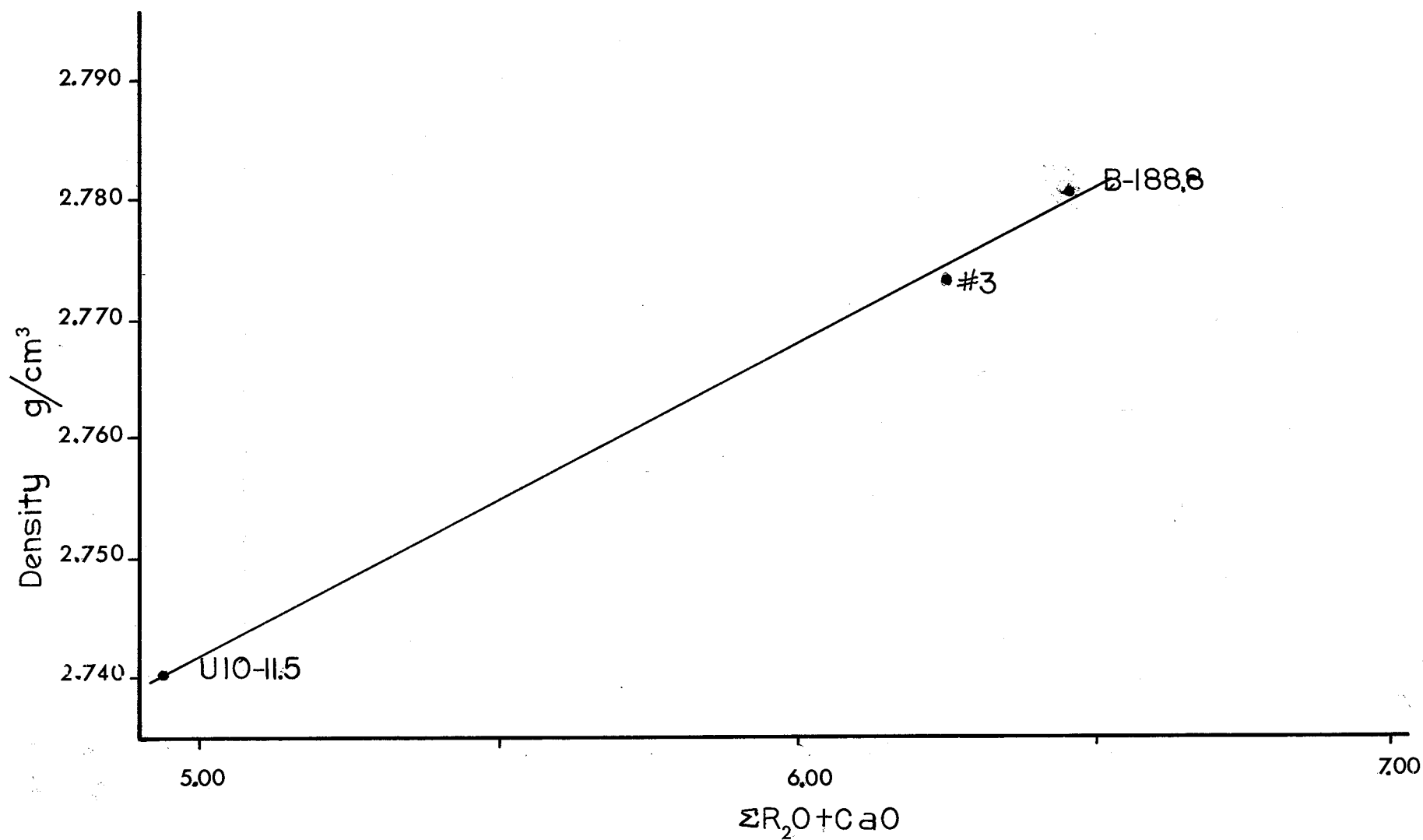


Figure 18. Density vs. $\Sigma\text{R}_2\text{O}$ for the three beryl samples chemically analysed in full.

TABLE XV

Physical Properties of Cesian Beryl (after Černý, 1972)

Sample Number	ϵ	ω	$\epsilon - \omega$	$a(\text{\AA})$	$c(\text{\AA})$
1 - 1 Core colourless	1.589	1.596	0.007	$9.2176 \pm .0009$	$9.2469 \pm .0020$
Rim pink	1.596	1.604	0.008	$9.2132 \pm .0007$	$9.2541 \pm .0013$
1 - 2 Colourless	1.602	1.610	0.008	-	-

of the second generation have even higher indices (Table XV). Partial chemical analysis of the pink outer zone showed 9.58 wt.% BeO, 0.32 MgO, 0.01 CaO, 0.12 FeO, 0.02 MnO, 1.6. Li₂O, 1.30 Na₂O, 0.80 K₂O, 0.18 Rb₂O and 7.16 Cs₂O. These contents agree with the unit cell dimensions shown in Table XV.

CHAPTER IV PETROLOGICAL CONCLUSIONS

(a) Pollucite

The eastern pollucite body of the Tanco pegmatite appears to be fairly homogenous and free of large scale internal zoning as indicated by both the refractive indices and the cesium content which drop only slightly toward the outer margins of the pollucite body.

According to Crouse and Černý (1972),

"The location of these [pollucite] bodies in the upper parts of the pegmatite, in the upper intermediate zone (5), suggests that they might represent monomineral segregations within this zone. This is supported by the presence of coarse and irregular "graphic" intergrowths of petalite and pollucite, and by some accumulation of amblygonite-montebrazite and manganoan apatite along the boundaries of the pollucite bodies. The alleged pollucite replacing spodumene observed by Wright (1963) is probably a late secondary cesian analcime (Černý, 1972b); pollucite seems to be contemporaneous with petalite which broke down to spodumene + quartz only later."

The uniformity of the pollucite may also support the concept of monomineralic separation.

The pollucite from the isolated pods appears to have a slightly lower cesium content (29.36 wt.% Cs_2O) than the pollucite from the eastern pollucite body (31.29 wt.% Cs_2O). These pods may also be small monomineralic separations since they show no metasomatic effects along the contact with the enclosing zone (5).

There are basically two types of alterations of the pollucite. The first type appears as veins 1 to 20 mm. thick cutting the massive pollucite in a polygonal network. These veins are composed mostly of spodumene, quartz, pollucite, microcline and albite. These coarse veins appear to be fracture fillings and not of metasomatic origin. The second type of alteration appears as fine veins or patches in the milky pollucite groundmass. The fine veins and patches are composed of

fine-grained spodumene (with minor quartz) and are usually rimmed with colourless mica. Some veins were noted to be completely filled only with colourless mica. Some of the spherical masses contained clay minerals, traces of which were also noted intermittently throughout the milky pollucite matrix. The small-scale veins and patches of alteration are believed to be metasomatic in origin because they replace pollucite around fissures.

(b) Secondary Cesian Analcime

According to Černý (1972), the alteration of spodumene + quartz intergrowths yielded some rare minerals, such as secondary Cs-analcime and secondary Cs-beryl in rather unusual assemblages.

(c) Beryl

In zone (6) the beryls occur along the contacts of fine-grained bluish albitic aplite and smoky to grayish quartz pods, and in a medium- to coarse-grained microcline-perthite. Several of the beryl samples also appeared associated with a greenish mica.

As shown in Chapter III, of this report, the refractive index(ω) (and in general ΣR_2O) of the beryls increases from the outer zones to the inner zones of the pegmatite. This increase in ΣR_2O and refractive index(ω) towards the center of the pegmatite suggests that in the later stages of differentiation the fluid from which the pegmatite crystallized was enriched in alkalis.

The beryl crystals are strongly zoned having the highest value of ω in the outermost zones of the crystal. Thus the outermost zones are more alkali-rich suggesting that the fluid from which they crystallized was more alkali-rich in the later stages of its differentiation.

(d) Secondary Cesian Beryls

Secondary cesian beryls found in the upper intermediate zone (5) formed as a result of late alteration of spodumene and quartz aggregates. Figure 12 in Chapter II shows the sequence of crystallization (according to Černý, 1972) of the one assemblage found to contain these rare secondary cesian beryls.

CHAPTER V ECONOMIC CONSIDERATIONS

(a) Pollucite

The pollucite zone of the Tanco pegmatite is the world's largest deposit of pollucite. The pollucite at the Tanco pegmatite contains on the average 32 wt.% Cs_2O . The pollucite may be of economic significance, in the future, if processes such as magnetohydrodynamics become widely used.

Magnetohydrodynamics is a method of generating electricity by direct heat conversion in which cesium acts as an ionizing agent in a helium plasma which is passed at high speed through a magnetic field. An electric current can be drawn off to run a generator. At present, research is being done on the application of magnetohydrodynamics on a large scale.

Other uses of cesium include the United States Government's Firefly project in which a canister of cesium is exploded in the ionosphere. The vaporized cesium is ionized by the heat of the explosion and disperses forming an electron cloud, from which signals may be bounced back to the earth within a radius of 700 miles from the launching site. Cesium has also been used in electronic (ion) engines for space propulsion. In tests run by the United States Government these engines were found to run for 17,000 hours (approximately 2 years).

The pollucite from the Tanco pegmatite shows regularly dispersed veining and alterations which lower the cesium content. This lowering of the cesium content of the pollucite seems relatively unimportant from an economic viewpoint because the grade of the ore still remains high (about 25 wt.% Cs_2O). What is important, however, is the

size of the pollucite body and the fact that the pollucite zone is essentially pure massive pollucite which could be mined easily and would need little further separation.

(b) Beryl

Beryl in the Tanco pegmatite occurs in zones (1), (2) and (9) but reaches maximum concentration in the central intermediate zone (6). The substitution of Li for Be in the beryl, however, lowers the BeO content of these beryls thus affecting their possible economic importance.

Beryl could be extracted economically as a byproduct of the separation of tantalum oxide minerals in present operation. If a suitable flotation method for the separation of beryl were found, it may possibly be the answer to the separation of the beryl for economic purposes.

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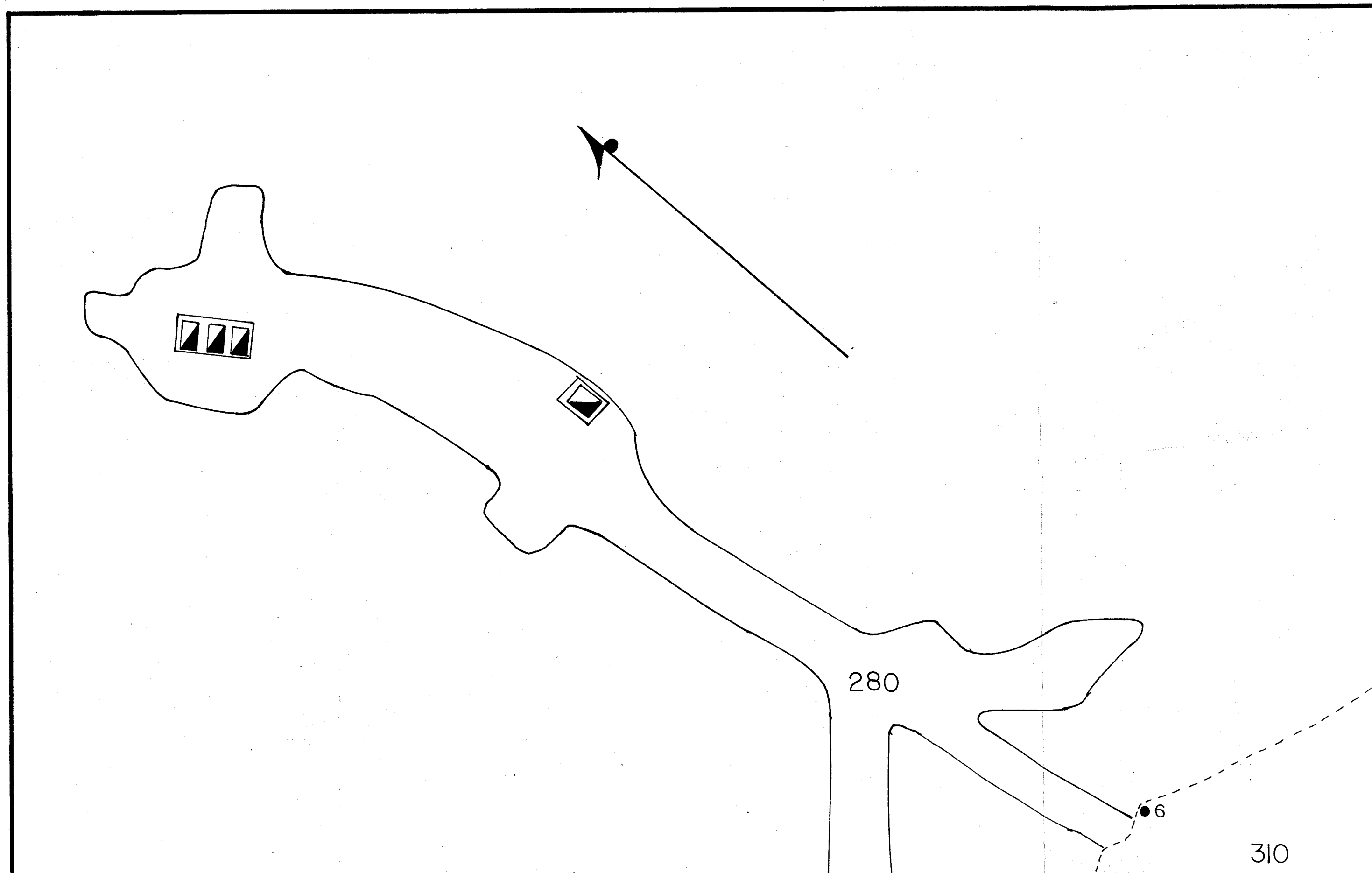
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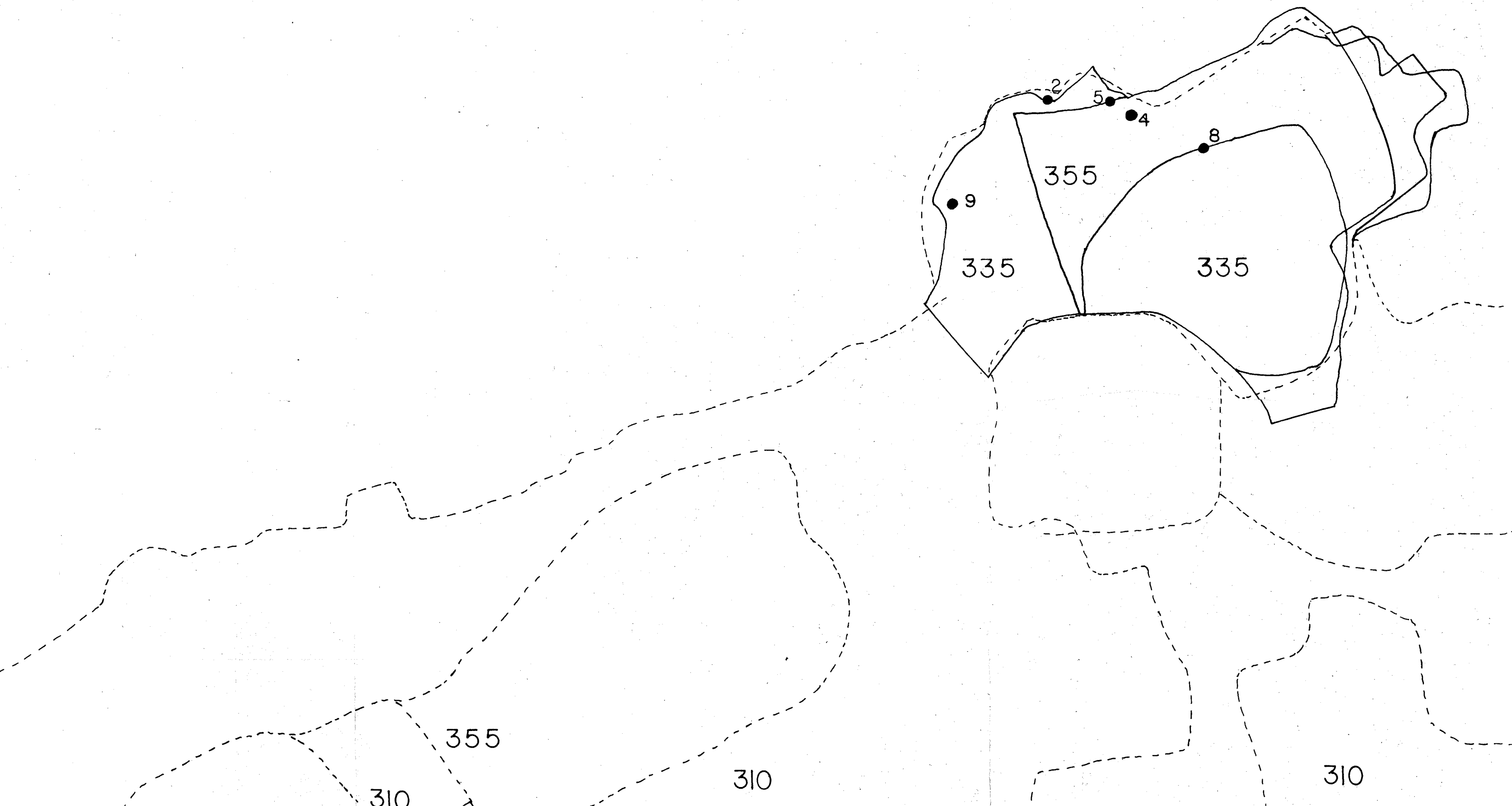
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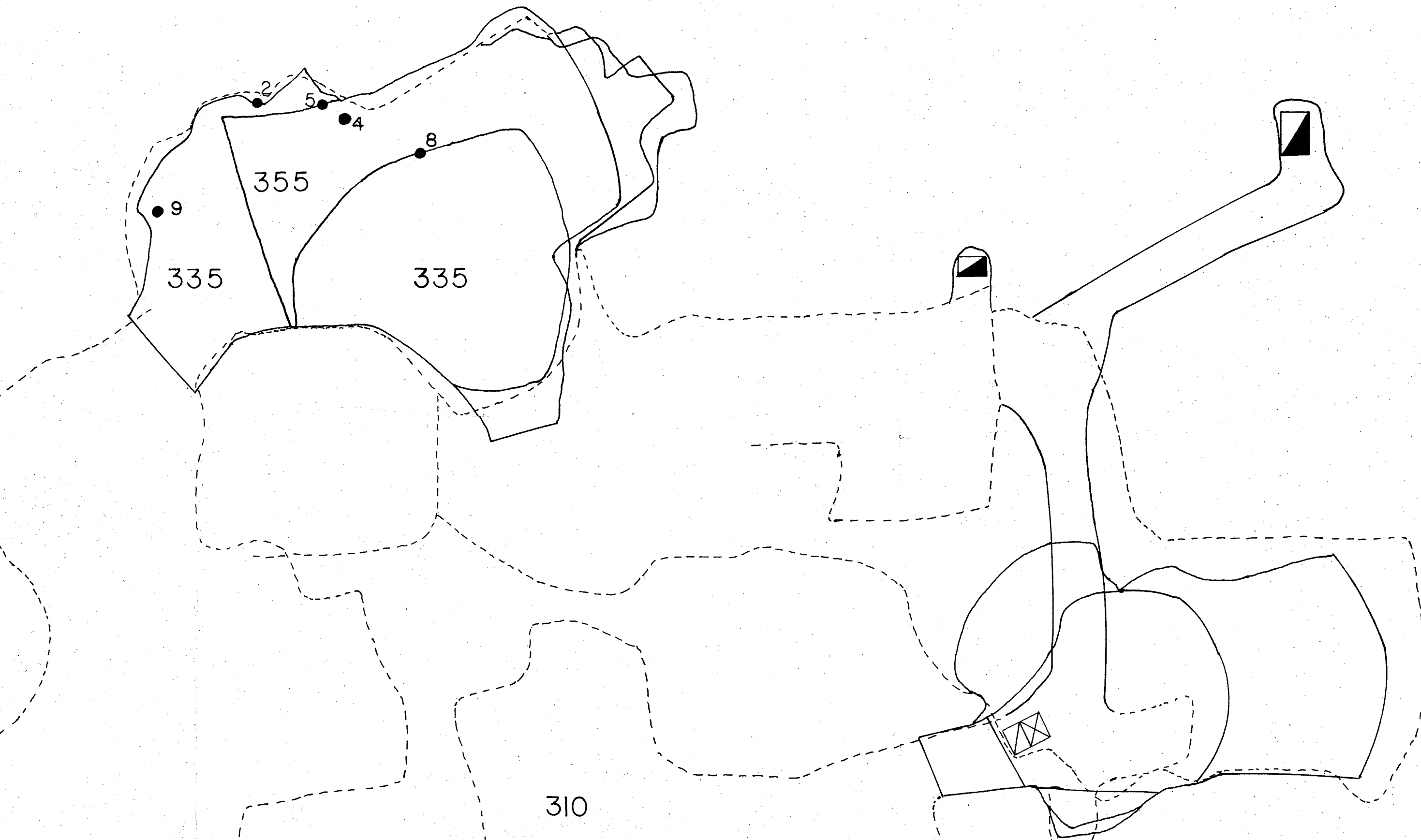
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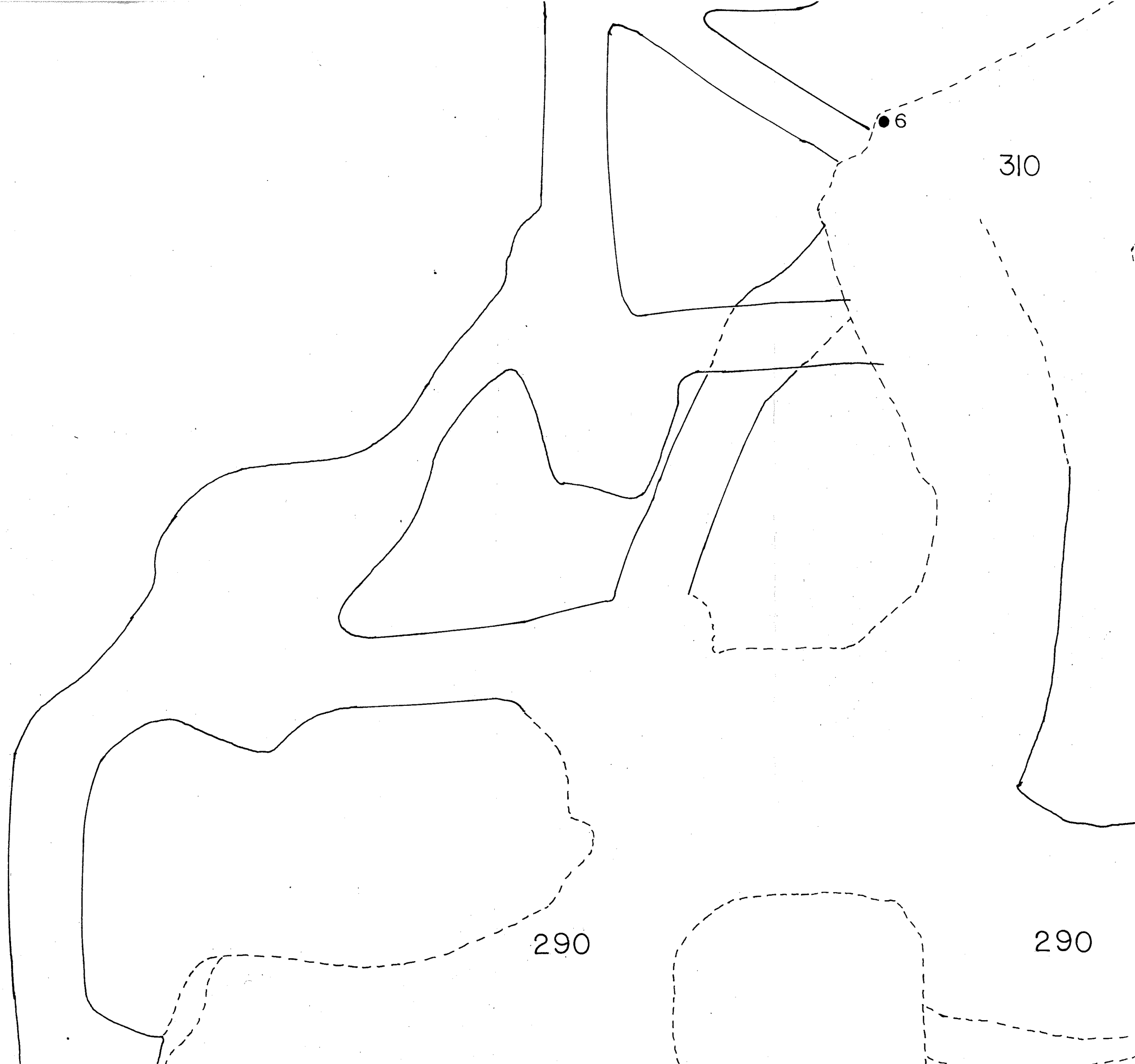
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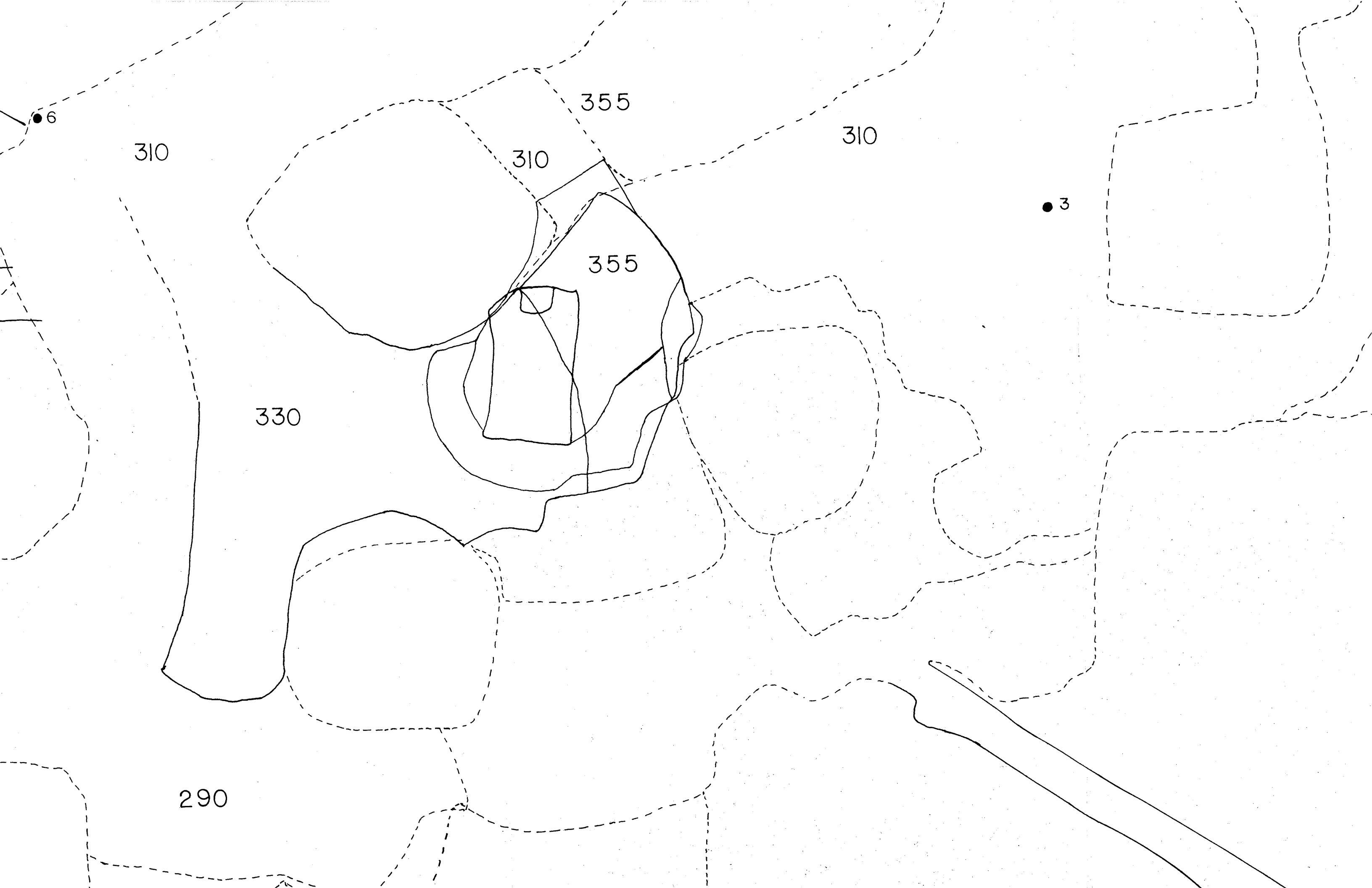
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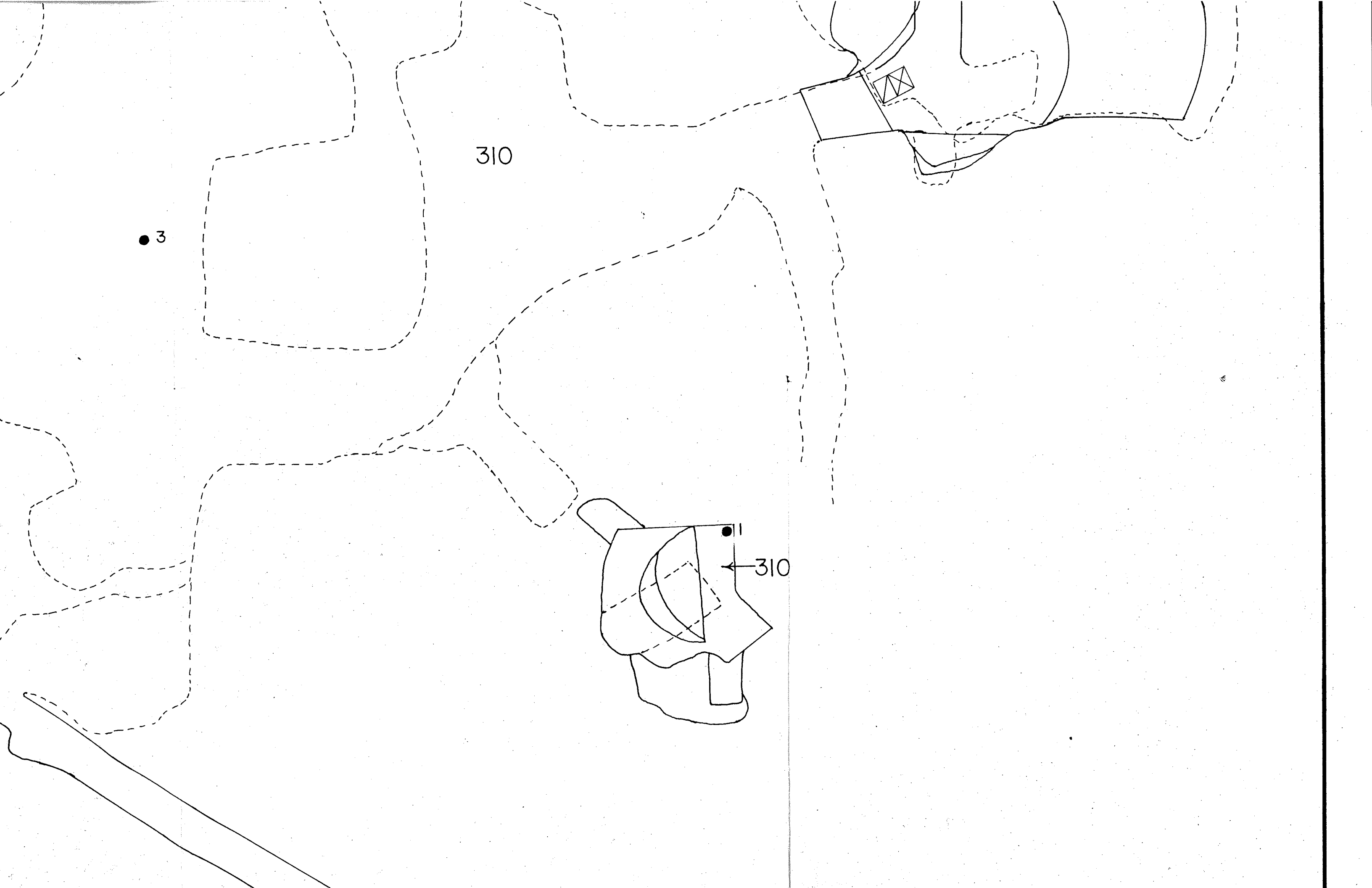


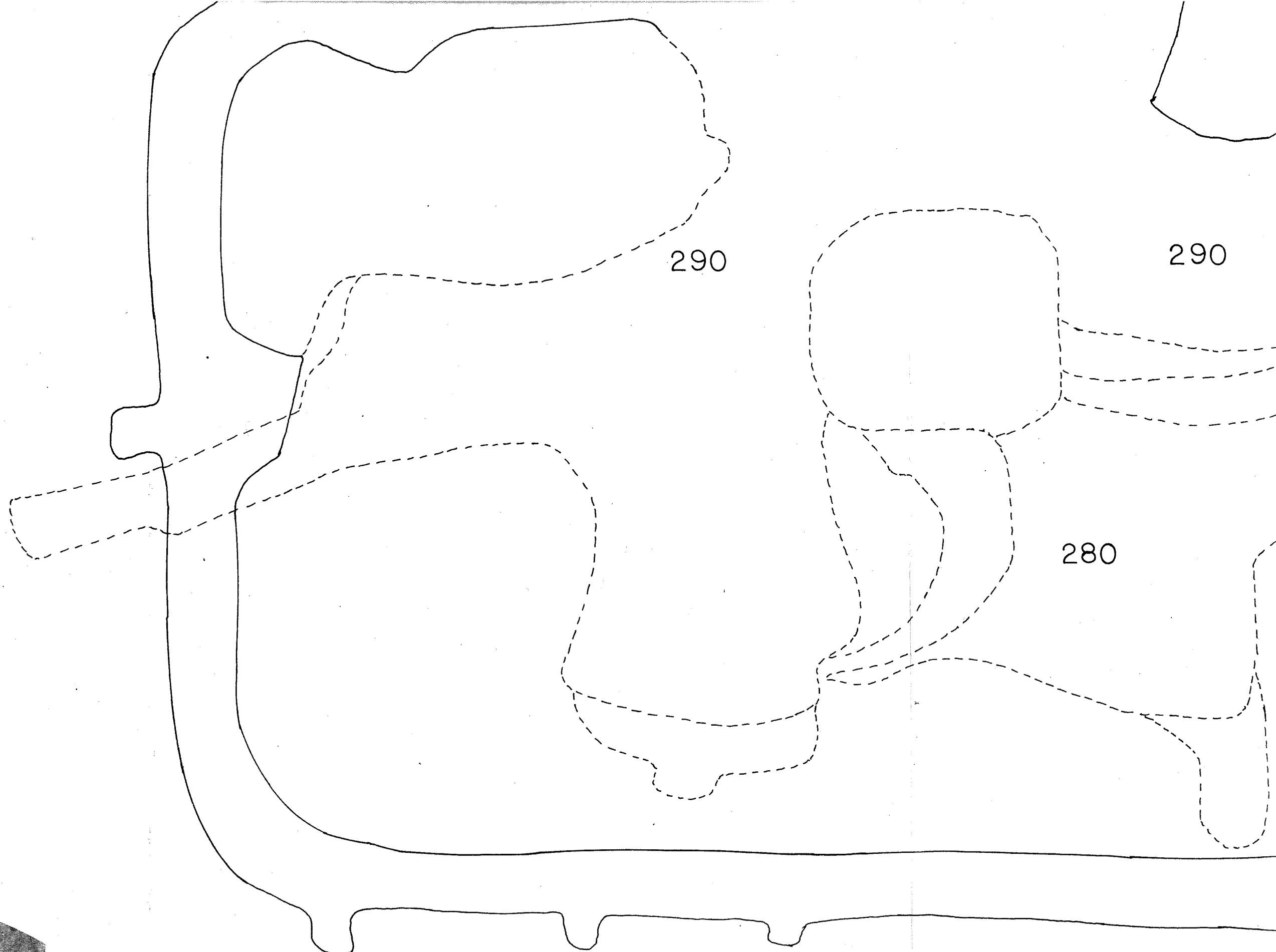






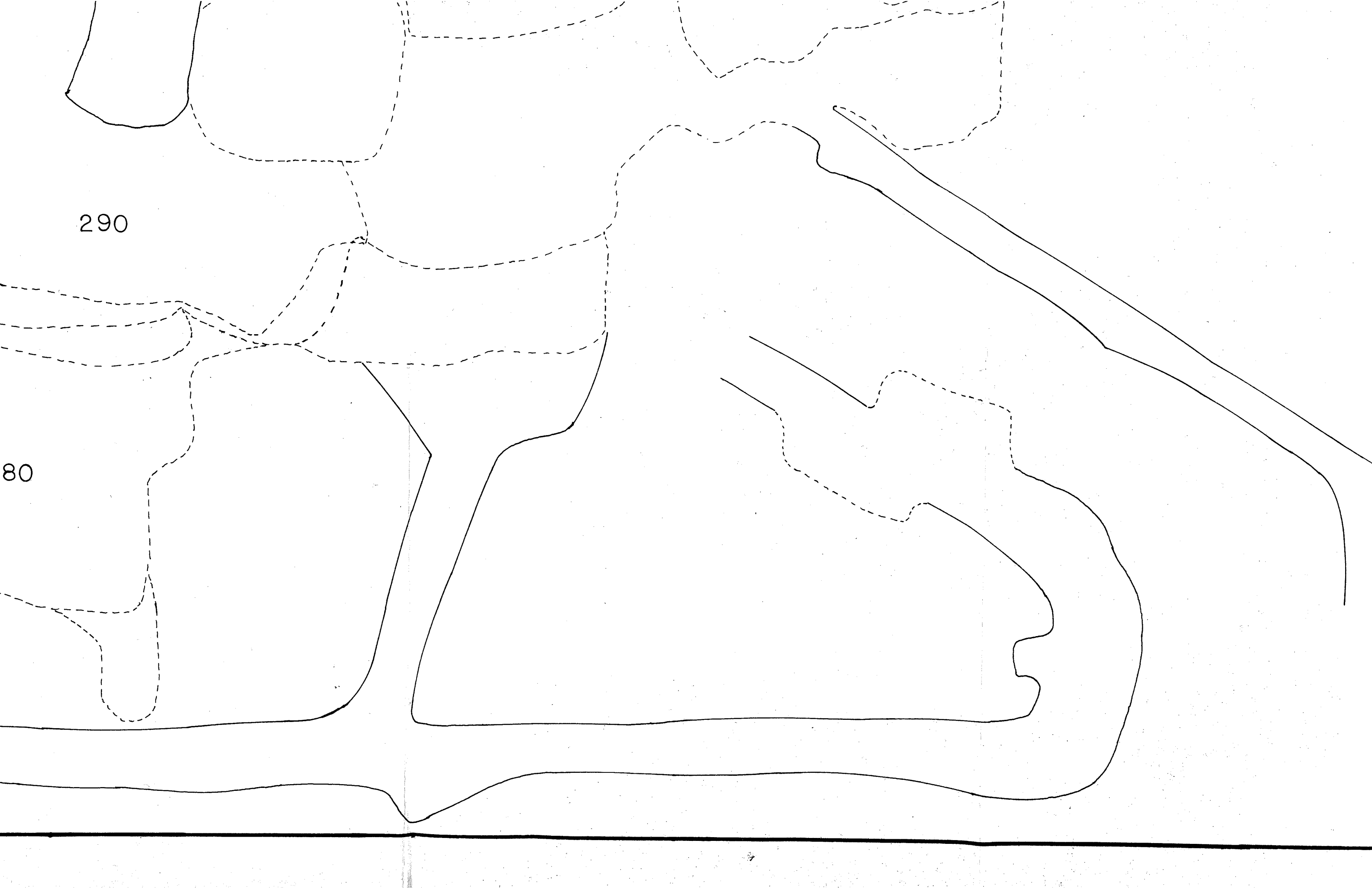






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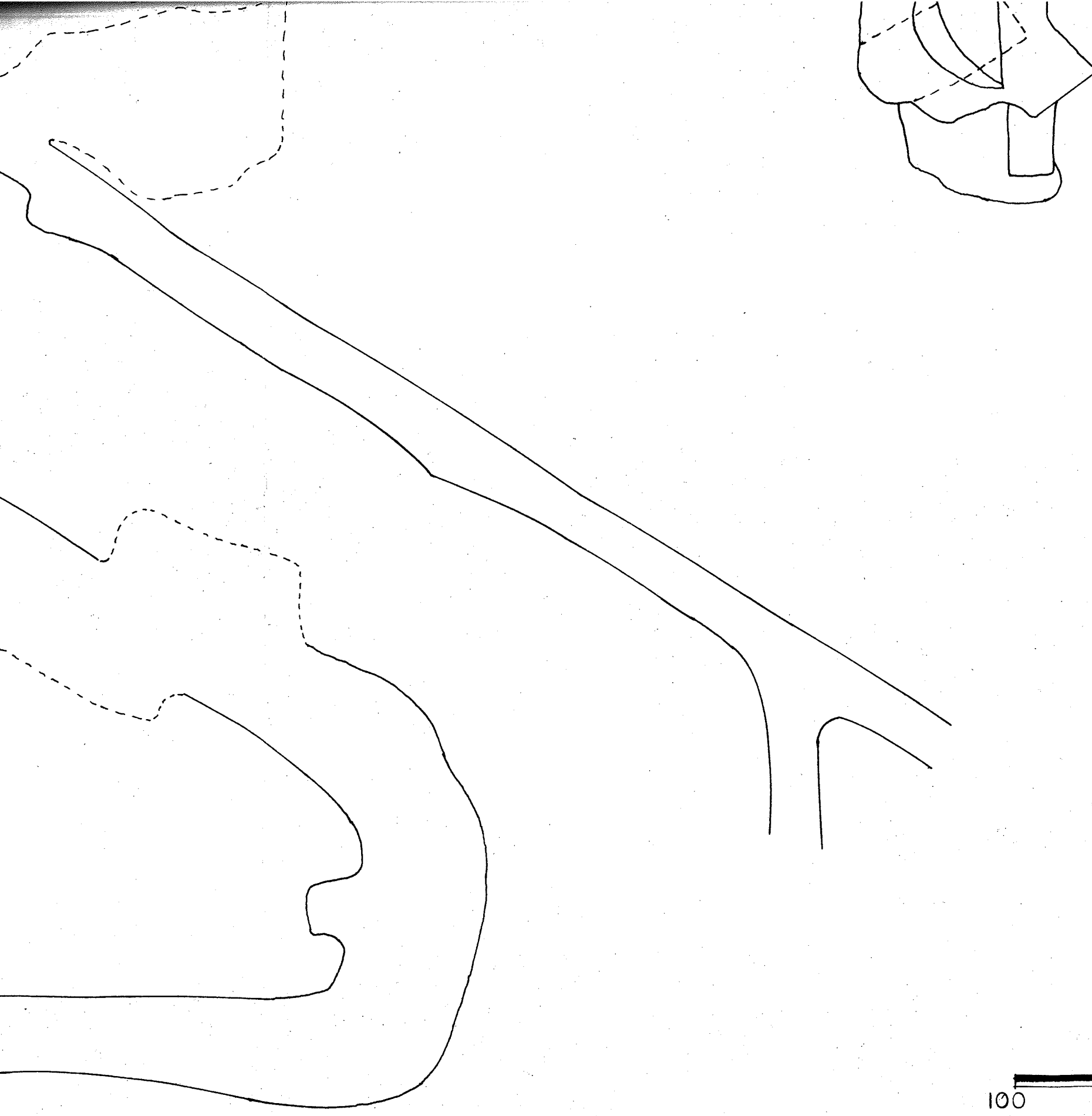
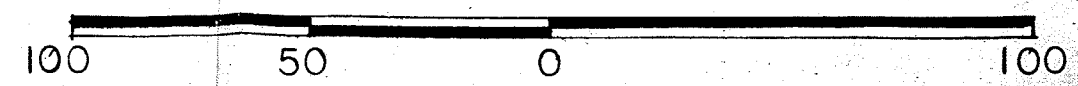
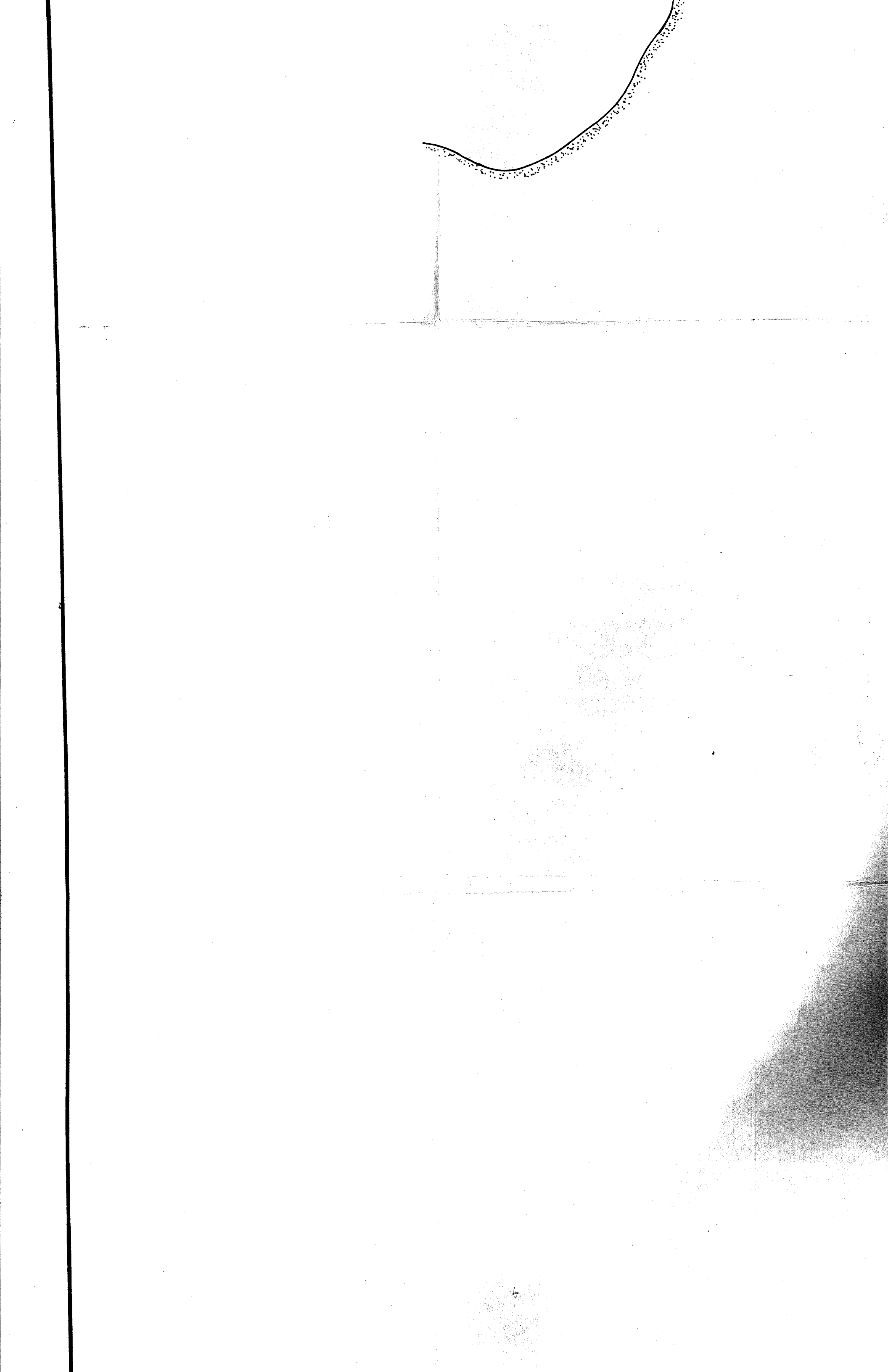


Figure 13. The Tanco mine showing the location of beryl samples collected underground from zone (6) (east). Based on maps of the Tantalum Mining Corporation of Canada Ltd..



• L 16

• L 19



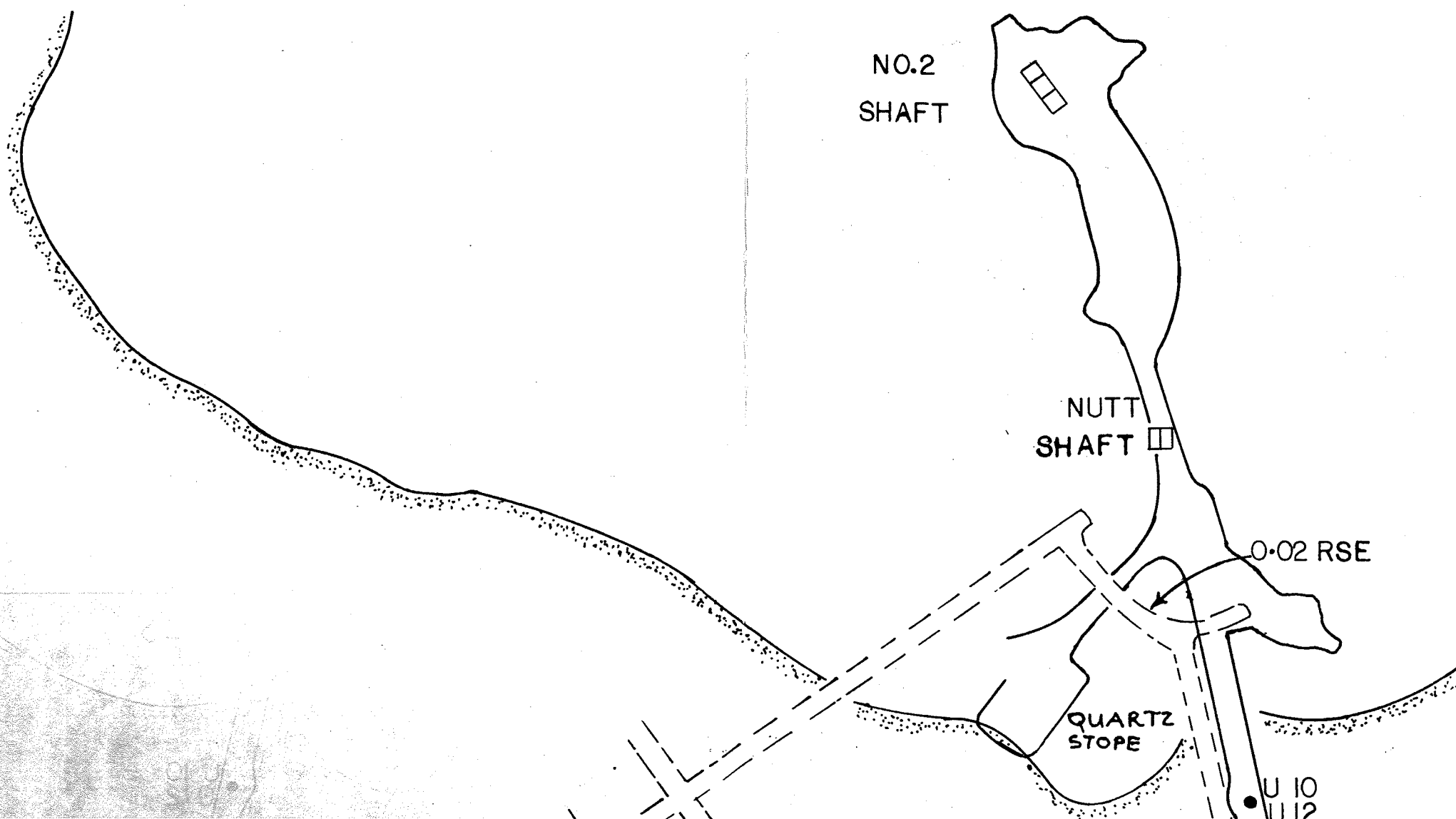
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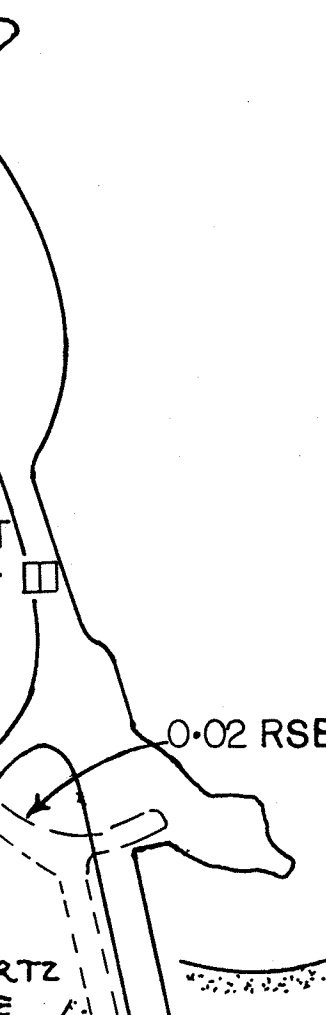
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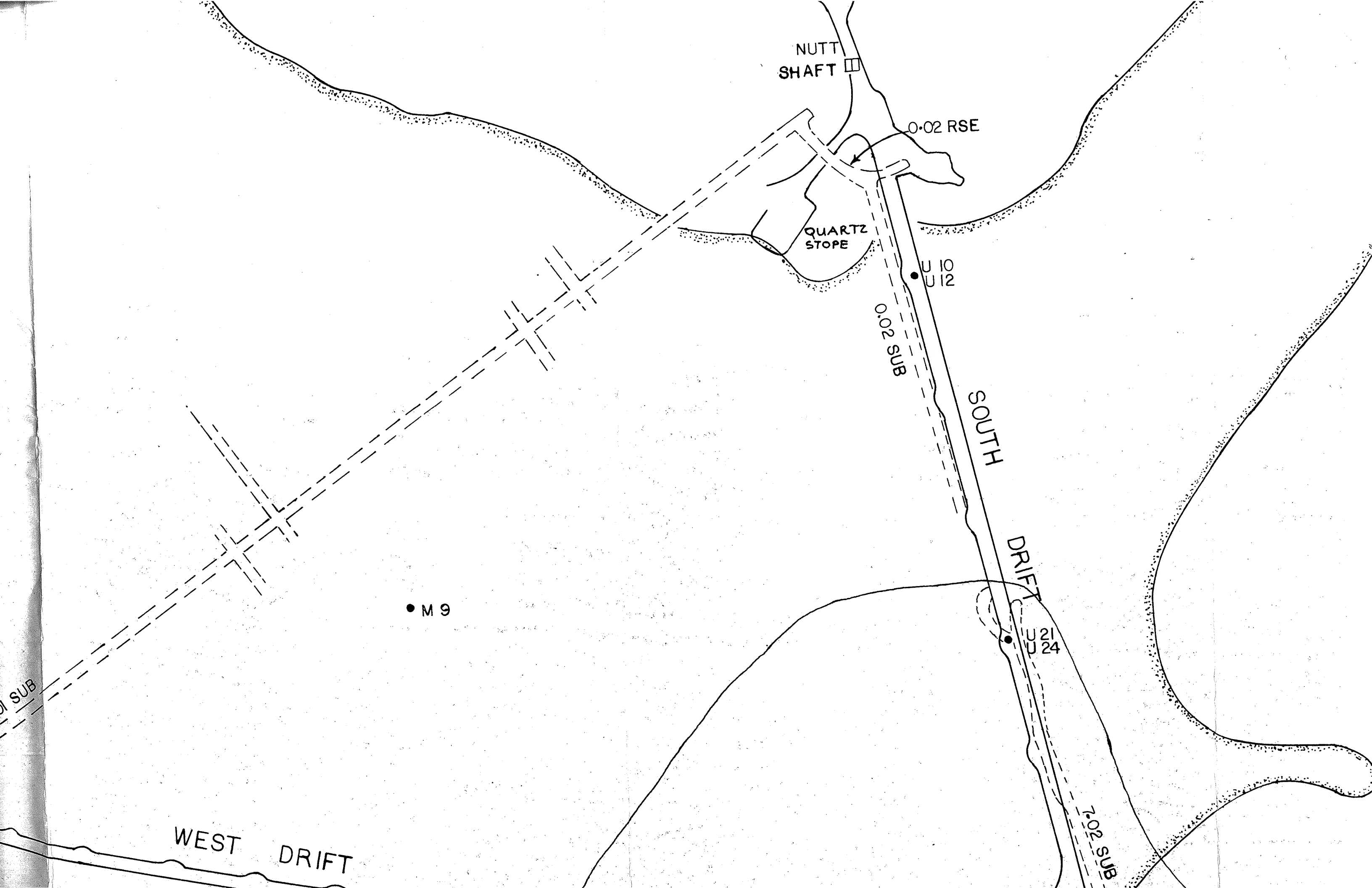
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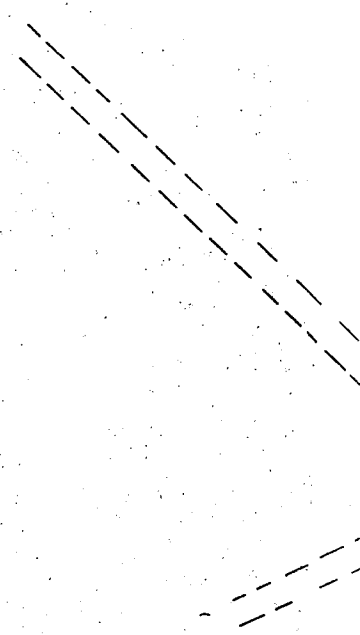




• L II

M 4
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• M 6



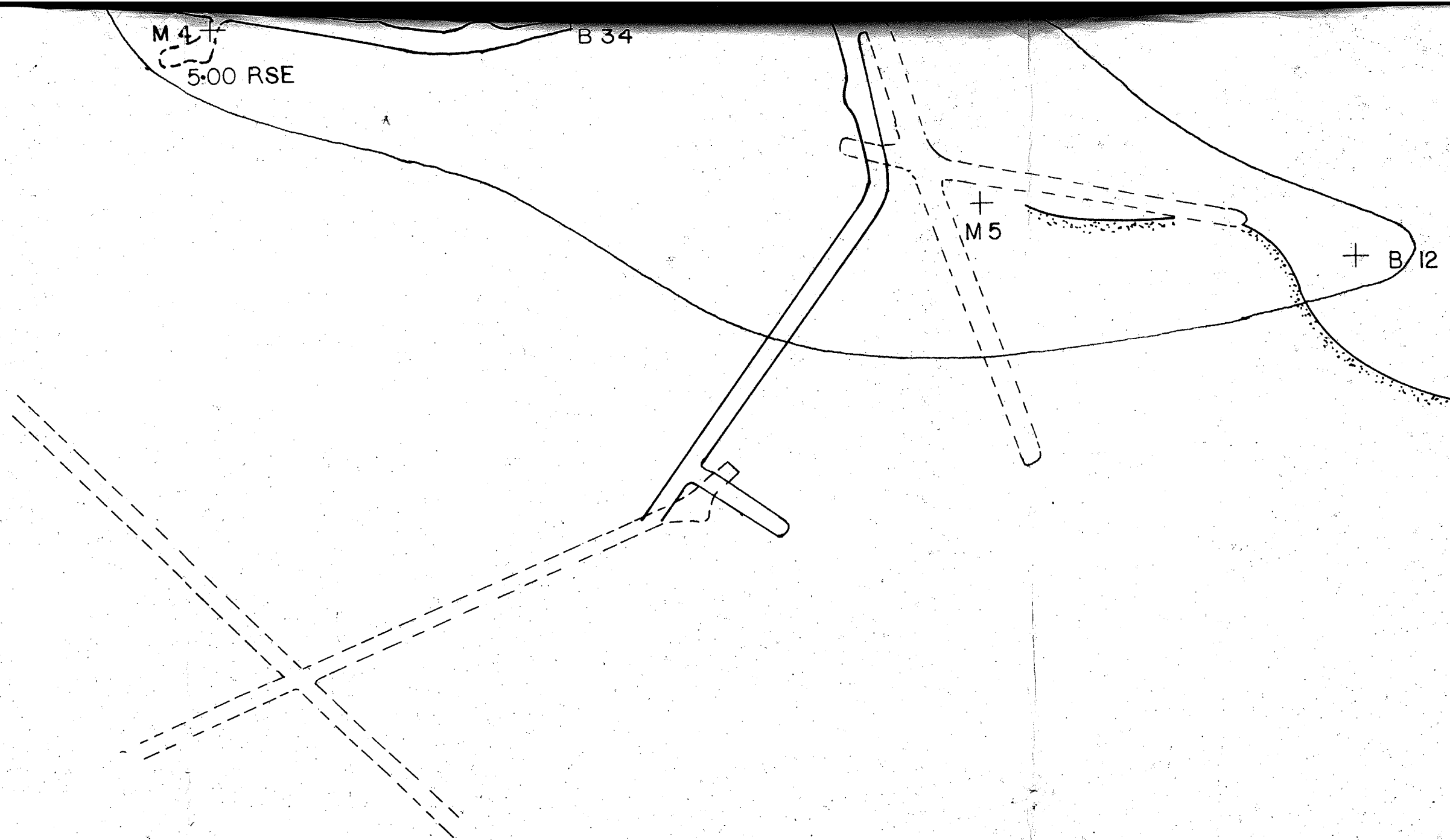


Figure 7. Plan of the Tanco mine showing the eastern pollucite body. Collars of drill holes sampled for pollucite are indicated by a circle, those sampled for beryl by a cross and those sampled for beryl and pollucite by a cross and circle. Based on maps of the Tantalum Mining Corporation of Canada Ltd..

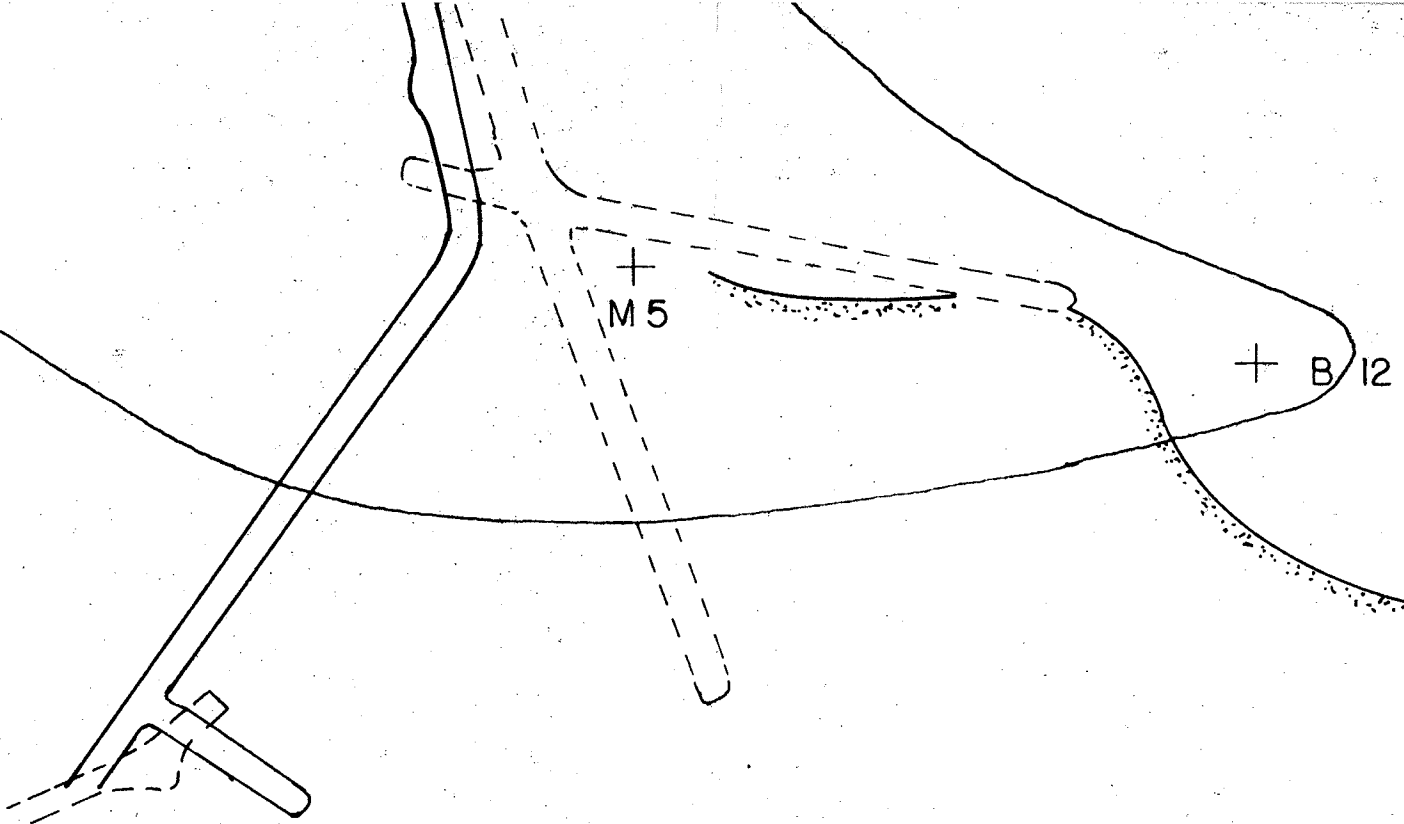


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FEET