State of Washington
ALBERT D. ROSELLINI, Governor

Department of Conservation
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DIVISION OF MINES AND GEOLOGY
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Report of Investigations No. 20

Geological Interpretation of

Airborne Magnetometer and Scintillometer Survey

Mt. Bonaparte, Bodie Mountain, Curlew, Aeneas, and Republic Quadrangles, Okanogan and Ferry Counties, Washington

Prepared by
HUNTING GEOPHYSICAL SERVICES, INC.

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1960

GEOLOGICAL INTERPRETATION

OF

AIRBORNE MAGNETOMETER AND SCINTILLOMETER SURVEY

MT. BONAPARTE, BODIE MOUNTAIN, CURLEW, AENEAS, AND REPUBLIC QUADRANGLES,

OKANOGAN AND FERRY COUNTIES, WASHINGTON

for the

DIVISION OF MINES AND GEOLOGY,
DEPARTMENT OF CONSERVATION OF THE
STATE OF WASHINGTON

Prepared by

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FOREWORD

We believe that it is a duty of State government to provide conditions that will encourage expansion of industries already located here and establishment of new industries to give full employment to our people. It is our policy to improve the economic climate in Washington in every way possible.

One of the factors essential to industrial growth is the availability of raw materials. We have in Washington an abundance of forest and agricultural products that may be used as raw materials for processing and manufacturing. The availability of these materials is, by their nature, fairly self evident. Mineral raw materials for industrial use also are available here in great variety, but detailed surveys are required in order to determine the extent and purity of these deposits.

We have started a program of geologic mapping and scientific testing that will provide the detailed knowledge of our mineral raw materials required in our industrial growth. This booklet and its accompanying maps give the results of one of the specific surveys—this one for iron ore—that have been initiated under this program.

It is a pleasure for me to present this report, which we believe is an important contribution to our knowledge of the mineral resources of Washington.

GOVERNOR

June 15, 1960

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INTRODUCTION

General Statement

At the request of the Division of Mines and Geology, Department of Conservation of the State of Washington, a combined airborne magnetic and radiometric survey has been carried out in northeastern Washington by Hunting Geophysical Services, Incorporated, of New York City.

The basic data are continuous airborne recordings of the total intensity of the earth's magnetic field and radiometric scintillometer recordings.

Flying took place between September 25 and October 30, 1959. Five 15-minute quadrangles within Ferry County and Okanogan County were surveyed: Mt. Bonaparte, Bodie Mountain, Curlew, Aeneas, and Republic. The survey area is indicated on the index map of figure 1. The aircraft used was a Cessna "180." Flight direction was east-west, lines were flown with an interval of 1,320 feet, and the average ground clearance was 500 feet. A total of 3,945 line miles was surveyed.

The survey area is part of the Okanogan Highlands physiographic province. It is characterized by north-south lowland areas of considerable depth alternating with equally prominent north-south uplands mostly lacking in marked continuity. The province has a relief of well over 7,000 feet but shows little of the roughness which might be expected. Smooth slopes are the rule, so that much of the area carries a soil cover. The 18-inch average annual rainfall is sufficient to support an abundant growth of pine trees and lesser vegetation.

Previous Investigations

In 1910 and 1911, Joseph B. Umpleby mapped the Republic and Myers Creek mining districts. The results of his work were published as Washington Geological Survey Bulletins 1 and 5. In 1954, T. M. Phetteplace mapped an area north and east of Chesaw as a Master of Science thesis. J. P. Dobell mapped and studied the petrology of the Toroda Creek-Kettle River area as a Doctor of Philosophy dissertation in 1955. In 1959, the United States Geological Survey placed on open file a preliminary map 1/ of the Curlew quadrangle by J. A. Calkins, R. L. Parker, and A. E. Disbrow. The Republic quadrangle and part of the Aeneas quadrangle were mapped 1/ by Siegfried Muessig and J. J. Quinlan of the

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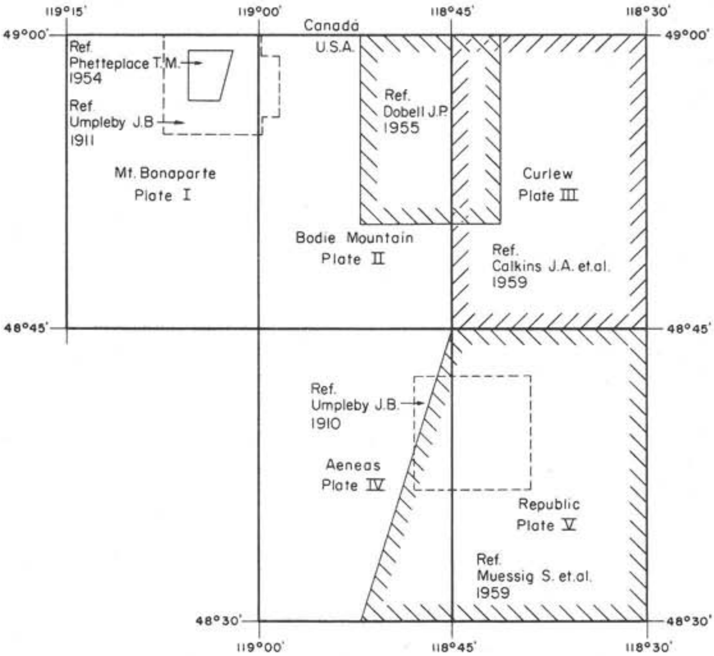
1/ These open-file maps are available only for inspection at the office of the U. S. Geological Survey, S. 157 Howard Street, Spokane, Wash., and the Washington Division of Mines and Geology, 335 General Administration Building, Olympia, Wash.



LOCATION MAP AND INDEX
TO
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FIGURE 1

Geological Survey, and the map was placed on open file in 1959. The areas covered by these maps are indicated on figure 1. These reports are listed in the selected bibliography of geology and iron and uranium occurrences on pages 7 to 11.

Maps and Overlays

Accompanying this report are five sets of maps for each of the five quadrangles, showing (1) aeromagnetic and radiometric data on a planimetric base, (2) the same data printed on translucent paper without a base map, for use as an overlay, and other overlay maps showing: (3) mineral deposits and locations of National Forest and State-owned lands, (4) height of the survey aircraft above ground, and (5) geologic interpretations. The overlay maps may be used in various combinations with each other and with the base map, which also shows aeromagnetic and radiometric data. These overlays may also be used with the U. S. Geological Survey topographic quadrangle maps as bases or with the geologic maps which have been open-filed by the Survey and which presumably eventually will be published.

GEOLOGY

General Statement

The following statement about the general geology is taken from Umpleby's (1910) description of the Republic mining district. In its essentials this description is considered appropriate for the entire survey area.

> The geologic history of the Republic district has as its great features sedimentation in the Paleozoic, erosion with minor vulcanism in the Mesozoic, igneous activity and erosion in the Tertiary, and continental glaciation in the Quaternary.
>
> The oldest rocks exposed in the district are the metamorphic equivalents of a great series of shales, sandstones, limestones and lava flows which are of Paleozoic age, and are provisionally assigned to the Carboniferous. After the deposition of this series, the area passed through a long period of crustal disturbance which, although not developing sharp folds, metamorphosed the beds and raised the area far above sea level. Either during this period of crustal disturbance or shortly thereafter great batholithic masses of granodiorite were intruded into the Paleozoic series.
>
> From the time of the granodiorite intrusions, which are probably of early or middle Mesozoic age, to middle Tertiary times, there was a great period of erosion which may be divided into two parts; a first, during which the entire area was reduced probably to base level (Eocene surface); and a second which was introduced by decided elevation and during which broad valleys at least 2,500 feet deep were developed.

The next rocks in order of formation are of Oligocene age, and occupy one of these broad, deep valleys. They are dacite flows, including great quantities of stream gravels. Overlying these, unconformably, are andesite breccias, lake beds, and andesite flows, all of which occur within the old erosion valley. Next in order of age are intrusive latite porphyries with which the ore deposits are thought to be genetically related.

From the time of the latitic intrusions to the Pleistocene, erosion was the dominant process, although during this time there was a short period of basaltic eruption. In the Pleistocene period, the Cordilleran ice sheet covered the entire area.

From the open-file preliminary maps of the Curlew and Republic quadrangles (Calkins and others, 1959; Muessig and Quinlan, 1959) the following description of the geological formations was prepared. Personal communication with Mr. Raymond L. Parker of the United States Geological Survey was of great assistance in the preparation of the description.

Pre-Permian metamorphic rocks

The oldest rocks in the Republic-Curlew area are the metamorphic rocks of Tenas Mary Creek and the metamorphic rocks of St. Peter Creek. These rocks are older than the Permian-Triassic rocks in the Republic graben. They may be Paleozoic or even Precambrian in age. Similar rocks in British Columbia have been called Grand Forks schist and Shuswap terrane.

Metamorphic rocks of Tenas Mary Creek

The Tenas Mary Creek rocks consist of high-grade metamorphic rocks ranging from granite gneiss to phyllite.

Phyllite—Dark-gray, lustrous phyllite with subordinate black and gray fine-grained quartzite.

Schist—Biotite-quartz schist, chlorite schist, cummingtonite schist, quartzite, and amphibolite.

Quartz-feldspar gneiss—Fine- to medium-grained quartz-plagioclase gneiss with variable amounts of biotite and hornblende; unit contains some amphibolite sills.

Hornblende schist—Dark-gray, well-laminated schist composed of hornblende, plagioclase, and quartz.

Quartzite—White, tan, and pink quartzite with interlayers of quartz-mica schist, minor marble, and calc-silicate rocks.

Marble—Coarsely crystalline marble interlayered with calc-silicate rocks, biotite schist, quartzite, and pegmatite.

Granitic gneiss—Mainly medium- to coarse-grained orthoclase-quartz-oligoclase gneiss.

Metamorphic rocks of St. Peter Creek

The metamorphic rocks of St. Peter Creek are also high-grade metamorphic rocks and probably have the same metamorphic history as the Tenas Mary Creek rocks. The age of the original sedimentary rocks is pre-Permian also, but these rocks may not be the same age as the original Tenas Mary Creek rocks. The St. Peter Creek rocks consist of:

Marble—White to gray, finely to coarsely crystalline marble, in places highly deformed.

Quartzite and schist—White, pink, and tan vitreous quartzite with thin mica schist partings; graphitic calc-silicate rocks, mica schist, and quartz-feldspar schist.

Other metamorphic rocks

The Republic quadrangle open-file map (Muessig and Quinlan, 1959) shows some metamorphic rocks of probable upper Paleozoic age. At present no correlation can be made between them and the metamorphic rocks of the Curlew quadrangle.

Permian-Triassic rocks

Umpleby (1910) refers to these rocks as the Paleozoic series; Pardee (1918) in the Colville Indian Reservation report calls them the Covada group. In the Curlew and Republic quadrangles these rocks are completely intruded by the Scatter Creek rhyodacite. They have been mapped as two units—greenstone and limestone. The greenstone includes greenstone, graywacke, graywacke conglomerate, quartzite, argillite, chert, and phyllite. The limestone is lenticular; some is Permian in age and some is Triassic.

Jurassic (?) rocks

Serpentine bodies in the Curlew quadrangle are cut by Scatter Creek rhyodacite, but serpentine intrudes Permian-Triassic limestone. Little (1957) in the Kettle River East Half Map Area, British Columbia, gives evidence suggesting that the serpentine is Jurassic (?) in age. The serpentine contains disseminated magnetite and small local concentrations of chromite.

Cretaceous (?) rocks

Granodiorite is extensive in the western parts of the Curlew and Republic quadrangles. The rock is dark gray and is composed of orthoclase and plagioclase feldspars, with lesser amounts of hornblende and biotite. Magnetite, pyrite, apatite, titanite, and rutile are the main accessory minerals. Local facies are granite, quartz monzonite, and diorite. These rocks are probably part of the so-called Colville batholith and may correlate with the Nelson intrusive rocks of British Columbia.

Tertiary rocks

The O'Brien Creek formation is what Umpleby (1910) called "dacite flow conglomerate." Calkins and others (1959) call it tuffaceous shale, sandstone, and conglomerate. In many places tuffaceous sandstone contains black argillite chips. Some conglomerate contains granodiorite boulders presumably from the Cretaceous (?) batholith. Calkins and others (1959) have assigned an Eocene (?) age to this formation.

The Sanpoil volcanic rocks correspond in part to Umpleby's (1910) andesite flows; however, with his andesite flows he included rocks which have been assigned to the Klondike Mountain formation. The Sanpoil volcanic rocks consist of flows and flow breccias ranging in composition from quartz latite to dacite. In places there are tuffaceous interbeds. In many places these volcanic rocks are intruded by bodies of Scatter Creek rhyodacite, and in some places the Sanpoil rocks cannot be distinguished with certainty from the Scatter Creek rocks because of the similarity in composition of rocks in these two formations.

The alkalic rocks of Shasket Creek consist of monzonite, hornblende syenite, nepheline (?) syenite, shonkinite, and syenite porphyry. They occupy a small area near Danville, between the Morning Star and Lone Star mines. They intrude the Permian-Triassic limestone and greenstone and are intruded by the Scatter Creek rhyodacite. The syenite contains a high proportion of magnetite. A provisional Eocene (?) or Oligocene (?) age has been assigned.

The Scatter Creek rhyodacite is a widespread formation in both the Republic and Curlew quadrangles. It occurs as dikes, sills, and irregular intrusive bodies that occupy a considerable part of the Republic graven. It has been suggested that the formation represents the intrusive equivalent of some of the Sanpoil volcanic rocks, but this has not been proved. In the Curlew quadrangle this formation has largely engulfed the Permian-Triassic and O'Brien Creek rocks and parts of the Sanpoil volcanic rocks.

The Scatter Creek rhyodacite consists of a variety of fine- to medium-grained porphyritic rocks ranging in composition from quartz monzonite to quartz diorite. Local facies of minor importance are syenite, diorite, and hornblendite. Also included in the formation are the quartz monzonite and quartz diorite dikes and irregular intrusive bodies that occur in the White Mountain area west of the Bacon Creek fault.

The quartz monzonite of Long Alec Creek intrudes the Scatter Creek rhyodacite and its inclusions in the area east of Curlew. The quartz monzonite of Herron Creek in the northern part of the Republic quadrangle is correlative. The Long Alec Creek rocks merge with rocks of similar lithology to the south that may be of Cretaceous (?) age in part. The quartz monzonite contains two principal facies, coarse inequigranular quartz monzonite and medium-grained equigranular quartz monzonite. Dikes of quartz latite porphyry are widespread and are believed to be related to the Long Alec Creek intrusive rocks.

The Klondike Mountain formation is the youngest bedrock formation (aside from certain dikes) in the Curlew quadrangle. It is younger than the Long Alec Creek intrusive rocks and lies unconformably on the Sanpoil volcanic rocks. It is divided into several map units. The Tom Thumb member at the base is what Umpleby (1910) called Lake Beds, and its flora has been extensively studied (Oligocene in age). The member is lenticular and does not appear in the Curlew quadrangle. For the most part, the Klondike Mountain formation consists of layers of coarse clastic and pyroclastic rocks with local tuffaceous sandstone, conglomerate, and mudstone in the lower part and thick, black to gray glassy flows (calcic in composition) in the upper part. Locally the lower part contains black glass, and locally the upper part contains volcanic breccia.

Some andesite porphyry, rhyolite, trachyandesite, and basalt dikes may be younger than the Klondike Mountain formation.

Ore Deposits

Published geologic reports are available on two mining districts within the area. The geologic environments of the two districts are quite different. A general description of the ore deposits of each district provides an index of the type of occurrences which may be anticipated in other parts of the survey area.

In the Myers Creek district a great series of Paleozoic sedimentary rocks, flows, and porphyrites have been intruded by granodioritic masses, probably during Mesozoic time. According to Umpleby (1911, p. 32), two classes of ore deposits are represented in the district. First, contact metamorphic replacement deposits occur along the contact between calcareous Paleozoic sedimentary rocks and the granodioritic intrusive rocks. The chief ore values are in chalcopyrite. Magnetite, however, is the most abundant ore mineral, often containing chalcopyrite in intimate intergrowth. The contact replacement deposits also contain small amounts of gold and silver. The second class of deposits is the vein-type occurrence. The veins are found in widely separated parts of the district and in all the rock types present. They have a general north-south strike in conformity with the major structural features of the region. The main values are in gold. Chalcopyrite, galena, and sphalerite are normally of lesser value. Gangue minerals include calcite, quartz, pyrite, and, in some places, pyrrhotite.

In the Republic district, according to Umpleby (1910), ore-bearing veins occur in Tertiary rocks. They are genetically related to latite porphyries and are composed of quartz, chalcedony, opal, calcite, and adularia. The chief values are in gold selenides and tellurides which in places assay several thousand dollars per ton. Subordinate silver values also occur as selenides. Chalcopyrite and pyrite are sparsely distributed in the veins.

The Buckhorn magnetite deposit, from which small shipments of iron ore have been made in the past, lies near the center of the north margin of the survey area. This deposit has been described in detail by Broughton (1943), Zoldok and others (1947), and Zapffe (1944, 1949). Other magnetite deposits in the area have been described in another report by Broughton (1945).

The Bi-Metallic molybdenum deposit has been described by Purdy (1954) and Storch (1946). Bancroft (1914) has described some of the ore deposits in the Republic, Belcher, and Danville districts. Additional information and references to other sources of data on mines and prospects in the survey area are given in a report by Huntting (1956).

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RADIOMETRIC SURVEY

General Statement

The radiometric survey was made as an adjunct to the magnetic survey. A Measurement Engineering Limited Model 1903R scintillation instrument was used. This instrument employs two thallium-activated sodium iodide crystals, each 2 inches in diameter and 4 inches thick. Each crystal is coupled to a photomultiplier tube. The crystals are not shielded; the unit, therefore, has a nondirectional response characteristic. The approximate sensitivity of the unit is 1,600 counts per minute per micro-Roentgen per hour. The calibration of the recorder was set at 6,000 counts per minute across the chart. The integrating time was 1 second.

Signal Sources

The radioactivity of rocks is produced primarily by potassium and members of the uranium and thorium radioactive decay series. Disintegration is by alpha, beta, and gamma rays. Alpha rays are helium atoms, and beta rays are electrons. Gamma rays are equivalent to X-rays and are generated by the transformation of mass to energy. The alpha and beta rays can travel only a very short distance through air before they are stopped. Gamma rays penetrate a foot or two of rock and relatively great distances in air. The scintillometer records the gamma ray activity.

Both the uranium and the thorium decay series have complex gamma spectra having energy peaks between zero and 2.77 million electron volts. In nature these are modified by absorption and scattering in the source material, in neighboring soil or rock, and in air. This results in an additional emission of gamma radiation. Therefore, the spectrum of the total gamma radiation above the surface of the source is composed of the primary radiation with a high proportion of secondary radiation. Most of the gamma flux comes from near the surface of the source, as self-absorption reduces the radiation from depths greater than one foot to negligible proportions. Similar attenuation results from the presence of inactive overburden. Consequently, it is seldom possible to correlate surface measurements of gamma radiation with grade of ore.

The effects of weathering and solution differ among the decay series and also among the different radioactive elements of each series. Ore deposits of radioactive elements weather quite differently from the radioactive elements in ordinary rock. In areas of mechanical disintegration the detritus of igneous rocks may be transported for miles without losing much of the original radioactivity. In regions of chemical disintegration the residual soils derived from radioactive rock may be very low in radioactivity due to surface leaching. Monazite, the chief mineral of thorium, is very resistant to weathering and solution; pitchblende and carnotite, on the other hand, are very easily dissolved and weathered.

Cosmic radiation and the scatter products produced by the cosmic ray bombardment of the atmosphere are sources of external signals in radiometric surveying.

The ionization effects due to cosmic rays increase with elevation and to some extent with latitude. The background effect due to cosmic rays must be subtracted from the recorded radiation intensity to determine the intensity of radiation from ground sources.

A third source of radiation is atmosphere radon gas, a daughter product from the radioactive decay of the uranium series. The atmospheric radon concentration is affected by meteorological conditions and may vary by as much as a factor of ten under conditions of extreme temperature inversion.

An additional source of radiation signals is contamination of the ground and air by synthetic products of nuclear fission. This source can be diagnosed only by systematic elimination of other possible sources.

In summary, the total gamma ray flux at a nominal 500-foot altitude comes from three principal sources. The relative contribution varies widely, depending upon the response characteristics of the detector, meteorological conditions, and the equivalent uranium content of the surficial material over which the measurement is made. However, an approximate distribution (Moxham, 1958) may be as follows: assuming the altitude is 500 feet and the rocks contain 0.001 percent uranium equivalent, cosmic radiation will contribute 35 percent, radon daughter products in the air 15 percent, and radiation from the ground surface 50 percent.

Detector Response

The detector response is determined by the geometrical relationship of the source and detector and by absorption and scattering in the intervening air. If the surface dimensions of the source are small compared with the distance of the detector above the source, the geometrical factor predominates and attenuation is approximately proportional to the square of the distance. With increasing source area, air absorption and scattering increase in relative importance, until for very large area sources they account entirely for flux variation with height. Thus the radiation profile obtained in flying at uniform altitude over an irregular surface of uniform radioactivity would be a replica of the topographic profile. In practice, a constant elevation profile over a large uniform geologic source also displays variations in radiation due to changes in the nature and moisture content of the overburden. Thus, a mineralogically homogeneous formation could produce an additive radiometric response from zero over a water-saturated residual soil to a maximum determined by the flux density on unweathered outcrop.

Evaluation of Results

An anomaly may be defined as any deviation from a normal or background indication. In considering the scintillation survey, anomalies may be defined by comparison of the observed profiles with two types of background signal levels: (1) at altitudes above about 2,500 feet the gamma radiation from ground sources is attenuated to such an extent that the major source of radiation is scattered gamma rays produced by cosmic particles; (2) because a small thickness of water acts as a shield against gamma radiation from the ground, observations over bodies of water are an effective means of evaluating the contributions of cosmic and atmospheric radon sources.

Most earth-forming materials contain minute but measurable quantities of radioactive minerals. Therefore, it is found that many geologic formations are characterized by radiometric anomalies when compared with the background as determined by one of the above methods.

An alternative reference level of gamma ray intensity is the local level of response of a geologic formation. Anomalies of restricted extent are defined when they exceed this local level of response. In order to be recognizable, such anomalies must exceed the noise level by at least 50 percent. Peaks less than this are not only difficult to recognize but frequently indicate no more than local changes in the character of the overburden or minor changes in rock facies.

In the selection of significant anomalies from the profiles of this survey the effects of height variations were studied closely and, as far as possible, removed. The assumption of an infinite source (horizontal dimensions greater than three times the flying height) provides for a change of 50 percent in observed gamma radiation for a change of 100 feet in flying height at a normal flying height of about 500 feet. These changes, brought about by absorption alone, are seen to account for most of the anomalies on the scintillometer records. Those anomalies which cannot be explained by such simple considerations are transposed to the scintillation maps.

Because of the strong topographic effect and the observed variation in cosmic and atmospheric background, it was decided to choose only those anomalies defined by reference to the local level of response. The locations of the anomalies are indicated by dots along the flight lines on plates 1 to 5 and on translucent overlays, plates 1-A to 5-A. The local background, anomaly amplitude, and the altitude of observation are indicated in the accompanying numerical code. The denominator indicates the local background level in hundreds of counts per minute. The numerator indicates the peak response above local background, also in hundreds of counts per minute. The number following the ratio indicates the ground clearance of the aircraft in feet. Thus 5/12,600, + would indicate a peak response of 500 counts per minute above a local background of 1,200 counts per minute, the observation being made while the aircraft had a ground clearance of approximately 600 feet. The plus symbol indicates that the anomaly appeared on a topographic high as indicated on the radioaltimeter record. A minus symbol indicates a topographic low, and a "g" symbol indicates the anomaly was on a steep topographic gradient. Absence of a symbol in the third position indicates that no pronounced correlation with topography was observed.

Ground Evaluation

The following remarks are intended as an aid in classifying and further evaluating the significance of the radiometric anomalies. Because the background noise was normally about 300 counts per minute, the peaks which exceed this figure by the greatest amount are least likely to represent only random fluctuations in the noise level. Anomalies located in areas of fairly deep alluvium are probably not significant in terms of bedrock radioactivity, since gamma ray penetration of soil cover is limited to approximately one foot. In examining the flight records it was occasionally observed that anomalies occurred in regions of steep gradients in the altimeter records. It is postulated that these anomalies may be due to outcrops of thinly covered areas on steep hill slopes. This requires field verification. With these considerations in mind, further investigation should be by geologic examination and testing by the normal ground radiometric methods.

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MAGNETIC SURVEY

General Statement

The magnetic data were recorded by a Varian (12-volt model) nuclear precession magnetometer, using a 512 gate. This instrument records the absolute magnitude of the ambient magnetic field with a precision of one count, which equals approximately 0.7 gammas in the survey. During the survey a magnetic monitoring device was operated on the ground at the base of flight operations in order to insure that no airborne magnetometer readings would be taken during periods of excessive magnetic disturbance.

The airborne magnetic survey data are reported as contoured magnetic maps (plates 1 to 5) and as contoured magnetic translucent overlays (pls. 1-A to 5-A).

Flight-line control was by means of United States Geological Survey photographs flown in 1953 at a height of 28,000 feet. The location of the flight lines was determined by a continuous photographic record taken during the survey. As already mentioned, lines were flown in an east-west direction at ¼-mile intervals and at a nominal ground clearance of 500 feet. Because of the extreme topographic variations it was impossible to maintain the nominal altitude of 500 feet. Actual heights ranged from approximately 300 feet to over 800 feet. The height of the aircraft above the ground was continuously recorded by an APN-1 radioaltimeter. The altimeter tapes were used to construct the contoured ground-clearance maps shown as translucent overlays, plates 1-C to 5-C.

Magnetic Characteristics of Rocks

Two types of magnetic polarization occur in rocks. Any substance which acquires a relatively strong magnetic polarization in weak inducing fields is described as ferromagnetic. Minerals of importance in magnetic prospecting are of this type. Ferromagnetic polarization may be thought of as a realignment of elementary magnetic domains in the direction of the inducing field. The factor of proportionality which relates the intensity of magnetization with the strength of the inducing field is the susceptibility and is designated by the letter "k". The relationship may be expressed as $I=kH$, where I is the intensity of magnetic polarization and H is the intensity of the inducing field. The product kH is termed the induced polarization.

A second type of magnetization found in igneous rocks is called remanent or thermoremanent magnetization. This magnetic polarization is acquired by igneous rocks as they cool through the Curie point temperature in the geomagnetic field. The direction of the remanent magnetization of igneous rock masses may have an important bearing on the interpretation of magnetic surveys since it may not conform with the present direction of the geomagnetic field. A divergence of direction of the remanent and induced magnetization may arise by folding or faulting of the magnetic rocks after the remanent polarization has been established. For reasons not fully understood at present, some structurally undisturbed rocks exhibit a remanent polarization opposite in direction from the present-day magnetic field of the earth. Some earth scientists have accepted this fact as evidence of paleomagnetic fields quite different from those existing today.

The total polarization of a rock may be described by the relationship

$$I = kH + R$$

where R is the remanent polarization. I, H, and R are all directional quantities.

The principal magnetic minerals are magnetite, pyrrhotite, ilmenite, specularite, and franklinite. Of these, magnetite has the greatest susceptibility, being on the order of 10 times that of pyrrhotite and on the order of 100 times that of the other minerals. Thus, by virtue of its high susceptibility and ubiquity, magnetite is by far the most important magnetic mineral and, in fact, determines the magnetic characteristics of most geologic materials. Rock types arranged in order of decreasing susceptibility are as follows:

1. Basic extrusive rocks
2. Basic plutonic rocks
3. Granites and other acid igneous rocks
4. Gneisses, schists, phyllites, and slates
5. Sedimentary rocks

The above order is only a statistical generalization, since the values reported for different specimens of the same rock type fluctuate manyfold. This fluctuation might be expected, as the susceptibility is determined by minor amounts of magnetite which can vary by large factors without affecting the classification of the rock. Therefore, a susceptibility determination of a rock specimen may be of little significance. Figure 2 shows the range and average values of susceptibility for various rock types. It has been observed that extrusive igneous rocks exhibit the greatest variability in polarization. The complex thermal gradients set up as a molten rock cools through the Curie temperature in subaerial conditions probably cause this variability.

INTERPRETATION OF AEROMAGNETIC DATA

General Statement

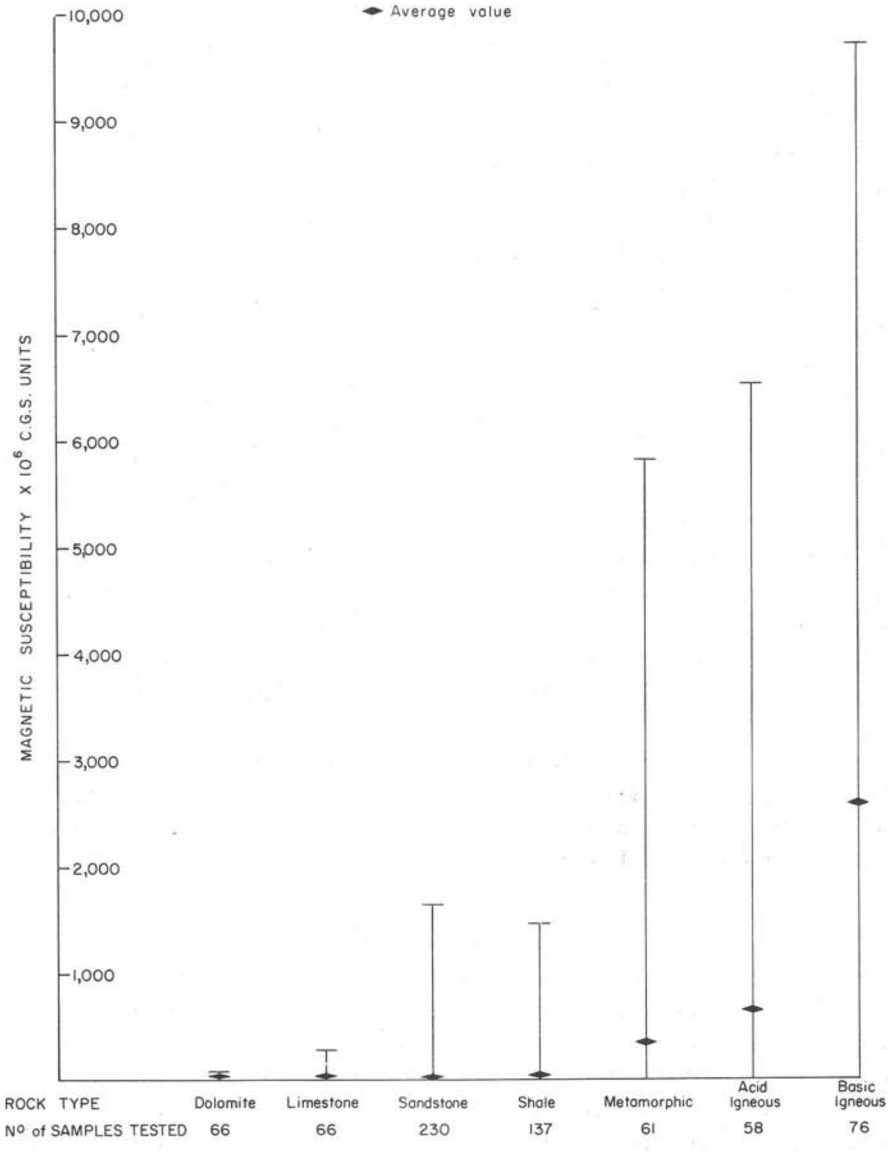
The interpretation of aeromagnetic data may be logically divided into two complimentary parts, one qualitative and the other quantitative. In order that the quantitative interpretation may have some degree of validity, at least three conditions must be fulfilled:

1. The observed data must be of high precision.
2. The observations must be spaced at distances considerably less than the horizontal dimensions or the depth of the causative body.
3. The anomaly in question must be free from disturbing effects of nearby magnetic masses.

In aeromagnetic surveys the first condition is quite readily fulfilled. The second condition, however, eliminates any precise analysis of anomalies which are observed on only one or two profiles. The third condition is rarely fulfilled in areas normally of interest in mineral exploration. As in the present case, such areas often exhibit a complex distribution of extrusive, intrusive, and metamorphic rocks, occurring essentially at the surface.

FIGURE 2

RANGE AND AVERAGE MAGNETIC SUSCEPTIBILITIES
OF SURFACE AND CORE SPECIMENS
AS MEASURED IN THE LABORATORY



Modified from Dobrin, Introduction to Geophysical Prospecting, p.270, McGraw-Hill, 1960

Mineralized regions are frequently in orogenic belts where strong topographic variation is characteristic; the consequent changes in ground clearance of the observing instrument produce distortions in magnetic anomalies. This situation is in contrast to petroleum surveys, in which the magnetic rocks are normally separated from the observing instrument by a thick sequence of relatively undisturbed sediments of low magnetic susceptibility.

Qualitative Interpretation

In the qualitative interpretation the magnetic contour maps were studied for magnetic features such as gradients, highs and lows, and disruptions and deflections of magnetic trends. Areas with different magnetic patterns were outlined, and an effort was made to correlate these differences in pattern and intensity with the known geology. Once a correlation was established, extrapolations were made wherever possible over areas where the geology was less well known. In this way, from the magnetic maps, geological interpretation maps (pls. 1-D to 5-D) were made, outlining the geological units that have diagnostic magnetic properties.

Faults were interpreted from magnetic gradients and from displacements of magnetic features.

Anomalies are due to the juxtaposition of lithologic units of contrasting polarization and, by inference, of contrasting magnetite content. Most anomalies arise from normal variations in the magnetite content of igneous rocks or from local magnetite concentrations in sediments or their metamorphic equivalents. Anomalies in metamorphic rocks may be due to original magnetite concentrations or to mobilization and concentration of iron during metamorphic processes. Because other elements are also mobilized during metamorphism, anomalies in metamorphic rocks may also have significance in terms of nonferrous mineralization. Only rarely, when some other control is available, is it possible to infer the presence of hydrothermal or contact metasomatic concentrations of magnetite.

The ground-clearance countour maps (pls. 1-C to 5-C) are useful in empirically evaluating the effect of topography. If comparison of the magnetic and ground-clearance maps reveals a strong correlation between a magnetic high and a topographic high, it can be assumed that the lower observation level is to some extent responsible for the magnetic anomaly.

Quantitative Interpretation

For any specified configuration of magnetic polarization contrast, one may compute uniquely the expected magnetic curve at any plane above the surface of the material. However, the converse situation is not true; it is not possible to compute the unique distribution of magnetic polarization which causes an observed anomaly. Various combinations of shape and polarization contrast can produce essentially the same magnetic field distribution. Therefore, an interpretation of the cause of a given magnetic anomaly depends to a certain extent upon some basic assumptions as to the shape of the causing body. In this survey, an analytical study of an anomaly was undertaken only when the geological interpretation required some additional information as to the depth of the body causing the anomaly.

It was not considered essential to the interpretation to calculate the exact depth of any of these bodies but merely to obtain information whether a certain body was cropping out or, if not, an order of its depth below the surface.

Three main methods of analysis were used in determining the parameters of the sources of anomalies. These are the dipping dike method (D), the pole and line of poles method (P), and the one-half slope method (S). The letters in parentheses are used in Appendix A to indicate the method applied.

Dipping dike method

The dipping dike method was developed by Hunting Survey Corporation Limited. It is applicable only to dikelike, flat-topped bodies that are long compared with the distance from the plane of observation to the top of the body. Certain characteristic parameters such as inflection points and the location of maxima and minima are read from magnetic profiles perpendicular to the strike of the body. Using these parameters on pre-calculated charts permits determination of depth, width, dip, and magnetic susceptibility of the body.

Pole and line of poles method

The theory of point poles and line of poles has been described by Smellie (1956). Determinations by the point pole method can be used only when the body dips in the direction of the earth's magnetic field and when the horizontal dimensions of the body are small compared to its depth. For the line of poles method the basic assumptions are that the width is small and the length of the body is large compared to the depth to the top; in other words, a thin, dikelike body. Depth determinations made on sources that are wide compared to the depth to the top produce values that are too large. The same is true of determinations on anomalies that are not well isolated from other magnetic sources. The estimated depth thus represents a maximum value.

One-half slope method

The one-half slope method has been outlined by Peters (1949). The points of half-maximum slope are empirically related to the depth of dikelike bodies that give rise to symmetrical anomalies. When the anomalies are not quite symmetrical, the two flanks are processed independently and the results averaged to obtain a depth approximation.

With certain simplifying assumptions, the dipping dike and the one-half slope methods may be made to yield an order of magnitude of the susceptibility contrast of the causative body with the surrounding rocks. Smellie (1956) gives expressions for susceptibility determinations. Their use, however, requires other controls or assumptions regarding the horizontal dimensions of the anomaly source. The accuracy of the estimates is severely limited by this fact.

Because the susceptibility determination is a function of the width of the causative body, it can be taken to represent an apparent average susceptibility over the width used.

The maximum error inherent in a depth determination is 15 to 20 percent of the calculated depth. An additional possibility of error is introduced due to the uncertainty in determining the characteristic curve parameters such as zero level, point of maximum gradient, etc., which are used in making the determination.

Appendix A is a tabulation of the results of analyses on selected anomalies. The determinations yield the distance from the plane of observation to the anomaly source. The ground clearance distances, which are probably accurate within plus or minus 50 feet, have been substracted from the computed distances to obtain the depth below the ground surface. The depths are followed by a plus or minus uncertainty range and by an estimate of the grade of the determination. An "A" grade is assigned when the basic assumptions of a purely analytical technique such as the dipping dike method appear to be satisfied. No "A" anomalies were encountered in the present analyses. Grade "B" indicates that a less exact method of analysis, such as Smellie's method, has been applied. Grade "C" indicates that the error in the depth determination may be fairly large due to some uncontrollable factors, but remains within the allowable 20 percent. A depth determination is marked "doubtful" (?) when its validity is not known, as will occur, for example, when the basic assumptions may or may not be correct.

Geological Interpretation of Mt. Bonaparte Quadrangle

The general response of this quadrangle is of the type usually associated in this area with the Paleozoic metamorphic rocks. Some features in the northern and northwestern part of the quadrangle show a slightly different magnetic pattern, and they may possibly be caused by acid to intermediate intrusive rocks. A rather weak circular feature in the central eastern part of the quadrangle may be caused by igneous rocks at depth. Other igneous rocks, not causing sufficient magnetic contrast to be noted, may very well occur in this quadrangle.

Some elongated north-south trending anomalies in the eastern part of the quadrangle are interpreted as being caused by dikelike features.

A magnetic gradient in the southwest corner of the quadrangle probably represents a geological contact, but not enough information is available to make any further geological conclusions.

Three different fault directions have been interpreted: a northwest-southeast direction, a north-northeast-south-southwest direction, and an east-west direction.

Some analytical work has been done on a number of individual anomalies.

M1 and M2

These anomalies could not be properly assessed because they fall too close to the edge of the quadrangle. Depth calculations on anomaly M1, using the one-half slope method, indicate a depth of 50 ft ±250 ft below the surface. The calculations are classified as C. The estimated width of the causing body is 1,000 ft. Magnetic susceptibility contrast is 0.002 c. g. s. units. Calculations on anomaly M2, using the one-half slope method, indicate a depth of 80 ft ±100 ft below the surface. The width of the causing body is estimated at 300 ft maximum. The magnetic susceptibility contrast is 0.006 c. g. s. units. The calculations are classified as C. Anomalies M1 and M2 both could be of economic interest.

M3

This anomaly falls within an area interpreted as an intrusive rock. It could be caused by a more basic differentiate of the intrusive material. Depth calculations, using the line of poles approximation, indicate a depth of 600 ft ±100 ft below the surface. The one-half slope method gives good agreement. The estimated width of the causing body is 1,320 ft. Magnetic susceptibility contrast is 0.005 c. g. s. units. The depth determination is graded as doubtful because the anomaly is rather complex. If the hypothesis that the anomaly can be treated as being caused by one body is wrong, the depth could be much smaller.

M4

Under this number some weak anomalies in an area interpreted as an intrusive rock are combined. A number of depth calculations using the one-half slope method have been carried out. They indicate that the anomalies are caused mostly by bodies at or close to the surface. Anomalies on flight line 2 indicate the following depths below the surface: 0 ft ±300 ft, 150 ft ±400 ft, 0 ft ±50 ft, and 80 ft ±250 ft. On flight line 6 greater depths are indicated; the western edge of the body seems to be at 750 ft below the surface, and another depth determination farther to the east indicates a depth of 350 ft ±300 ft below the surface. The depth determinations confirm the picture of an intrusion partly reaching the surface.

M5

This anomaly is part of an elongated north-south trending feature attributed to a dikelike body. Depth calculations, using the pole approximation and the one-half slope method, indicate a depth of 800 ft ±300 ft below the surface. The large range of uncertainty is caused by the fact that the anomaly has some strike extent. The grade of the depth determination is C. The estimated width of the causing body is 2,700 ft.

M6

This anomaly is located at the eastern edge of a magnetic feature thought to be the result of magmatic activity at depth and could therefore have some potential economic interest. The pole approximation has been used and indicates a depth of 300 ft ±100 ft below the surface. The depth determination is considered doubtful; the depth might be less. The anomaly is poorly defined, but there is definite indication for an east-west strike. The calculations are done on an east-west profile instead of on a perpendicular north-south profile.

M7

This anomaly traverses the crest of Bimetallic Mountain. The Bi-Metallic molybdenum deposit is located about one mile northeast of the anomaly. This deposit is reported to be on the northern margin of the Colville batholith (Purdy, 1954, p. 34). The batholith apparently has a magnetic susceptibility not diagnostically different from the Paleozoic metasediments in this quadrangle.

Depth calculations, using the line of poles approximation, indicate that the cause of the anomaly lies at the surface. Estimations of the width of the causing body are not possible, but the width is probably less than 100 ft. Magnetic susceptibility contrast is 0.006 c. g. s. units. The grade of the depth determination is B. The anomaly might have some potential economic interest.

M8

This anomaly is part of the elongated anomalies in the eastern part of the quadrangle. Calculations, using the one-half slope method, indicate a depth of 1,300 ft ±350 ft below the surface. The line of poles approximation agrees very well. The grade of the depth determination is C. The estimated width of the causing body is 2,700 ft. The magnetic susceptibility contrast is 0.001 c. g. s. units. The dipping dike method does not give satisfactory results, and it is possible that the anomaly is caused by several parallel dikes instead of by one rather wide dike.

The calculations on anomalies M5 and M8 indicate that the dikelike features possibly do not reach the surface.

M9

This anomaly appears in the extreme southwest corner of the quadrangle. The anomaly appears to be part of a strong magnetic feature of undetermined extent or significance.

Geological Interpretation of Bodie Mountain Quadrangle

Most of the area shows also the same type of magnetic response generally associated in this region with the Paleozoic metasedimentary rocks and gneisses. Three features in the eastern part of the mapped area show a slightly different magnetic pattern, and they are believed to be caused by intrusive rocks. The easternmost of these features, continuing into the Curlew quadrangle, has indeed been mapped as graniodiorite. The other two features show negative anomalies of a type associated in the Republic quadrangle with intrusive bodies of the Scatter Creek rhyodacite.

Some irregular anomalies in the northern part of the mapped area fall in an area generally mapped as Tertiary volcanic rocks. It is possible, however, that some of these anomalies are caused by basic intrusive rocks.

A trend of rather strong magnetic anomalies in the southwestern part of the area is thought to be caused by basic intrusive rocks.

Two directions of faulting have been interpreted: a north-northeast-south-southwest direction which is the older and probably the more important one, and an approximately east-west direction which is the younger one and offsets the other direction of faulting.

Some analytical work has been done on a number of individual anomalies.

B1

This anomaly falls in the area of the Buckhorn magnetite deposit. Magnetite mineralization occurs as replacement bodies in Paleozoic limestone near the contact of the limestone and a quartz-bearing hornblende syenite (Broughton, 1943, p. 12; Zoldok and others, 1947). The magnetite occurs essentially at the surface. A study of flight lines 11, 14, and 15 shows that the causing body is very magnetic and is limited in depth extent to close to the surface,[2/] but calculated results cannot be obtained other than by curve matching. The bordering by negative anomalies to the north is typical for thin tabular bodies.

B2

The one-half slope method has been used on this anomaly, and the calculations show that the causing body lies at the surface. The grade of the determination is C. The estimated width is 250 ft. The magnetic susceptibility contrast is as high as 0.01 c.g.s. units, and it is therefore felt that this anomaly has some potential economic interest.

B3

A depth determination, using the one-half slope method, indicates a depth of 40 ft below the surface. The determination is classified as C. The estimated width of the causing body is 1,300 ft, and the magnetic susceptibility contrast is 0.002 c. g. s. units.

B4

The dipping dike method shows a depth of + 250 ft ±50 ft, indicating that the anomaly is not caused by a downward-extending body. The anomaly is probably caused by a flat-lying body with limited depth extent. The body may occur at the surface (volcanic formation ?).

B5

A depth determination, using the one-half slope method, indicates that this anomaly is caused by a body at the surface. The determination is classified as C. The estimated width of the causing body is 1,000 ft, and the magnetic susceptibility contrast is 0.002 c. g. s. units.

B6

The one-half slope method has been used on this anomaly, and depth of the causing body is calculated at 250 ft ±100 ft below the surface. Its width is estimated as 2,000 ft. The magnetic susceptibility contrast is 0.007 c. g. s. units. The depth calculation is classified as doubtful because it is believed that the anomaly is caused by at least two bodies.

B7

This anomaly falls on the flank of an area interpreted as a basic intrusion and could therefore have a potential economic interest. Depth calculations, using the one-half slope method, indicate a depth of 120 ft below the surface. The depth calculation is classified as C. Width estimations indicate a width of 1,400 ft for the causing body, and the magnetic susceptibility contrast is 0.002 c. g. s. units.

2/ Editor's note: However, mine workings show iron ore to a depth of more than 100 feet below the pit floor, and diamond drilling (Zoldok and others, 1947) shows magnetite at a depth of at least 950 feet.

B8

This anomaly is very similar in location and attitude to anomaly B7, and the same general remarks are valid here. Depth calculations, using the one-half slope method, indicate a depth of 170 ft below the surface. The determination is classified as C. The width of the causing body is estimated at 800 ft. Magnetic susceptibility contrast is 0.005 c. g. s. units.

B9 and B10

These anomalies both fall in areas interpreted as underlain by intrusive bodies of the Scatter Creek formation. The one-half slope method has been used, and the calculations indicate that both anomalies are caused by bodies lying at or near the surface. However, the determinations are classified as C, or doubtful. Anomaly B10 has an estimated width of 1,000 ft and a magnetic susceptibility contrast of 0.0005 c. g. s. units. A depth determination on a negative anomaly south of anomaly B9 indicates a depth of 100 ft ±250 ft below the surface. The depth determinations all indicate that the intrusive bodies reach the surface.

B11

This anomaly falls in the area mapped by Dobell (1955) as the Kelly Mountain granodiorite. The mapped intrusive rock extends several miles north of this anomaly, however. The lack of correlation may be explained by assuming that the magnetic properties of part of the granodiorite do not differ diagnostically from the magnetic properties of the surrounding formations and that the anomaly is caused by local variation in composition of the granodiorite.

The anomaly is very disturbed, and the line of poles approximation can not be used. The one-half slope method indicates a depth of 400 ft ±800 ft below the surface, but the calculation is classified as doubtful. The estimated width of the causing body is 1,600 ft. Magnetic susceptibility contrast is 0.001 c. g. s. units.

Geological Interpretation of Curlew Quadrangle

This quadrangle has been mapped in detail by Calkins and others (1959). A large part of the mapped area is underlain by Tertiary formations, but Paleozoic formations do crop out in the western part of the area. The magnetic picture reflects partly the Paleozoic formations, either cropping out or underlying the Tertiary formations; the Tertiary formations contribute to the magnetic picture only where their thickness and magnetic properties are such as to enable them to influence the intensity of the magnetic field. These influences can be very strong locally and thus confuse the picture of the underlying Paleozoic rocks.

The granodiorite of Kelly Mountain in the southwestern part of the mapped area can be outlined from the magnetic data, showing good agreement with the mapped geology. A magnetic trend with a more-or-less east-west direction, north of Kettle River, coincides approximately with a zone mapped as "marble and related rocks." Some other, rather strong anomalies in the northeastern corner of the quadrangle coincide with mapped serpentine intrusions of Jurassic (?) age.

Of the Tertiary formations which can be traced through the magnetic data, the first that should be mentioned are the Oligocene basalts of Mount Elizabeth and Franson Peak. They are characterized by magnetic lows that may be caused by reversed magnetization.

The slightly older (Eocene) Sanpoil volcanic rocks that underly the basalts are indicated in the magnetic data as weakly to moderately positive anomalies.

East of Curlew Creek are some anomalous areas that can be correlated with the Scatter Creek rhyodacite formation, which in these localities probably consists of quartz dioritic or dioritic intrusive bodies.

In the northwestern part of the quadrangle some irregular, more-or-less elongated anomalies have been observed, and they can be correlated with some diorite or quartz diorite dikes also belonging to the Scatter Creek rhyodacite formation.

In the eastern part of the mapped area the quartz monzonitic intrusive rocks (Eocene-Oligocene) that can be outlined from the magnetic data show an interesting feature. The southern part of the quartz monzonite seems to be slightly stronger magnetically than the northern part. This may be due to some magmatic differentiation.

A magnetic high in the northeastern part of the area is interpreted as being caused by the Eocene intrusive Shasket Creek diorite, gabbro, monzonite, and porphyritic syenite.

Faulting in various directions has been interpreted, the main directions being north-northeast-south-southwest, east-northeast-west-southwest, and approximately east-west.

Some analytical work has been done on a number of individual anomalies.

<u>C1</u>

Some calculations on some of the elongated anomalies in this general area, using the one-half slope method, show depths varying between 0 ft and 350 ft below the surface, indicating that some, but not necessarily all, of the dikes reach the surface. The calculations are classified as doubtful.

<u>C2</u>

This anomaly falls within an area mapped as Eocene intrusive rocks of various composition (intrusive rocks of Shasket Creek). The anomaly is very complex and not too well defined and, moreover, is distorted due to changes in elevation on the various flight lines. The one-half slope method and the point pole approximation have been used, and the calculated depths range from 300 ft to 1,100 ft. These results are not acceptable, because the point pole approximation on an east-west profile indicates a maximum depth of 360 ft. It is believed that the body is at a shallower depth, as the body is probably too wide for the basic assumptions to be valid.

<u>C3</u>

This anomaly is located immediately south of anomaly C2. Depth calculations, using the line of poles approximation, indicate a depth of 750 ft ±100 ft below the surface. The width of the causing body is estimated at 1,000 ft, and the magnetic susceptibility contrast is 0.01 c. g. s. units. The depth determination is graded C. The determination checks reasonably well with the one-half slope method.

Anomalies C2 and C3 both indicate a source probably below the surface, and they could be attributed to various causes. The intrusive rocks of Shasket Creek could be the cause, but it is not impossible that serpentine of Jurassic (?) age, which has been observed south and east of these anomalies, exists here at depth.

C4

This anomaly corresponds with outcrops of Jurassic (?) serpentine. Depth calculations on flight lines 13 and 15, using the one-half slope method, show the cause of the anomaly to be at the surface. The calculations are classified as C.

C5

This anomaly falls within an area mapped partly as intrusives of the Scatter Creek formation and partly as Sanpoil volcanic rocks. Depth calculations on this anomaly are considered unreliable, as the anomaly is very complex. The main anomaly probably is caused by a body at depth, and the distortions, by features reaching the surface.

C6

This anomaly is very poorly defined, and depth calculations with a reasonable accuracy could not be carried out. The causing body could be at the surface or at considerable depth. If the body were at the surface, it could be of possible economic interest, as it coincides approximately with Paleozoic limestone that elsewhere contains magnetite mineralization. A ground survey to better define this anomaly is recommended.

C7

This anomaly falls in an area mapped as Permian and Triassic greenstone and Tertiary quartz monzonite. As these formations usually do not produce strong anomalies in this region, the anomaly could be caused by magnetite mineralization and therefore have possible economic significance. The one-half slope method indicates a depth of 80 ft ±200 ft below the surface. The determination is classified as C. The width of the causing body is estimated at 800 ft, and the magnetic susceptibility contrast is 0.004 c. g. s. units.

C8

This anomaly falls within the same geological formation as anomaly C5, and the same general remarks are valid here. A very doubtful depth calculation, using the one-half slope method, indicates a depth of 0 ft ±250 ft.

C9

A depth calculation on this anomaly, using the one-half slope method, indicates a depth of 250 ft above the ground surface. This indicates that the body probably occurs at surface and has little depth extension.

Geological Interpretation of Aeneas Quadrangle

The eastern part of this quadrangle has been mapped by Muessig and Quinlan (1959) and is shown to be underlain by granodiorite and Tertiary volcanic rocks.

The magnetic data indicate that the mapped area is mostly occupied by granodiorite, metasedimentary rocks, and/or gneiss. In the northwestern part of the area is outlined the continuation of a basic intrusive rock that has been interpreted in the Bodie Mountain quadrangle.

An area of negative anomalies in the same location is interpreted as Scatter Creek rhyodacitic intrusive rock.

Some elongated anomalies in the center of the mapped area are interpreted as being caused by dikelike features. These possibly are associated with the Tertiary volcanism.

In the southern part of the quadrangle a small area showing a different magnetic pattern is interpreted as being caused by an intrusive body, possibly granodiorite.

In the eastern part of the quadrangle various Tertiary volcanic formations can be outlined, notably the Sanpoil volcanics that are clearly indicated by strong positive anomalies. Some outcrops of the Scatter Creek rhyodacite formation show up as weak positive anomalies in this same area, this in apparent contradiction with observations in the Republic and other quadrangles where these same formations locally are characterized by negative anomalies. A difference in composition probably is responsible for this.

Faulting mainly in north-northeast and northeast directions is indicated.

Some analytical work has been done on a number of individual anomalies.

A1

Depth determinations, using the one-half slope method, indicate a depth of 250 ft above the surface. This indicates that the body is probably at surface and has little downward extension. Other anomalies in the same general area may indicate a slightly greater depth.

A2

A depth determination, using the one-half slope method, indicates a depth of 0 ft ±100 ft. The determination is classified as C.

A3

A depth determination on the northern part of this dikelike feature, using the one-half slope method, indicates a depth of 0 ft ±100 ft. The grade of the determination is C.

A4

Some north-south elongated anomalies in this general area may be caused by dikelike bodies. Actual depth calculations can not be made, but the anomalies seem to indicate that the causing body is probably at or near the surface.

A5 and A6

Rough depth determinations, using the one-half slope method, indicate that the causing body is at or near the surface.

A7

This anomaly is very distorted, and a reliable depth determination can not be obtained. The causing body is probably within 200 ft of the surface.

A8

Depth determinations, using the one-half slope method, indicate that the causing body is at the surface. The determination is graded C. The width is estimated at 600 ft, and the magnetic susceptibility contrast is 0.003 c. g. s. units.

Geological Interpretation of Republic Quadrangle

This quadrangle has been mapped by Muessig and Quinlan (1959), and the magnetic picture shows a remarkable agreement with the known geology. The quartz monzonite in the eastern part of the mapped area can be outlined with great accuracy; magnetic anomalies in this area are probably due to changes in composition of the quartz monzonite. The Scatter Creek formation shows up as rather weak positive anomalies in the eastern part of the quadrangle and as negative anomalies in the western part. Here too, a possible change in composition may be the cause of this difference. The volcanic rocks of the Sanpoil formation show up as rather strong positive anomalies, and this formation can be outlined rather accurately.

Faulting is interpreted in various parts of the quadrangle, mostly in approximately north-south and east-west directions. Some faulting in northwest-southeast and northeast-southwest direction is also indicated.

Some analytical work on individual anomalies has been carried out.

R1

This anomaly falls within an area mapped as Sanpoil volcanic rocks. Depth calculations, using the one-half slope method, indicate a depth of 130 ft ±370 ft below the surface. The anomaly is rather complex, however, and the determination is therefore classified as doubtful.

R2

A number of weak positive anomalies combined under this number do not yield accurate depth determinations. A rough estimation indicates that the causing bodies are at or near the surface. This particular area is underlain by Permian greenstone and Eocene rhyodacitic intrusive rocks of the Scatter Creek formation.

R3

This anomaly falls within the Scatter Creek formation. A depth calculation on one flank of the anomaly, using the one-half slope method, indicates that the causing body lies at the surface. The determination is classified as doubtful.

R4 and R5

These anomalies both fall in an area mapped as Sanpoil volcanic rocks. R4 indicates a depth of 0 ft ±150 ft, using the one-half slope method, and R5 indicates a depth of 0 ft ±50 ft, using the same method. Both determinations are classified as C.

MINERAL COMMODITY DATA

It is almost axiomatic that one should seek gold where it has been found. Plates 1-B to 5-B are indexes to mineral commodity occurrences within the survey area. The eight elements most frequently found in the area are designated by symbols. These elements are: gold, silver, lead, zinc, copper, molybdenum, iron, and tungsten. Mineral commodities found less frequently are indicated by their standard chemical symbol. These are: arsenic - As, chromium - Cr, antimony - Sb, manganese - Mn, nickel - Ni, cobalt - Co, selenium - Se, and uranium - U.

The center of the commodity symbol indicates the location of a mineral occurrence. The number or numbers adjacent to the commodity symbol are the reference numbers from Washington Division of Mines and Geology Bulletin 37, Inventory of Washington Minerals, Part II—Metallic Minerals, in two volumes. For example, the number "4" is found adjacent to a copper symbol on the Curlew quadrangle in Ferry County. Reference to volume 2 discloses that number 4 copper occurrence in Ferry County is the Walla Walla occurrence. Reference to volume 1 under Walla Walla in the copper section discloses information concerning location, elevation, access, property, ownership, ore, ore minerals, gangue, type of deposit, development, production, and additional references.

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Appendix A

Table of Depth Calculations

Number	Depth (feet)	Grade [1/]	Method [2/]	Remarks [3/]
		Mt. Bonaparte Quadrangle		
M1	50 ±250	C	S	W = 1,000 ft. K = 0.002 c.g.s. units
M2	80 ±100	C	S	W = 300 ft. max. K = 0.006 c.g.s. units
M3	600 ±100	?	P	W = 1,320 ft. K = 0.005 c.g.s. units Good agreement with one-half slope method. Depth should be considered as a maximum depth
M4	varying from 0 to 750	C	S	Depth determinations were made on several anomalies in this general area
M5	800 ±300	C	P	W = 2,700 ft. Good agreement with the one-half slope method
M6	300 ±100	?	P	Poorly defined anomaly; depth might be less
M7	0	B	P	W = less than 100 ft. K = 0.006 c.g.s. units
M8	1,300 ±350	C	S	W = 2,700 ft. K = 0.001 c.g.s. units Good agreement with the line of poles approximation. Dipping dike method does not work
M9	No determination			
		Bodie Mountain Quadrangle		
B1	probably at surface			Body limited in depth extent; no actual depth calculations possible
B2	0	C	S	W = 250 ft. K = 0.01 c.g.s. units

1/ See page 22.

2/ See pages 21-22.

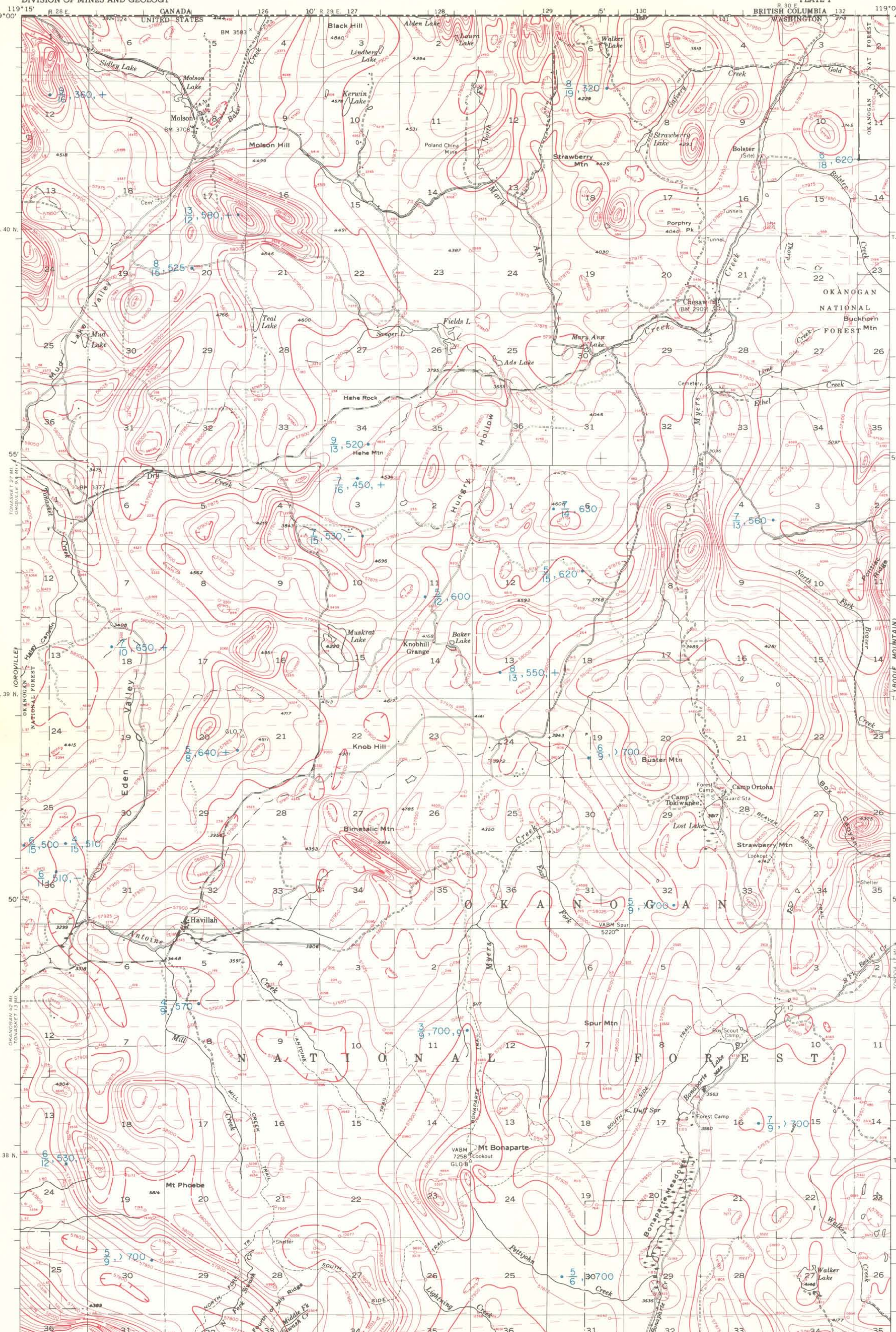
3/ W = estimated width of the causing body
K = magnetic susceptibility contrast

Number	Depth (feet)	Grade	Method	Remarks
B3	40	C	S	W = 1,300 ft. K = 0.002 c.g.s. units
B4	probably at surface			Dipping dike method indicates limited depth extent of the causing body
B5	0	C	S	W = 1,000 ft. K = 0.002 c.g.s. units
B6	250 ±100	?	S	W = 2,000 ft. K = 0.007 c.g.s. units Probably more than one body
B7	120	C	S	W = 1,400 ft. K = 0.002 c.g.s. units
B8	170	C	S	W = 800 ft. K = 0.005 c.g.s. units
B9	at or near surface	?	S	
B10	at or near surface	?	S	W = 1,000 ft. K = 0.0005 c.g.s. units
B11	400 ±300	?	S	W = 1,600 ft. K = 0.001 c.g.s. units
		Curlew Quadrangle		
C1	varying from 0 to 350	?	S	Depth determinations have been made on several anomalies in this general area
C2	360 max.	?	P	Basic assumptions, probably not valid
C3	750 ±100	C	P	W = 1,000 ft. K = 0.01 c.g.s. units Reasonable agreement with the one-half slope method
C4	0 ±100	C	S	Some distortion from nearby anomaly
C5 & C6	No determinations			
C7	80 ±200	C	S	W = 800 ft. K = 0.004 c.g.s. units
C8	0 ±250	?	S	Very doubtful determination, as the anomaly is very complex
C9	probably at surface	?	S	Body has little depth extent

Number	Depth (feet)	Grade	Method	Remarks
			Aeneas Quadrangle	
A1	probably at surface	?	S	Body has little depth extent
A2	0 ±100	C	S	
A3	0 ±100	C	S	
A4	probably at surface			Anomalies too complex
A5 & A6	probably at surface	?	S	Very unreliable determinations
A7	No determinations			
A8	at surface	C	S	W = 600 ft. K = 0.003 c.g.s. units
			Republic Quadrangle	
R1	130 ±370	?	S	Complex anomaly
R2	probably at or near surface			
R3	at surface	?	S	Only one flank of the anomaly used
R4	0 ±150	C	S	
R5	0 ±50	C	S	

STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY

REPORT OF INVESTIGATIONS NO. 20
PLATE 1



Base from U. S. Geological Survey topographic quadrangle map

Aeromagnetic and scintillometer survey flown 500 feet above ground, 1959 by HUNTING GEOPHYSICAL SERVICES, INC.

AEROMAGNETIC AND SCINTILLOMETER SURVEY OF MOUNT BONAPARTE QUADRANGLE OKANOGAN COUNTY, WASHINGTON

SCALE 1:62500

1 ½ 0 1 2 3 4 MILES

3000 0 3000 6000 9000 12000 15000 18000 21000 FEET

1 .5 0 1 2 3 4 5 KILOMETERS

EXPLANATION

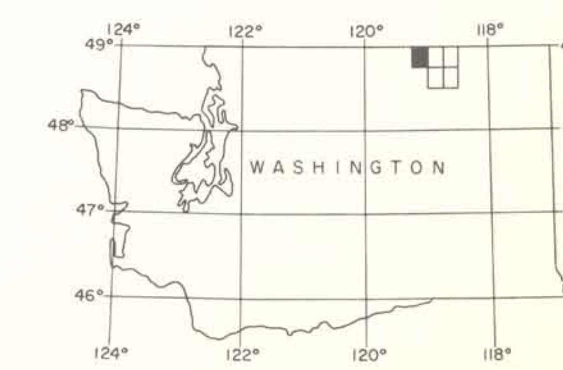
MAGNETIC CONTOUR INTERVAL — 25 GAMMAS
500 GAMMA CONTOUR
100 GAMMA CONTOUR
50 GAMMA CONTOUR
25 GAMMA CONTOUR

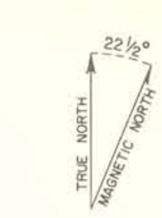
MAGNETIC CONTOUR ENCLOSING AREA OF LOWER MAGNETIC INTENSITY

MEAN FLIGHT LINE SPACING — 1320 FEET
FIDUCIAL POINTS
FLIGHT LINES

NOTE

The contours represent absolute values of the total intensity of the earth's magnetic field. The data are obtained continuously along the flight lines and are accurately plotted on these lines. Between flight lines the contours are drawn by interpolation and therefore may be in error. Terrain clearance is nominally 500 feet, but due to sharp variations in ground elevation the clearance is not constant and may locally reach 800 feet.





APPROXIMATE MEAN DECLINATION 1958

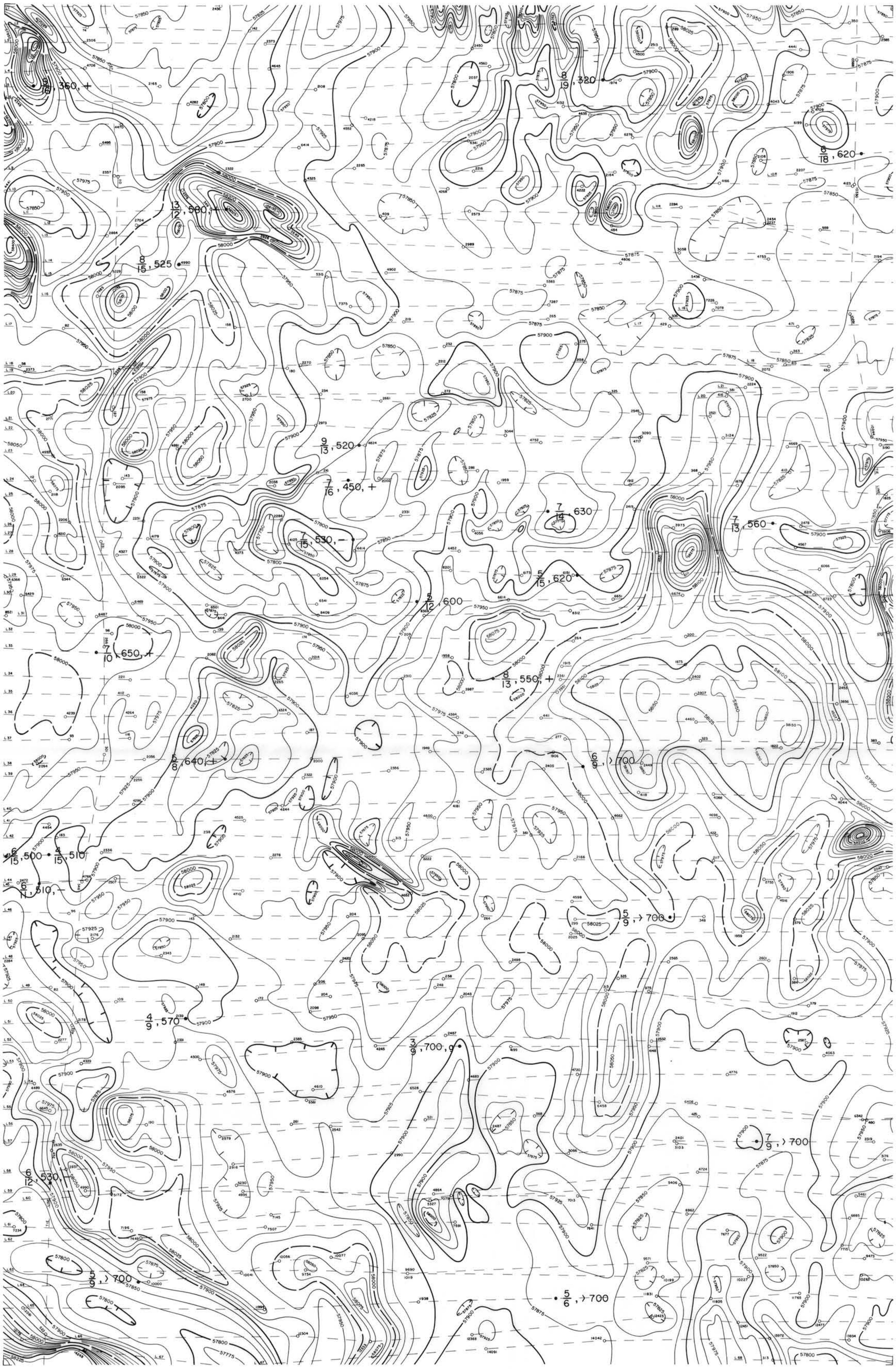
SCINTILLATION ANOMALIES

Location • 5/12, > 700, (+, −, g)

- Peak response 500 counts per minute above local background.
- Terrain clearance greater than 700 feet.
- Negative topographic correlation.
- Anomaly on steep topographic gradient.
- Positive topographic correlation.
- Local background 1200 counts per minute.

STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY

REPORT OF INVESTIGATIONS NO. 20
PLATE 1 - A

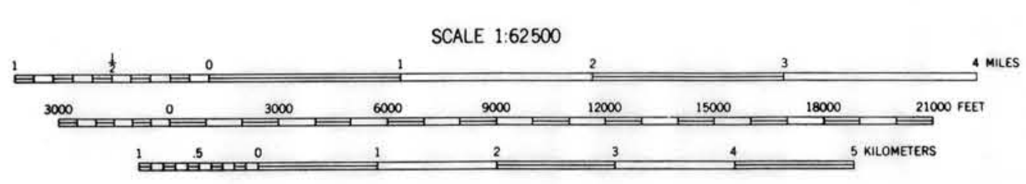


Base from U. S. Geological Survey
topographic quadrangle map

Aeromagnetic and scintillometer survey
flown 500 feet above ground, 1959
by
HUNTING GEOPHYSICAL SERVICES, INC.

AEROMAGNETIC AND SCINTILLOMETER SURVEY OF MOUNT BONAPARTE QUADRANGLE OKANOGAN COUNTY, WASHINGTON

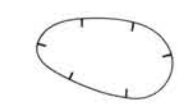
SCALE 1:62500



1960

EXPLANATION

MAGNETIC CONTOUR INTERVAL _ _ 25 GAMMAS
500 GAMMA CONTOUR
100 GAMMA CONTOUR
50 GAMMA CONTOUR
25 GAMMA CONTOUR

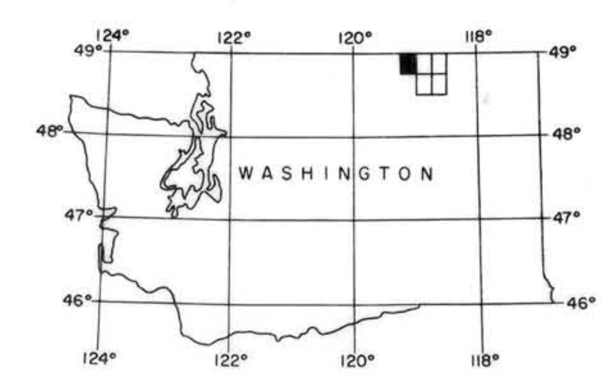


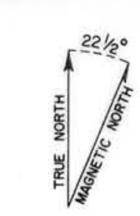
MAGNETIC CONTOUR ENCLOSING AREA OF LOWER MAGNETIC INTENSITY

MEAN FLIGHT LINE SPACING _ _ _ _ 1320 FEET
FIDUCIAL POINTS _ _ _ _ _ _ _ _ _ _ _ _ 36900
FLIGHT LINES

NOTE

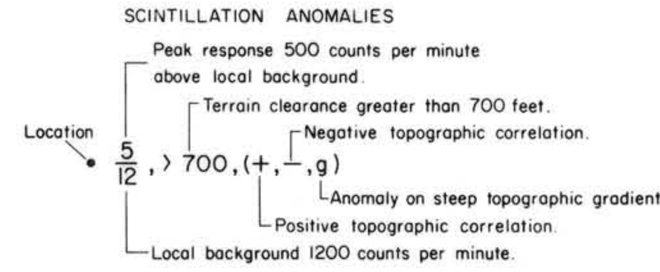
The contours represent absolute values of the total intensity of the earth's magnetic field. The data are obtained continuously along the flight lines and are accurately plotted on these lines. Between flight lines the contours are drawn by interpolation and therefore may be in error. Terrain clearance is nominally 500 feet, but due to sharp variations in ground elevation the clearance is not constant and may locally reach 800 feet.





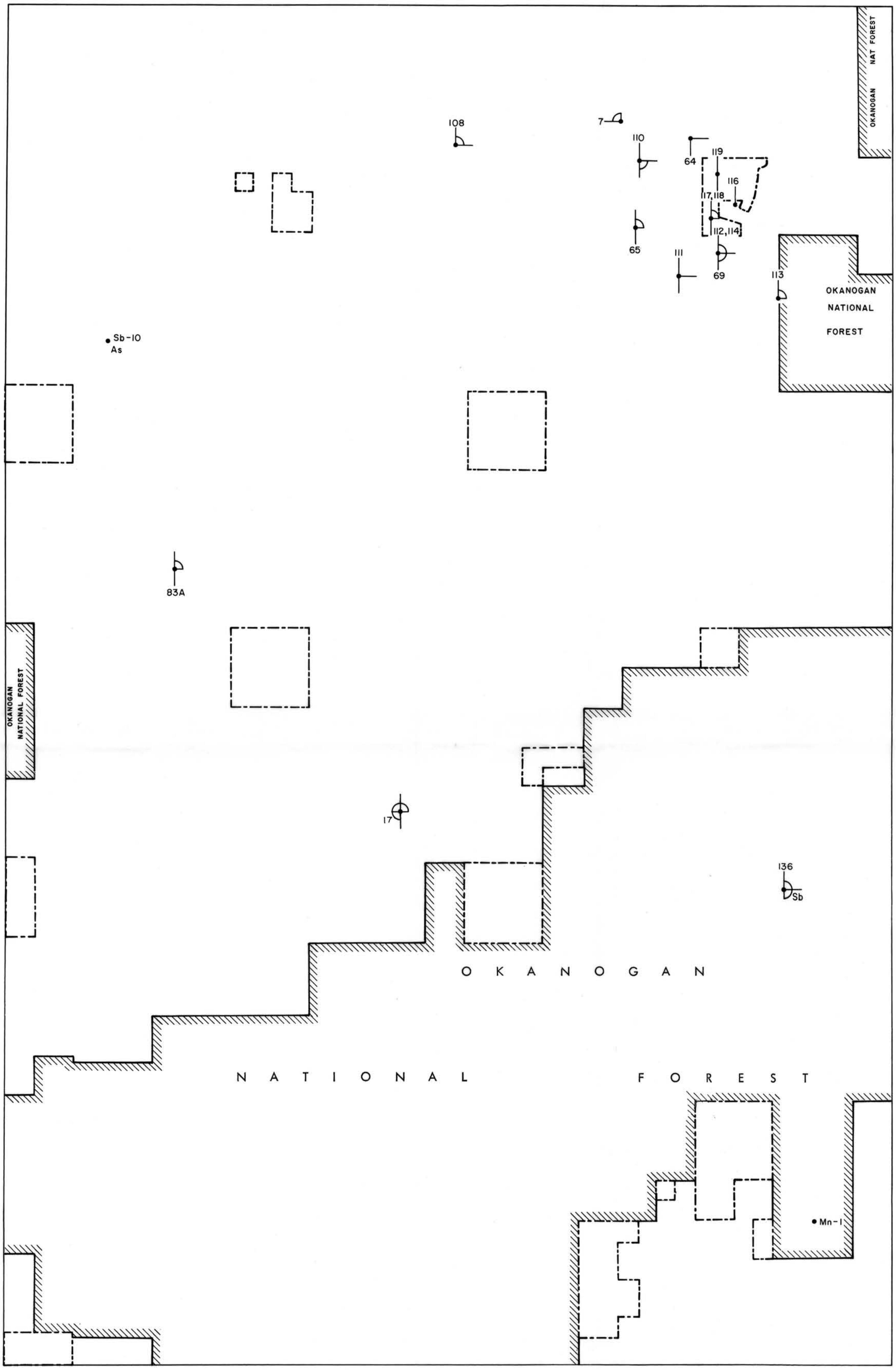
APPROXIMATE MEAN DECLINATION 1958

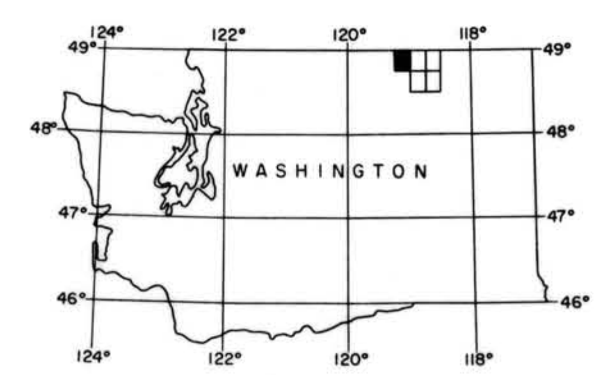
SCINTILLATION ANOMALIES



STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY

REPORT OF INVESTIGATIONS NO. 20
PLATE 1-B



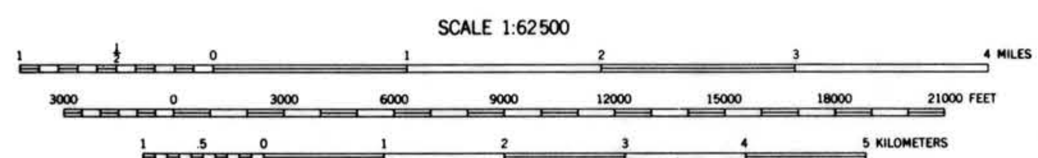


APPROXIMATE MEAN DECLINATION 1958

National Forest boundary
State-owned land boundary

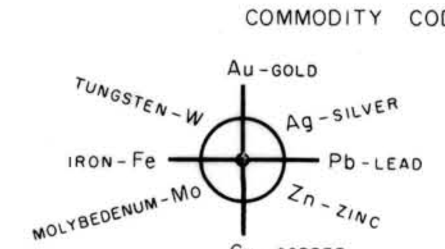
MINERAL DEPOSITS MAP
MT. BONAPARTE QUADRANGLE
OKANOGAN COUNTY, WASHINGTON

SCALE 1:62500



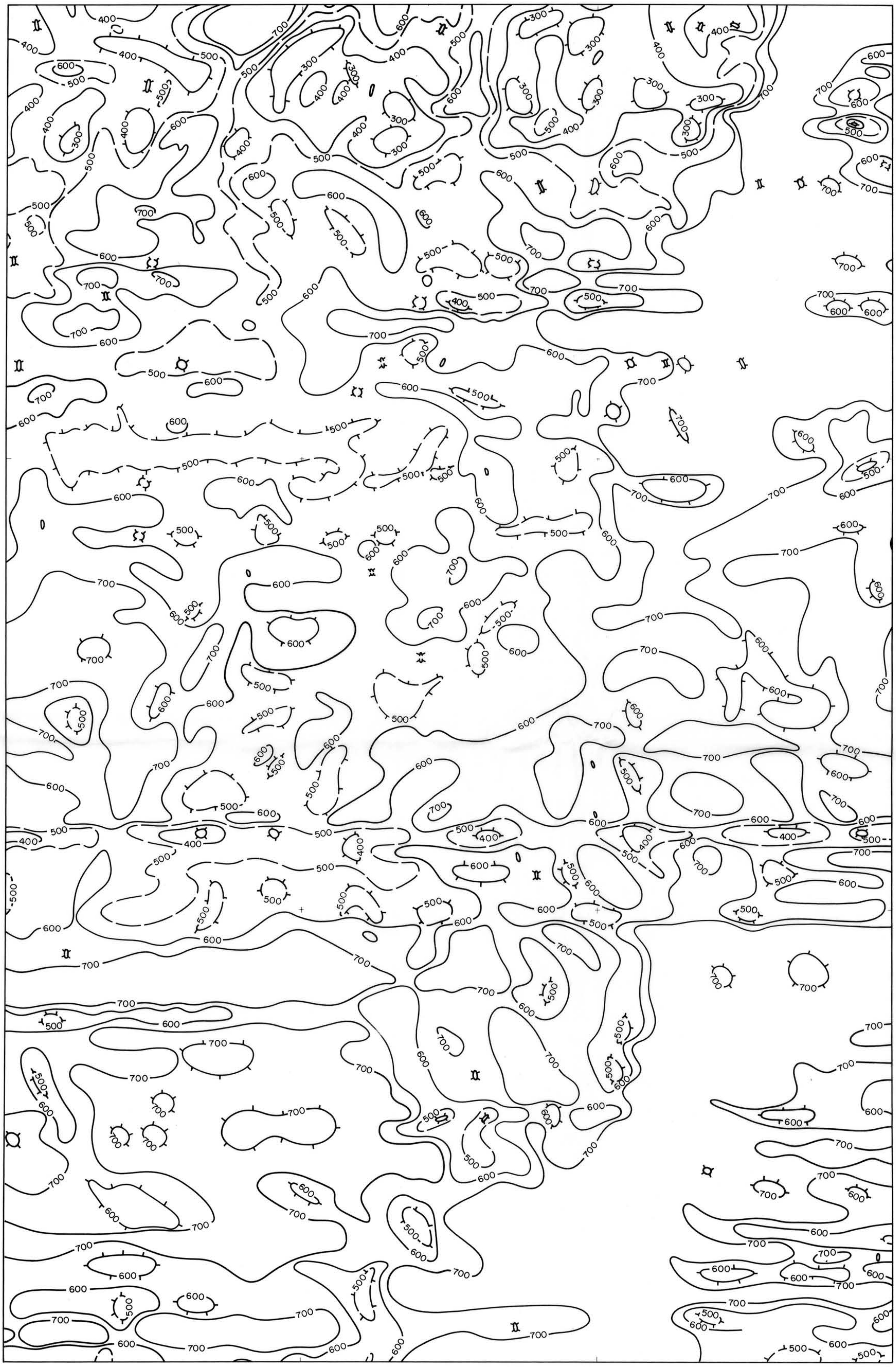
1960

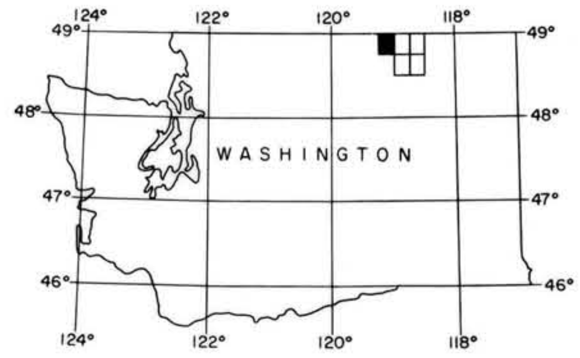
COMMODITY CODE

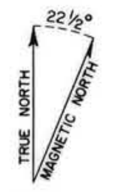


Pt PLATINUM
Se SELENIUM
Sb ANTIMONY
As ARSENIC
Mn MANGANESE
Ni NICKEL
Co COBALT

NOTE: Numbers are the reference number by commodity and county as listed in Bulletin 37, Inventory of Washington Minerals, Part II Metallic Minerals, Marshall T. Huntting, Division of Mines and Geology, 1956.
e.g. ●——— 6, Occurrence # 6 of Lead in Ferry Co. or in Okanogan Co.





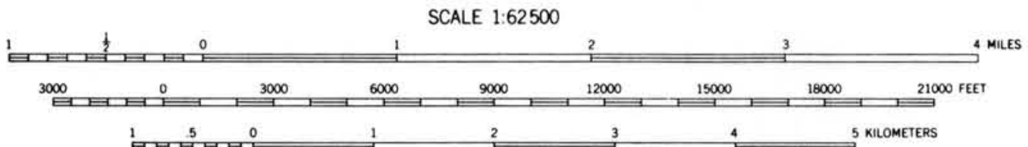


APPROXIMATE MEAN DECLINATION 1958

GROUND CLEARANCE MAP
MT. BONAPARTE QUADRANGLE
OKANOGAN COUNTY, WASHINGTON

The contours represent the height of the aircraft above ground. The data are accurately plotted along the flight lines but have been drawn by interpolation between the lines. Hachured contours may be indicative of areas of higher topographic relief.
Contour interval 100 feet

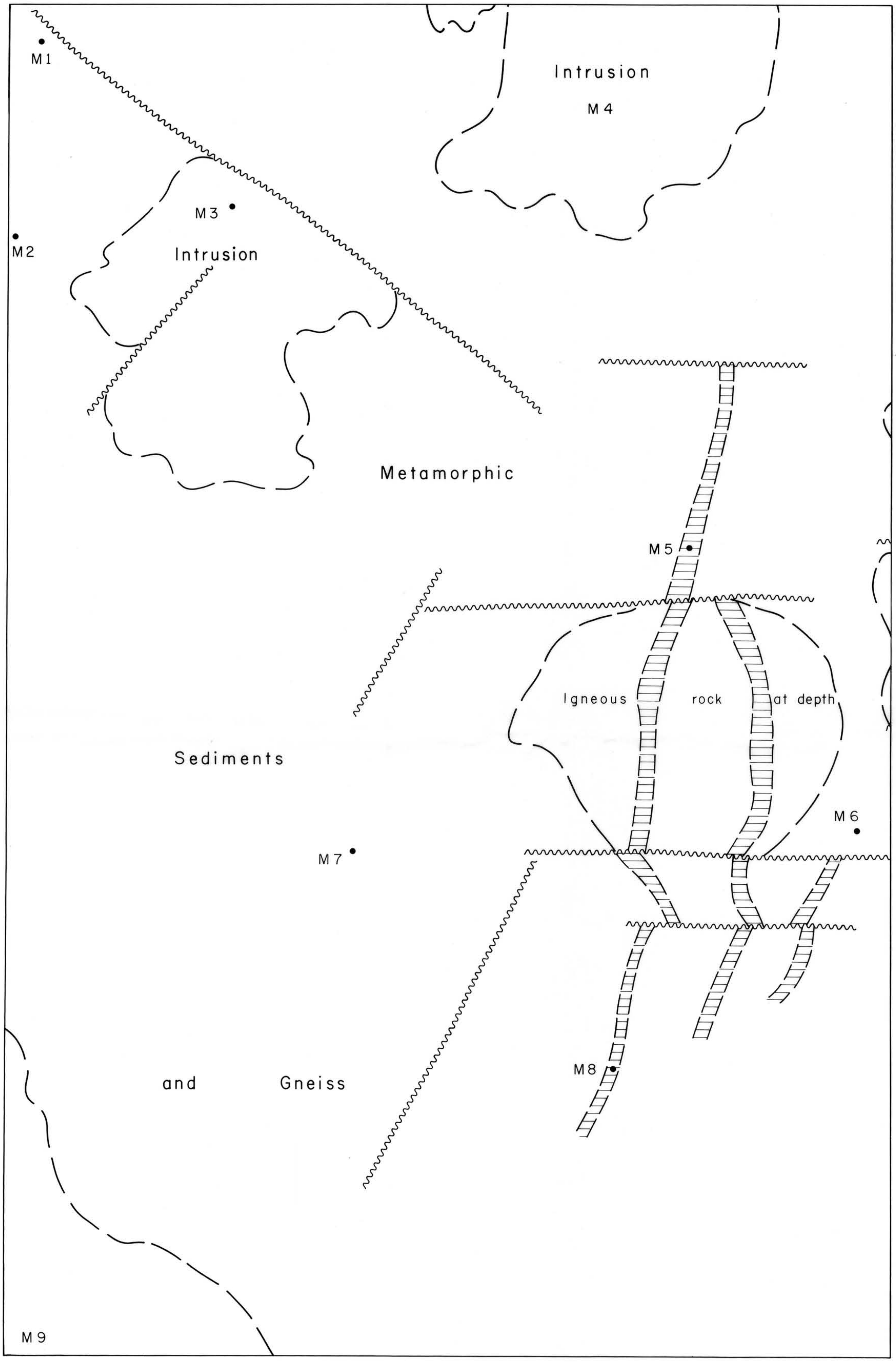
SCALE 1:62500

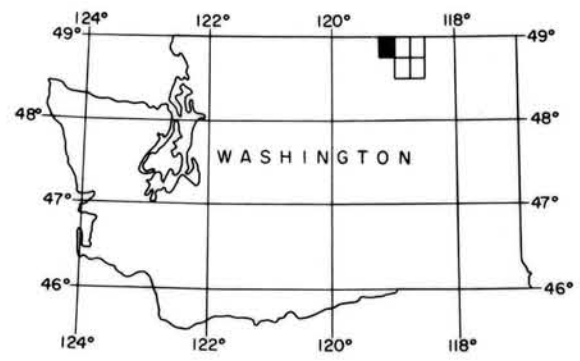


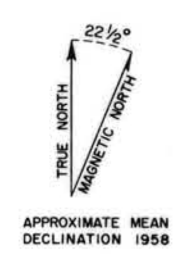
1960

STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY

REPORT OF INVESTIGATIONS NO. 20
PLATE 1 – D







INTERPRETATION

Geological contact

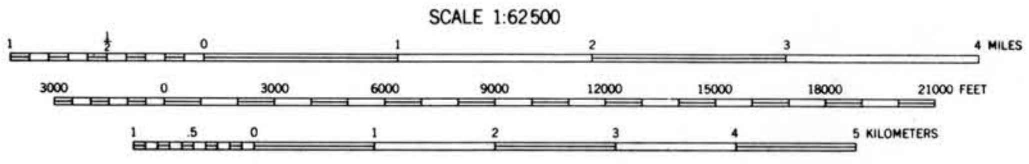
Fault

Dike

Depth determination • M 7

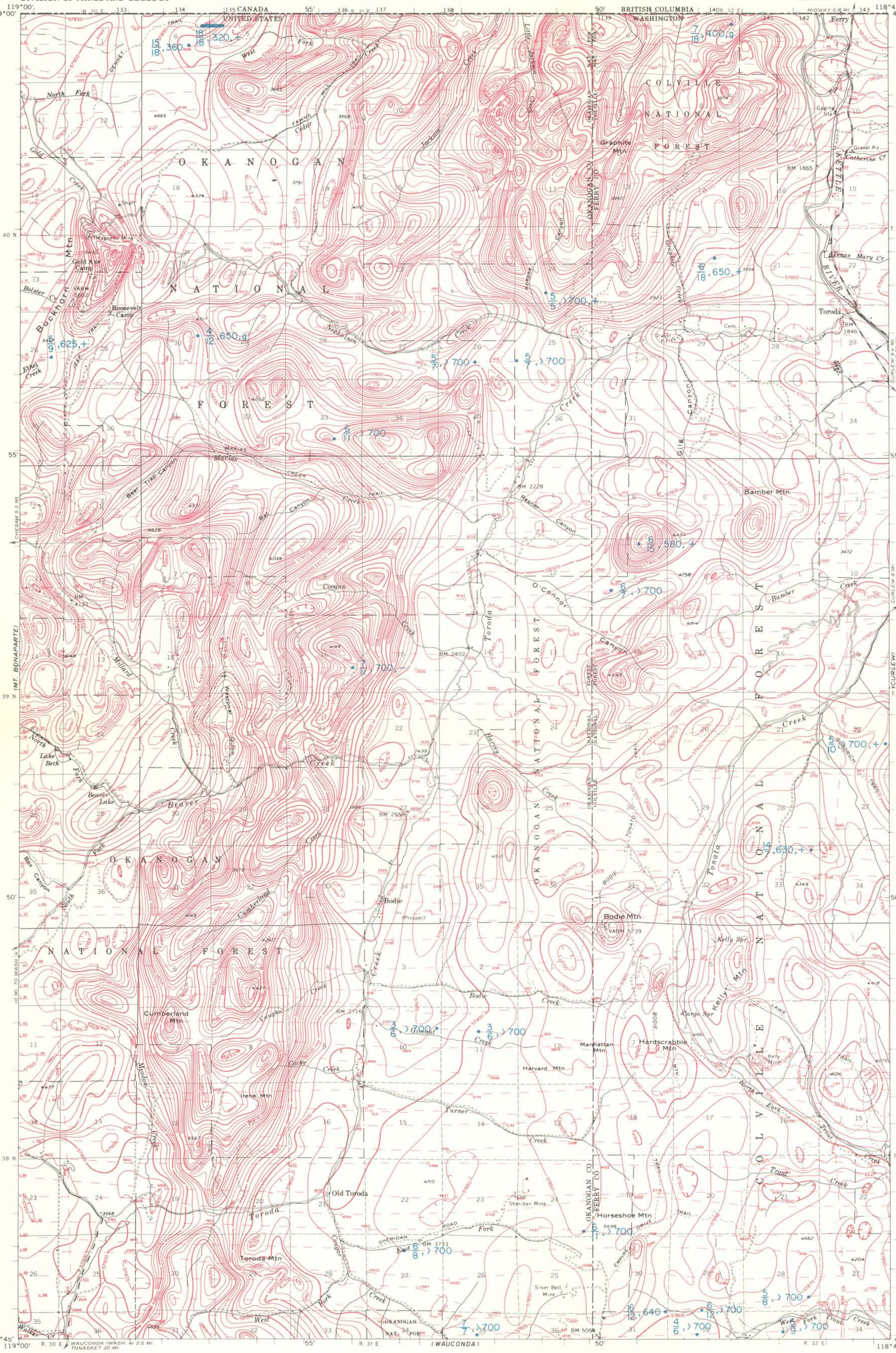
GEOLOGY INTERPRETED FROM AEROMAGNETIC DATA
MT. BONAPARTE QUADRANGLE
OKANOGAN COUNTY, WASHINGTON

SCALE 1:62500



1960

STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY



Base from U. S. Geological Survey topographic quadrangle map

Aeromagnetic and scintillometer survey flown 500 feet above ground, 1959 by HUNTING GEOPHYSICAL SERVICES, INC.

AERONAGNETIC AND SCINTILLOMETER SURVEY OF BODIE MOUNTAIN QUADRANGLE OKANOGAN AND FERRY COUNTIES, WASHINGTON

SCALE 1:62500

1 ½ 0 1 2 3 4 MILES

3000 0 3000 6000 9000 12000 15000 18000 21000 FEET

1 .5 0 1 2 3 4 5 KILOMETERS

EXPLANATION

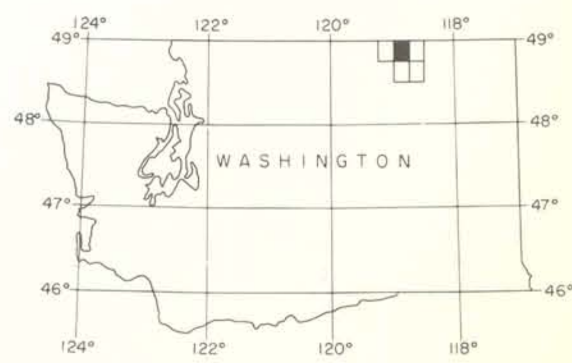
MAGNETIC CONTOUR INTERVAL ... 25 GAMMAS
500 GAMMA CONTOUR
100 GAMMA CONTOUR
50 GAMMA CONTOUR
25 GAMMA CONTOUR

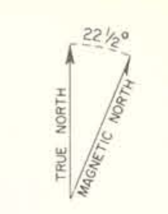
MAGNETIC CONTOUR ENCLOSING AREA OF LOWER MAGNETIC INTENSITY

MEAN FLIGHT LINE SPACING ... 1320 FEET
FIDUCIAL POINTS
FLIGHT LINES

NOTE

The contours represent absolute values of the total intensity of the earth's magnetic field. The data are obtained continuously along the flight lines and are accurately plotted on these lines. Between flight lines the contours are drawn by interpolation and therefore may be in error. Terrain clearance is nominally 500 feet, but due to sharp variations in ground elevation the clearance is not constant and may locally reach 800 feet.





APPROXIMATE MEAN DECLINATION 1958

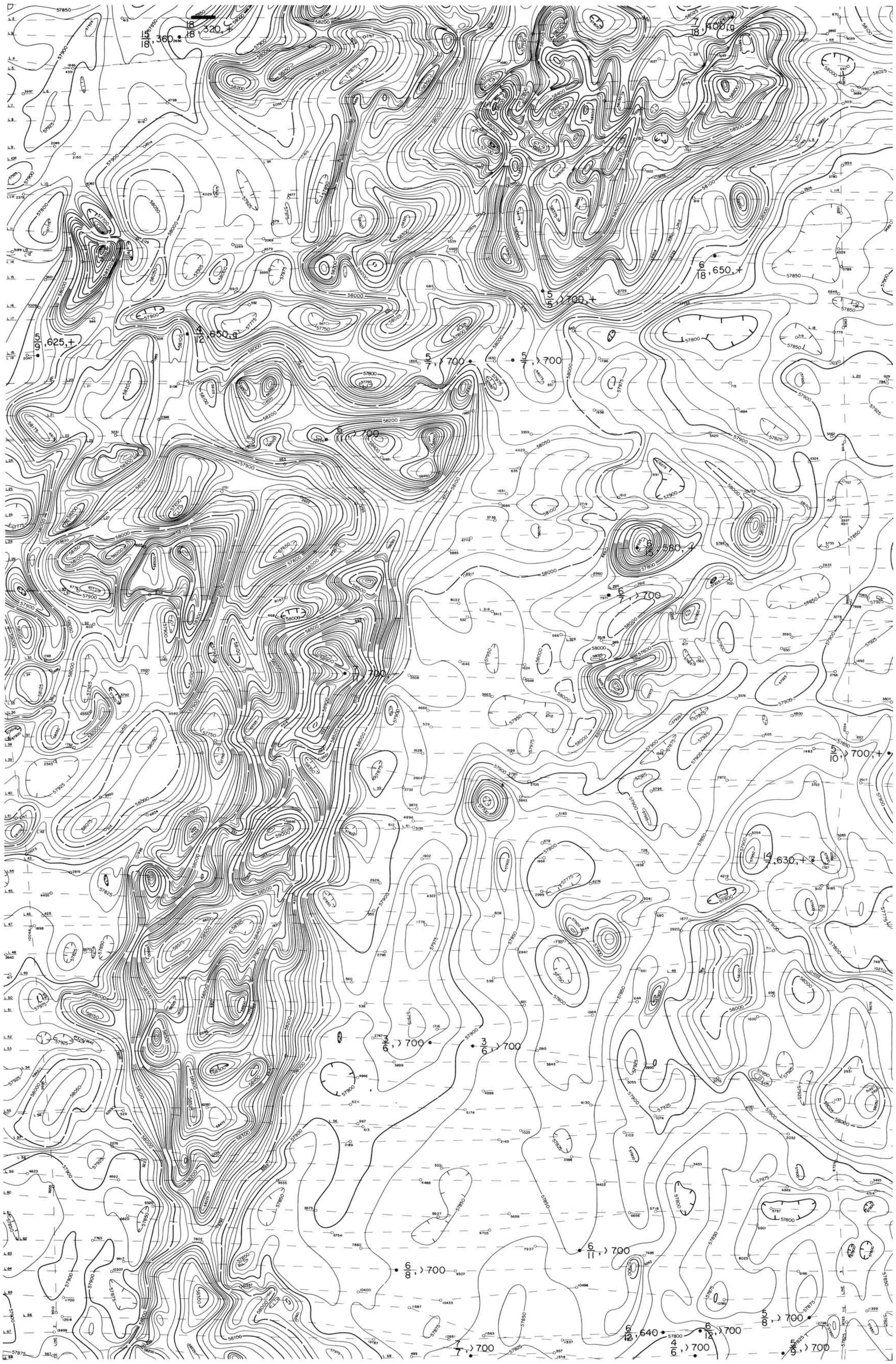
SCINTILLATION ANOMALIES

Location • 5/12, 〉700, (+, –, g)

- 5 — Peak response 500 counts per minute above local background.
- 〉700 — Terrain clearance greater than 700 feet.
- – — Negative topographic correlation.
- g — Anomaly on steep topographic gradient.
- + — Positive topographic correlation.
- 12 — Local background 1200 counts per minute.

STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY

REPORT OF INVESTIGATIONS NO. 20
PLATE 2 - A



Base from U. S. Geological Survey topographic quadrangle map

Aeromagnetic and scintillometer survey flown 500 feet above ground, 1959
by
HUNTING GEOPHYSICAL SERVICES, INC.

AEROMAGNETIC AND SCINTILLOMETER SURVEY OF BODIE MOUNTAIN QUADRANGLE OKANOGAN AND FERRY COUNTIES, WASHINGTON

SCALE 1:62500

1 ½ 0 1 2 3 4 MILES

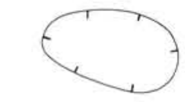
3000 0 3000 6000 9000 12000 15000 18000 21000 FEET

1 .5 0 1 2 3 4 5 KILOMETERS

1960

EXPLANATION

MAGNETIC CONTOUR INTERVAL — 25 GAMMAS
500 GAMMA CONTOUR
100 GAMMA CONTOUR
50 GAMMA CONTOUR
25 GAMMA CONTOUR

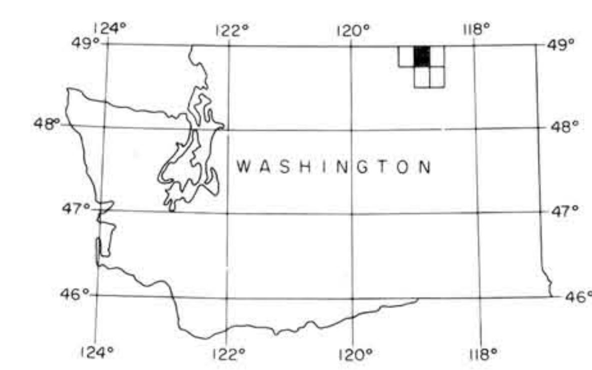


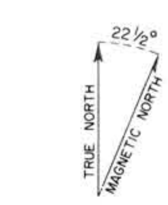
MAGNETIC CONTOUR ENCLOSING AREA OF LOWER MAGNETIC INTENSITY

MEAN FLIGHT LINE SPACING — 1320 FEET
FIDUCIAL POINTS — 3690 ○
FLIGHT LINES

NOTE

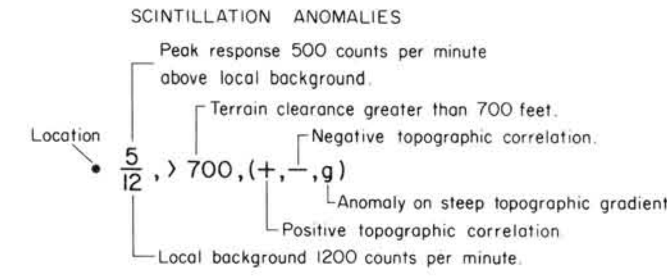
The contours represent absolute values of the total intensity of the earth's magnetic field. The data are obtained continuously along the flight lines and are accurately plotted on these lines. Between flight lines the contours are drawn by interpolation and therefore may be in error. Terrain clearance is nominally 500 feet, but due to sharp variations in ground elevation the clearance is not constant and may locally reach 800 feet.

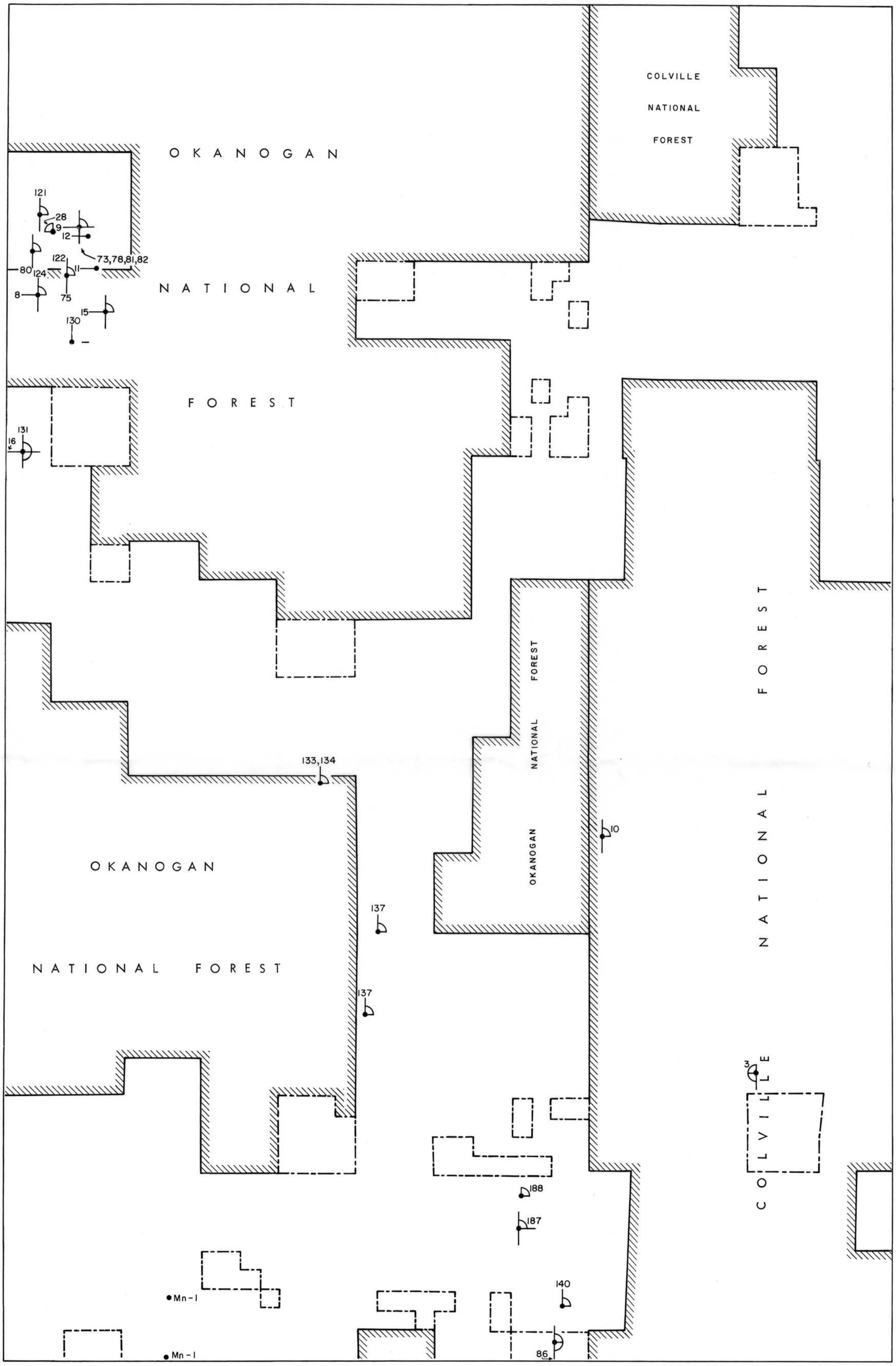


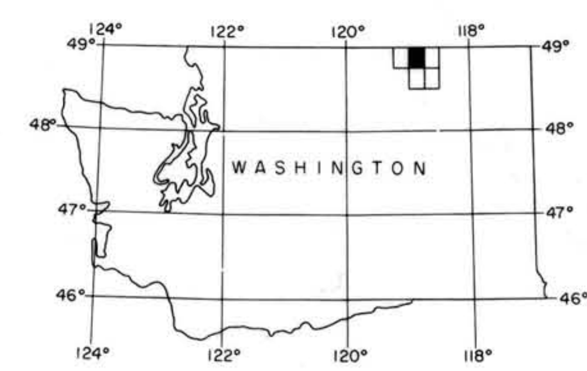


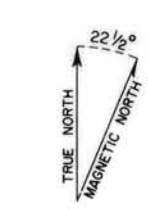
APPROXIMATE MEAN DECLINATION 1958

SCINTILLATION ANOMALIES









APPROXIMATE MEAN
DECLINATION 1958

National Forest boundary
State-owned land boundary

MINERAL DEPOSITS MAP
BODIE MOUNTAIN QUADRANGLE
OKANOGAN AND FERRY COUNTIES, WASHINGTON

SCALE 1:62500

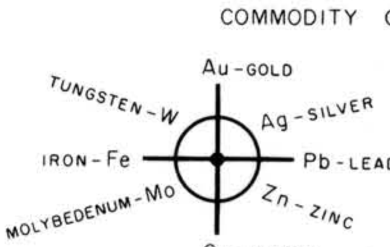
1 ½ 0 1 2 3 4 MILES

3000 0 3000 6000 9000 12000 15000 18000 21000 FEET

1 .5 0 1 2 3 4 5 KILOMETERS

1960

COMMODITY CODE

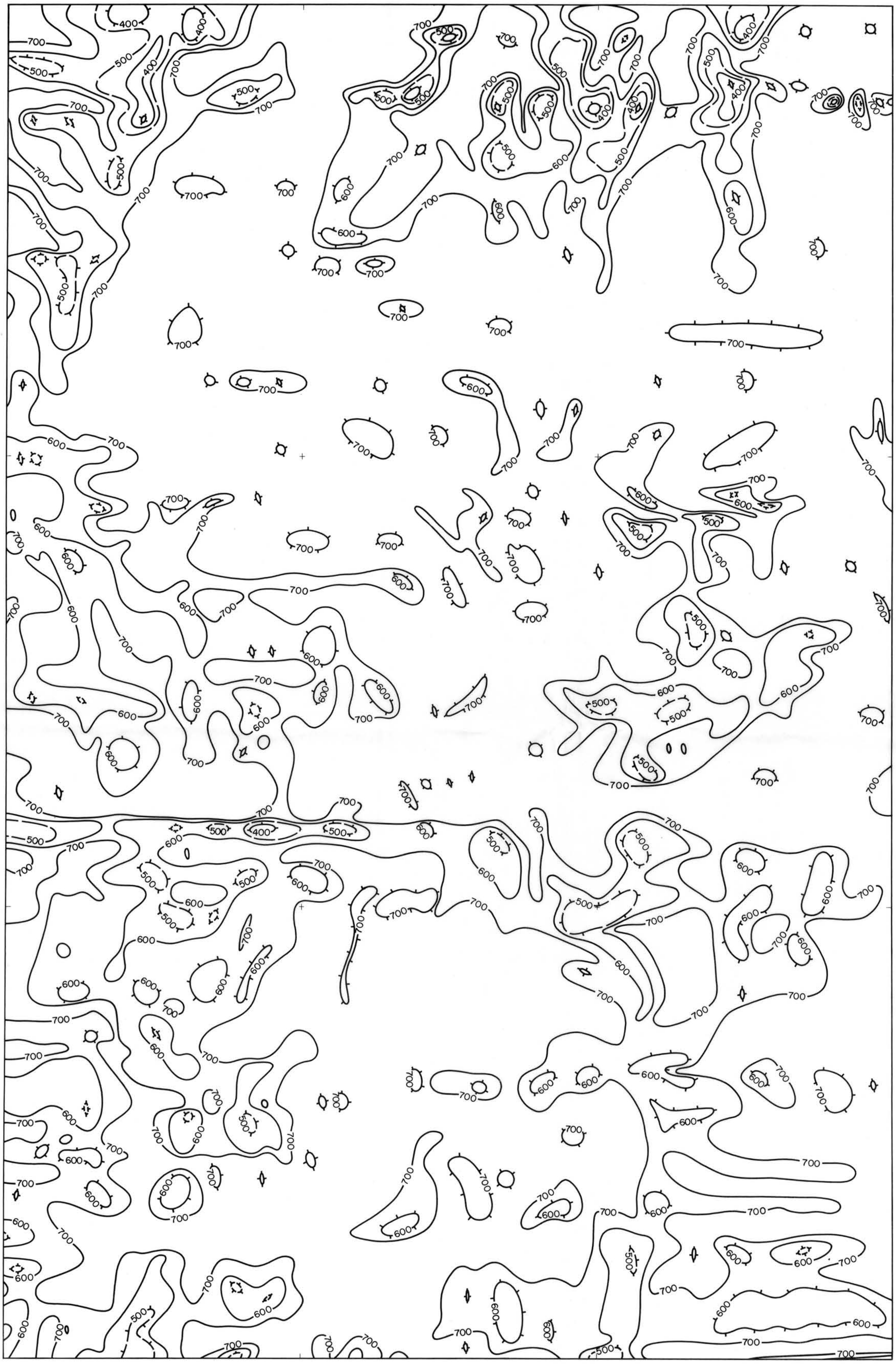


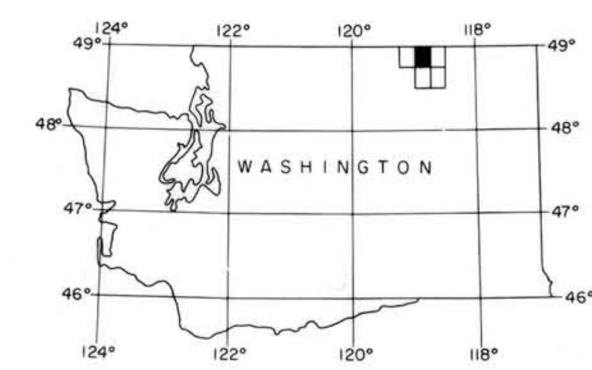
Pt	PLATINUM
Se	SELENIUM
Sb	ANTIMONY
As	ARSENIC
Mn	MANGANESE
Ni	NICKEL
Co	COBALT

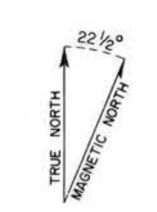
NOTE: Numbers are the reference number by commodity and county as listed in Bulletin 37, Inventory of Washington Minerals, Part II Metallic Minerals, Marshall T. Huntting, Division of Mines and Geology, 1956.
e.g. ●—— 6, Occurrence # 6 of Lead in Ferry Co. or in Okanogan Co.

STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY

REPORT OF INVESTIGATIONS NO. 20
PLATE 2 - C





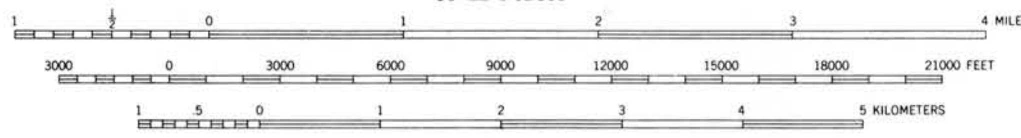


APPROXIMATE MEAN DECLINATION 1958

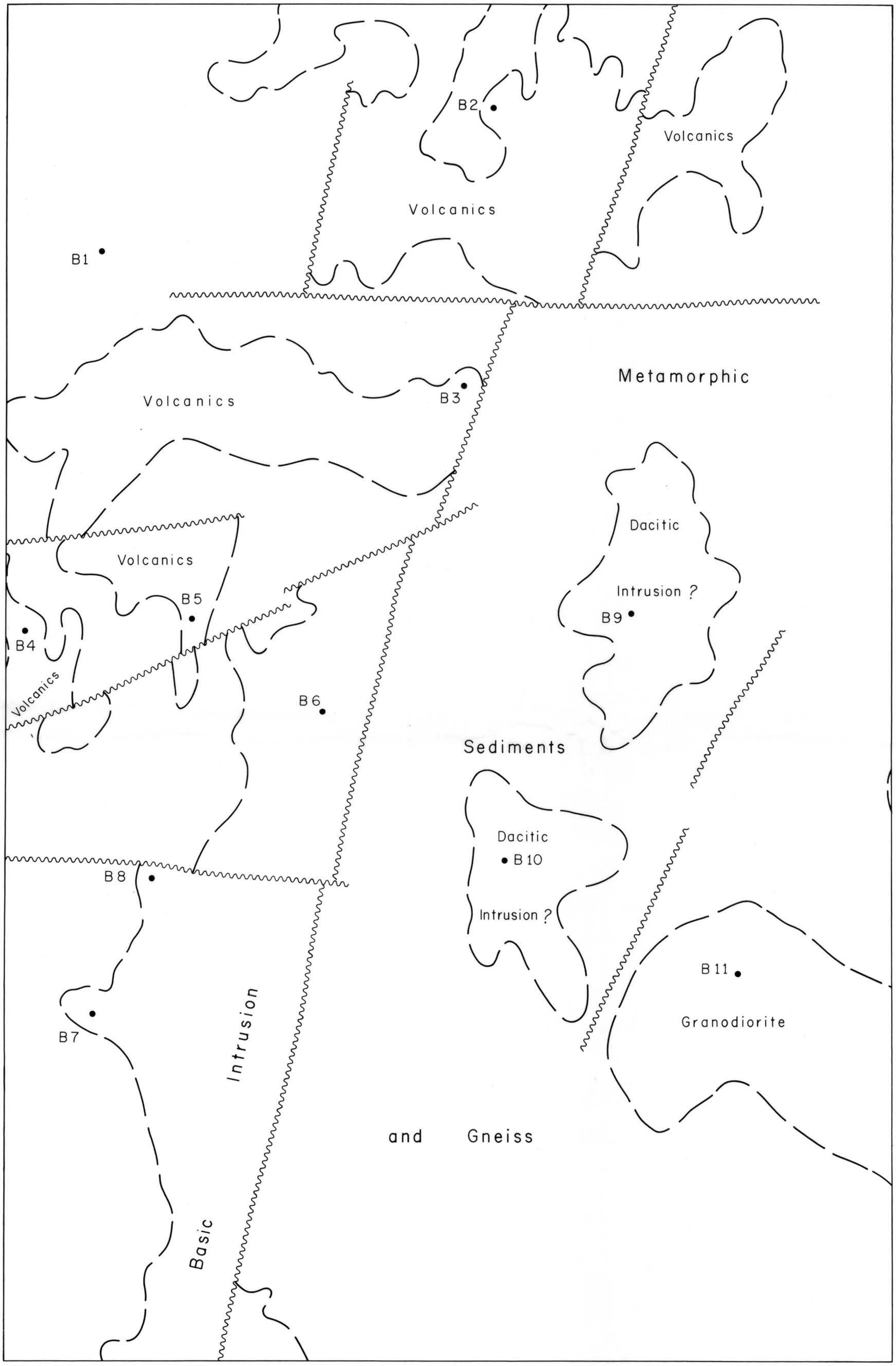
GROUND CLEARANCE MAP
BODIE MOUNTAIN QUADRANGLE
OKANOGAN AND FERRY COUNTIES, WASHINGTON

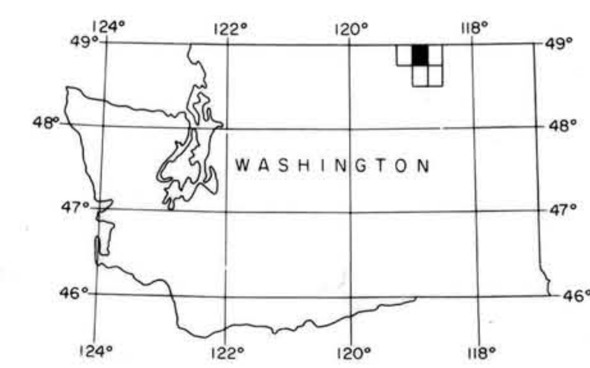
The contours represent the height of the aircraft above ground. The data are accurately plotted along the flight lines but have been drawn by interpolation between the lines. Hachured contours may be indicative of areas of higher topographic relief.
Contour interval 100 feet

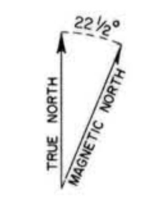
SCALE 1:62500



1960







APPROXIMATE MEAN DECLINATION 1958

INTERPRETATION

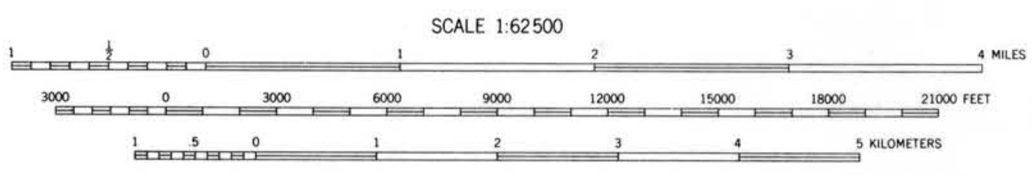
Geological contact

Fault

Depth determination • B11

GEOLOGY INTERPRETED FROM AEROMAGNETIC DATA
BODIE MOUNTAIN QUADRANGLE
OKANOGAN AND FERRY COUNTIES, WASHINGTON

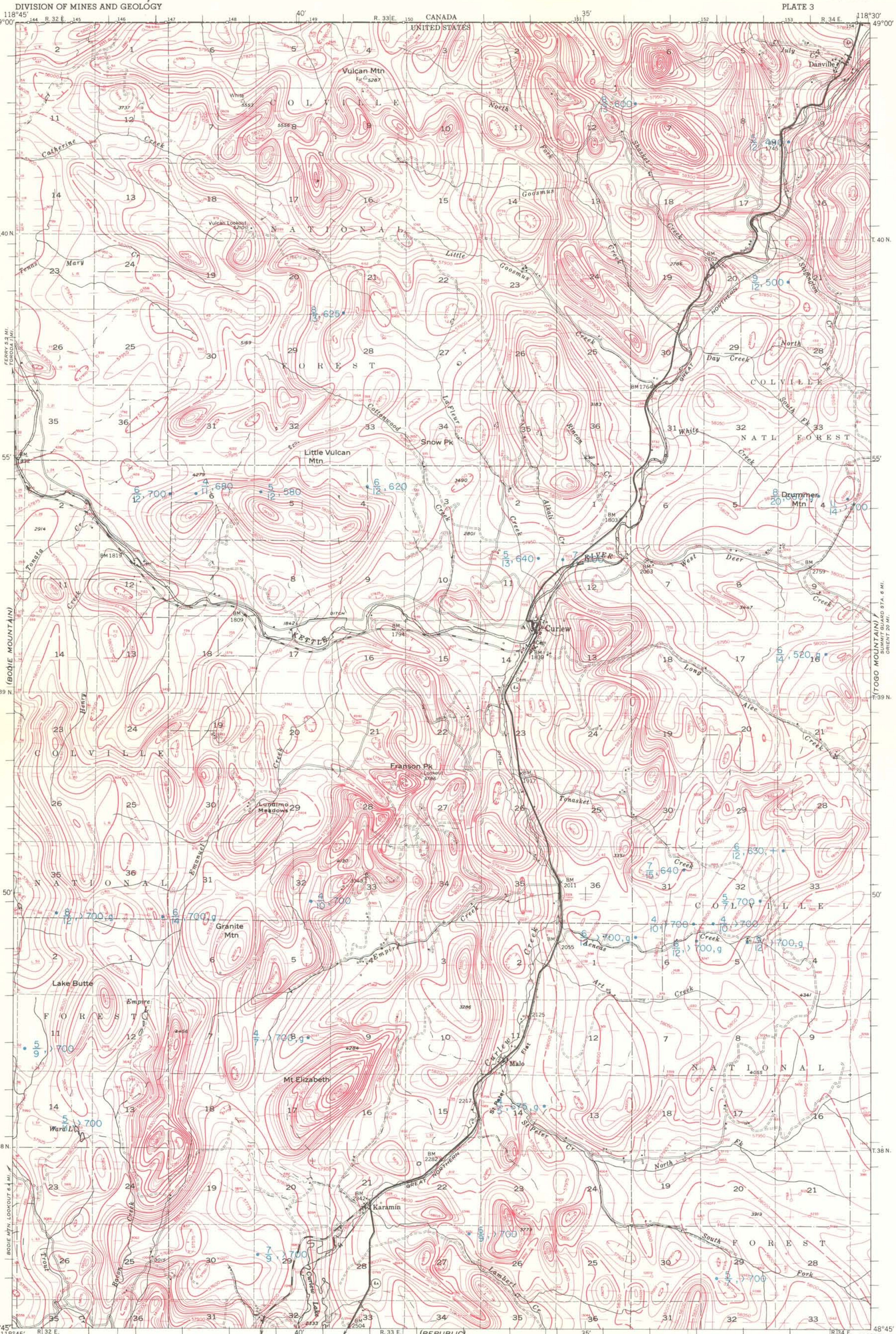
SCALE 1:62500



1960

STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY

REPORT OF INVESTIGATIONS NO. 20
PLATE 3



Base from U. S. Geological Survey topographic quadrangle map

Aeromagnetic and scintillometer survey flown 500 feet above ground, 1959 by HUNTING GEOPHYSICAL SERVICES, INC.

AEROMAGNETIC AND SCINTILLOMETER SURVEY OF CURLEW QUADRANGLE FERRY COUNTY, WASHINGTON

SCALE 1:62500

1 ½ 0 1 2 3 4 MILES

3000 0 3000 6000 9000 12000 15000 18000 21000 FEET

1 .5 0 1 2 3 4 5 KILOMETERS

EXPLANATION

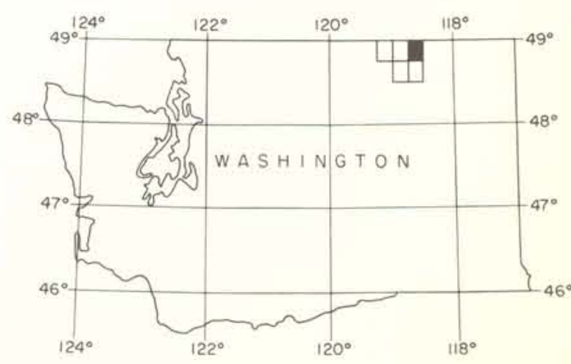
MAGNETIC CONTOUR INTERVAL — 25 GAMMAS
500 GAMMA CONTOUR
100 GAMMA CONTOUR
50 GAMMA CONTOUR
25 GAMMA CONTOUR

MAGNETIC CONTOUR ENCLOSING AREA OF LOWER MAGNETIC INTENSITY

MEAN FLIGHT LINE SPACING — 1320 FEET
FIDUCIAL POINTS
FLIGHT LINES

NOTE

The contours represent absolute values of the total intensity of the earth's magnetic field. The data are obtained continuously along the flight lines and are accurately plotted on these lines. Between flight lines the contours are drawn by interpolation and therefore may be in error. Terrain clearance is nominally 500 feet, but due to sharp variations in ground elevation the clearance is not constant and may locally reach 800 feet.



22½°
TRUE NORTH
MAGNETIC NORTH

APPROXIMATE MEAN DECLINATION 1958

SCINTILLATION ANOMALIES

Location • 5/12, > 700, (+, −, g)

- Peak response 500 counts per minute above local background.
- Terrain clearance greater than 700 feet.
- Negative topographic correlation.
- Anomaly on steep topographic gradient.
- Positive topographic correlation.
- Local background 1200 counts per minute.

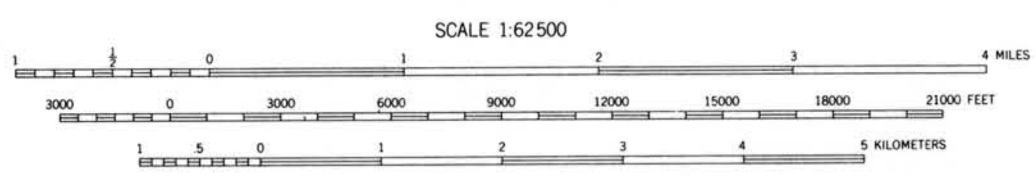
STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY

Base from U. S. Geological Survey topographic quadrangle map

Aeromagnetic and scintillometer survey flown 500 feet above ground, 1959 by HUNTING GEOPHYSICAL SERVICES, INC.

AEROMAGNETIC AND SCINTILLOMETER SURVEY OF CURLEW QUADRANGLE FERRY COUNTY, WASHINGTON

SCALE 1:62500



1960

EXPLANATION

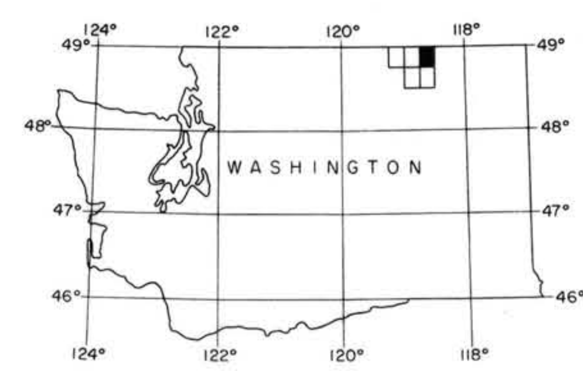
MAGNETIC CONTOUR INTERVAL — 25 GAMMAS
500 GAMMA CONTOUR
100 GAMMA CONTOUR
50 GAMMA CONTOUR
25 GAMMA CONTOUR

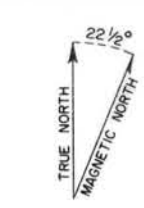
MAGNETIC CONTOUR ENCLOSING AREA OF LOWER MAGNETIC INTENSITY

MEAN FLIGHT LINE SPACING — 1320 FEET
FIDUCIAL POINTS — 36900
FLIGHT LINES

NOTE

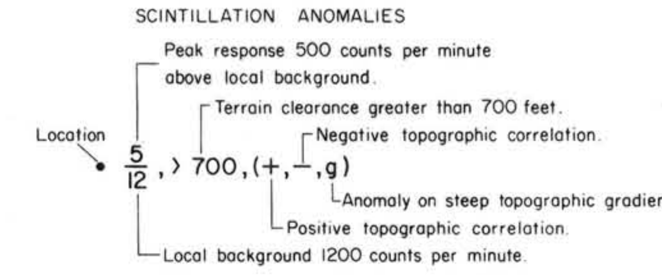
The contours represent absolute values of the total intensity of the earth's magnetic field. The data are obtained continuously along the flight lines and are accurately plotted on these lines. Between flight lines the contours are drawn by interpolation and therefore may be in error. Terrain clearance is nominally 500 feet, but due to sharp variations in ground elevation the clearance is not constant and may locally reach 800 feet.

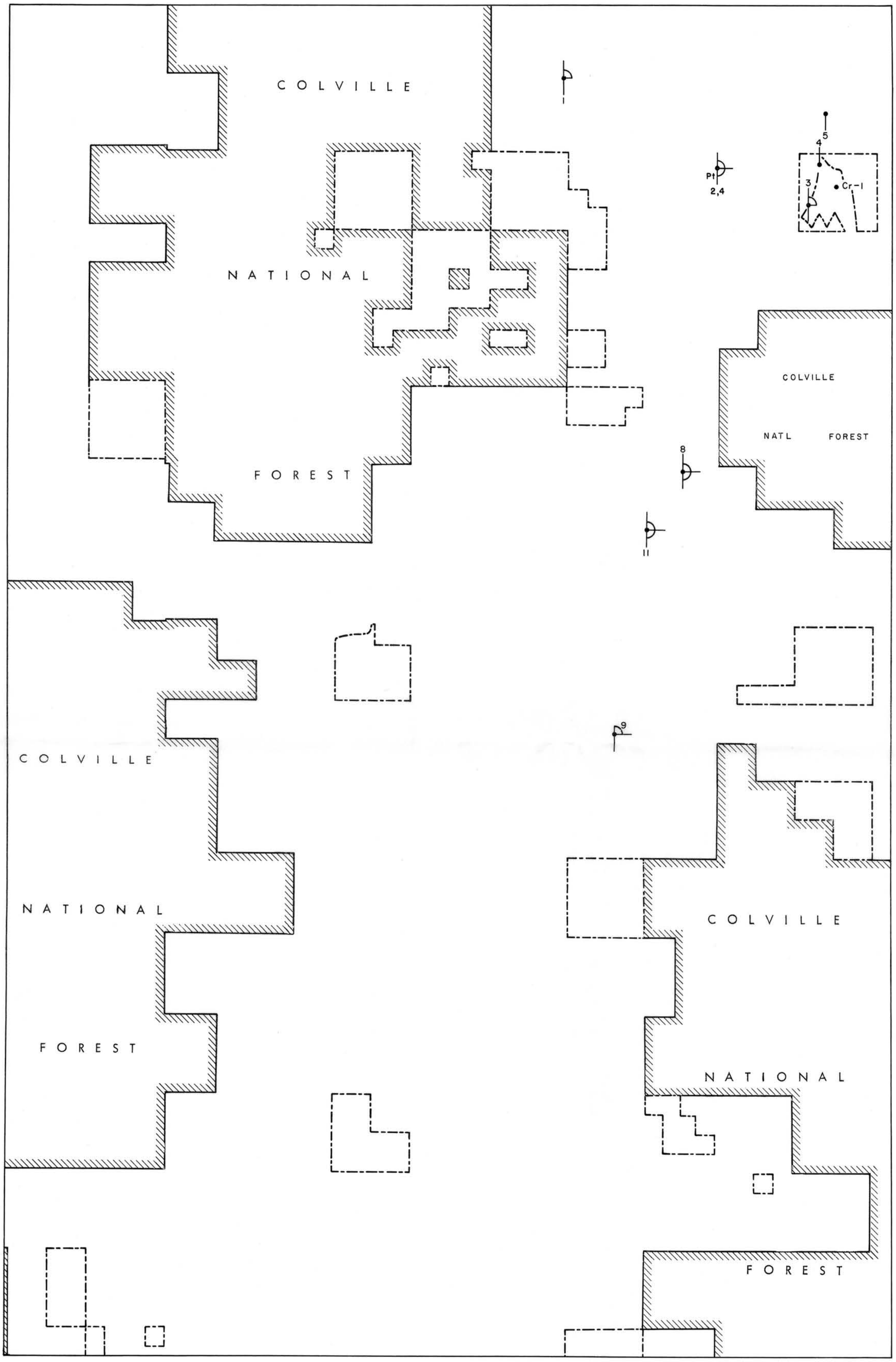


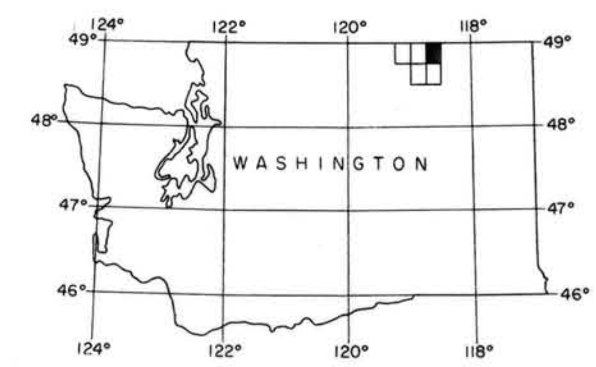


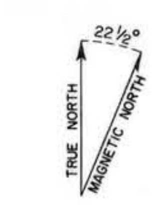
APPROXIMATE MEAN DECLINATION 1958

SCINTILLATION ANOMALIES







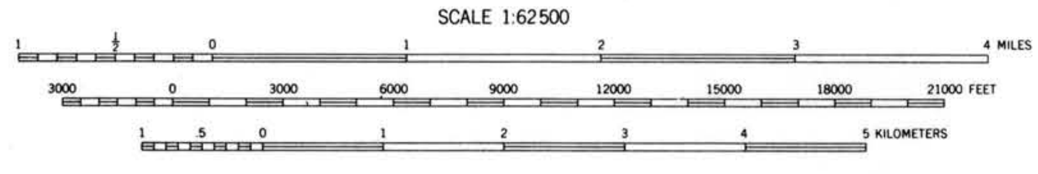


APPROXIMATE MEAN DECLINATION 1958

National Forest boundary
State-owned land boundary

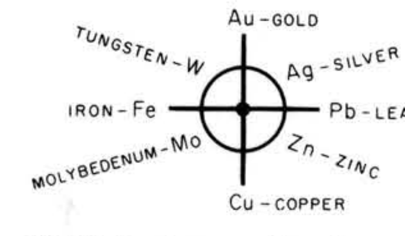
MINERAL DEPOSITS MAP
CURLEW QUADRANGLE
FERRY COUNTY, WASHINGTON

SCALE 1:62500



1960

COMMODITY CODE

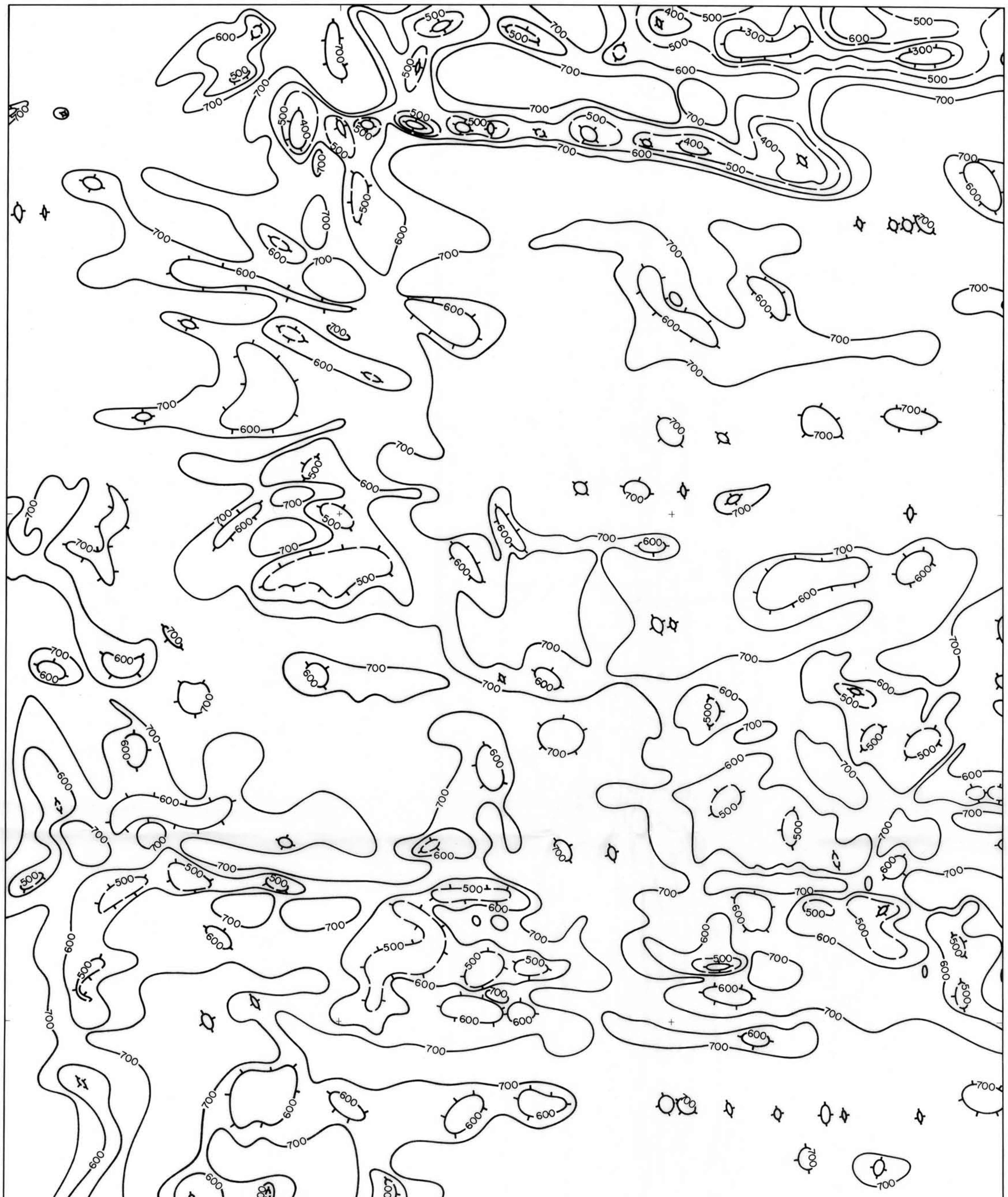


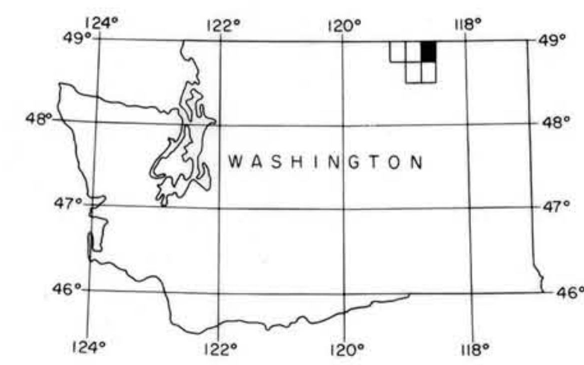
Pt PLATINUM
Se SELENIUM
Sb ANTIMONY
As ARSENIC
Mn MANGANESE
Ni NICKEL
Co COBALT

NOTE: Numbers are the reference number by commodity and county as listed in Bulletin 37, Inventory of Washington Minerals, Part II Metallic Minerals, Marshall T. Huntting, Division of Mines and Geology, 1956.
e.g. ●——— 6, Occurrence # 6 of Lead in Ferry Co. or in Okanogan Co.

STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY

REPORT OF INVESTIGATIONS NO. 20
PLATE 3 – C



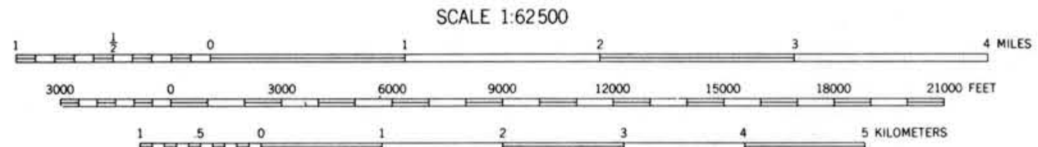


APPROXIMATE MEAN DECLINATION 1958

GROUND CLEARANCE MAP
CURLEW QUADRANGLE
FERRY COUNTY, WASHINGTON

The contours represent the height of the aircraft above ground. The data are accurately plotted along the flight lines but have been drawn by interpolation between the lines. Hachured contours may be indicative of areas of higher topographic relief.
Contour interval 100 feet

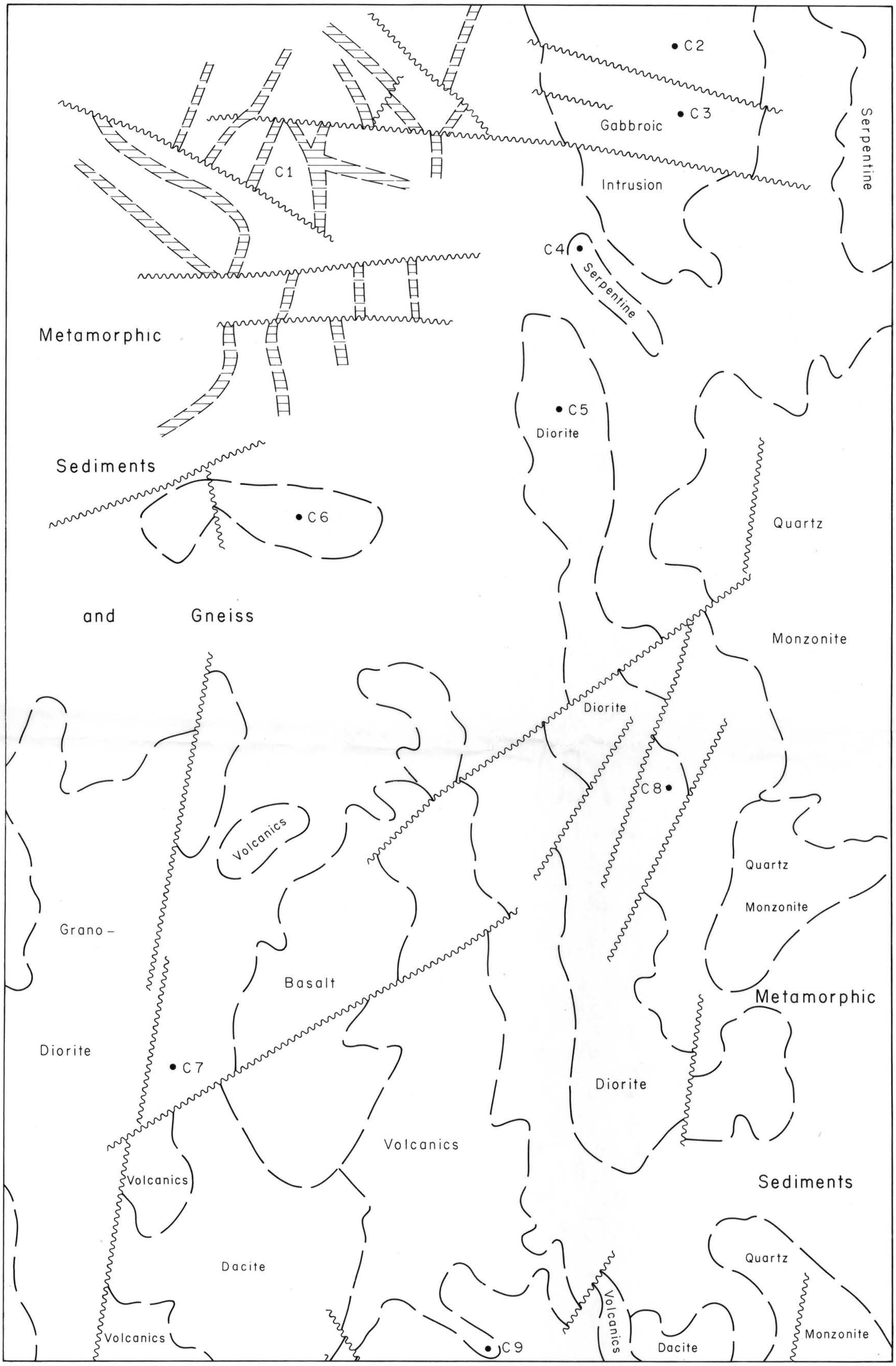
SCALE 1:62500

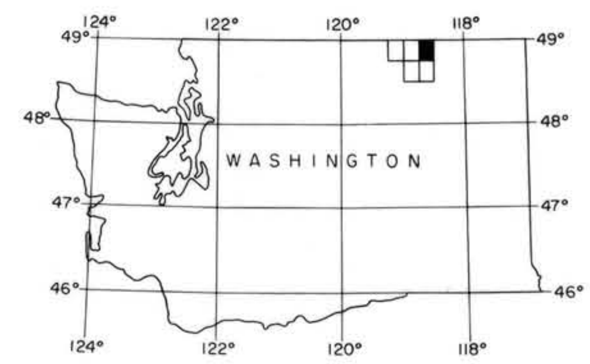


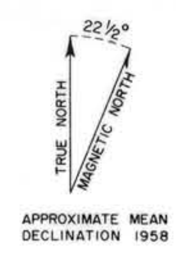
1960

STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY

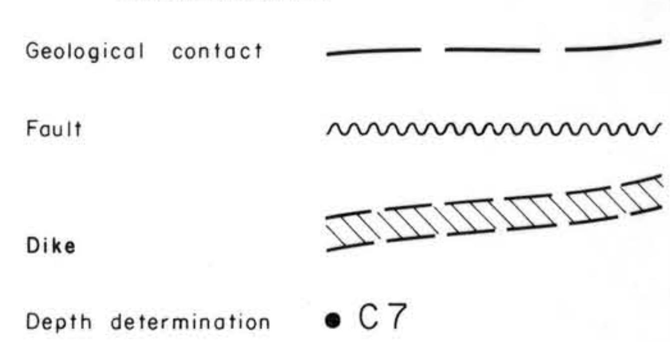
REPORT OF INVESTIGATIONS NO. 20
PLATE 3 - D





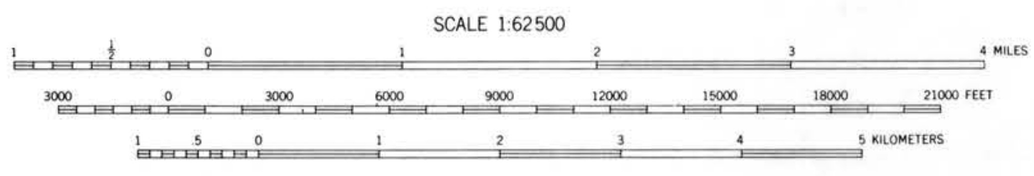


INTERPRETATION



GEOLOGY INTERPRETED FROM AEROMAGNETIC DATA
CURLEW QUADRANGLE
FERRY COUNTY, WASHINGTON

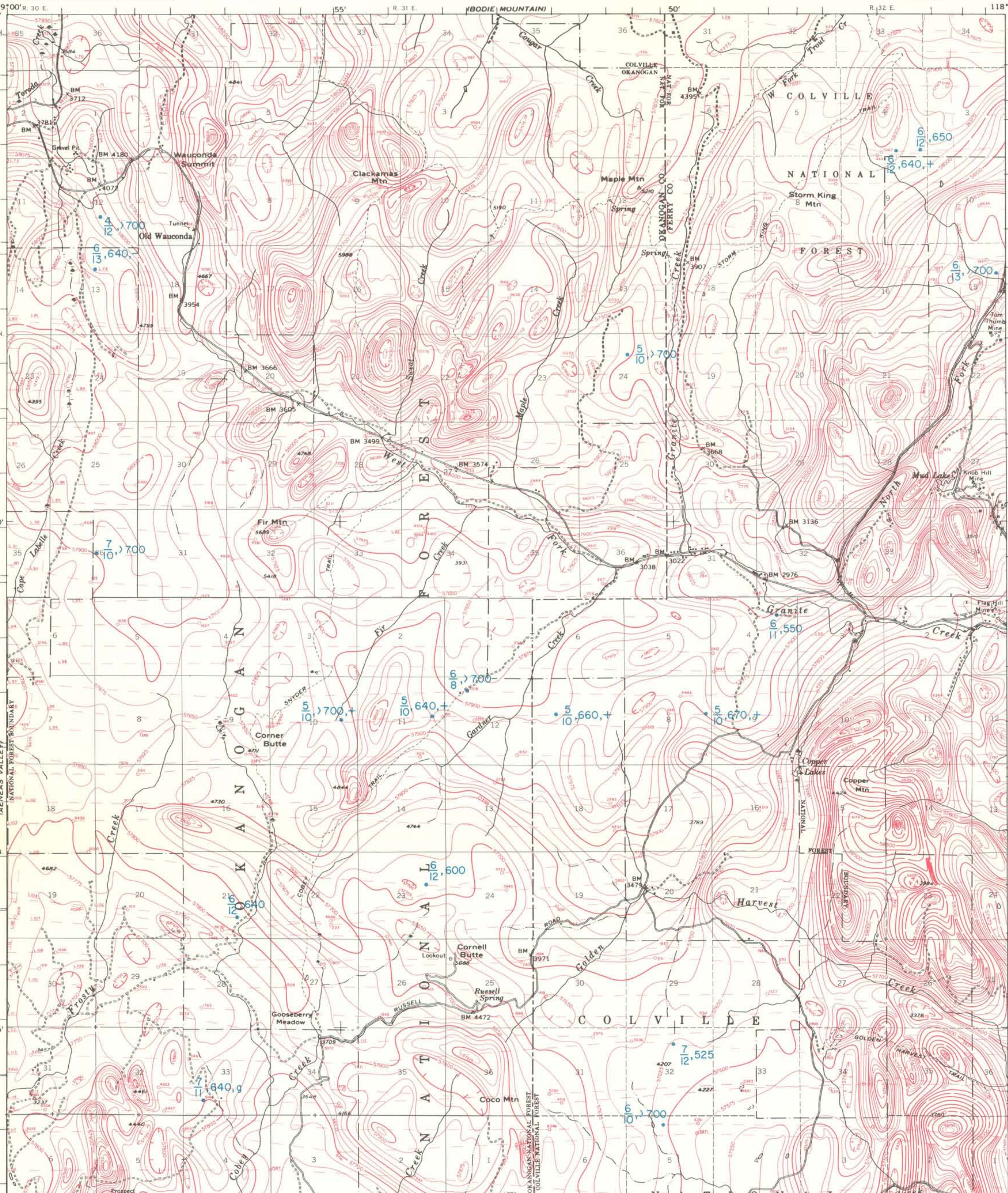
SCALE 1:62500



1960

STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY

REPORT OF INVESTIGATIONS NO. 20
PLATE 4



119°00' 48°45' — 118°45' 48°45'

48°30' 119°00' — 118°45' 48°30'

Base from U. S. Geological Survey topographic quadrangle map

Aeromagnetic and scintillometer survey flown 500 feet above ground, 1959 by HUNTING GEOPHYSICAL SERVICES, INC.

AEROMAGNETIC AND SCINTILLOMETER SURVEY OF AENEAS QUADRANGLE OKANOGAN AND FERRY COUNTIES, WASHINGTON

SCALE 1:62500

1 ½ 0 1 2 3 4 MILES

3000 0 3000 6000 9000 12000 15000 18000 21000 FEET

1 .5 0 1 2 3 4 5 KILOMETERS

EXPLANATION

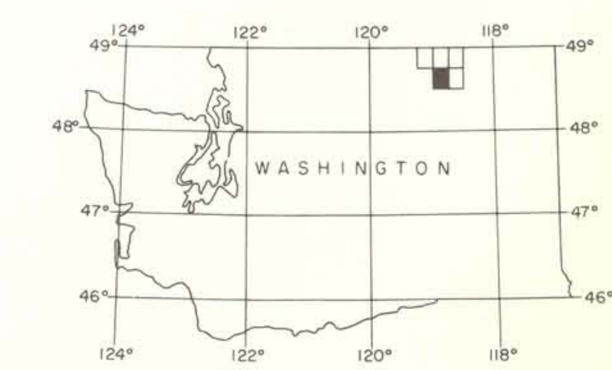
MAGNETIC CONTOUR INTERVAL 25 GAMMAS
500 GAMMA CONTOUR
100 GAMMA CONTOUR
50 GAMMA CONTOUR
25 GAMMA CONTOUR

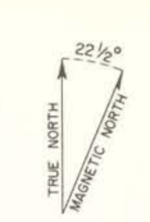
MAGNETIC CONTOUR ENCLOSING AREA OF LOWER MAGNETIC INTENSITY

MEAN FLIGHT LINE SPACING 1320 FEET
FIDUCIAL POINTS
FLIGHT LINES

NOTE

The contours represent absolute values of the total intensity of the earth's magnetic field. The data are obtained continuously along the flight lines and are accurately plotted on these lines. Between flight lines the contours are drawn by interpolation and therefore may be in error. Terrain clearance is nominally 500 feet, but due to sharp variations in ground elevation the clearance is not constant and may locally reach 800 feet.



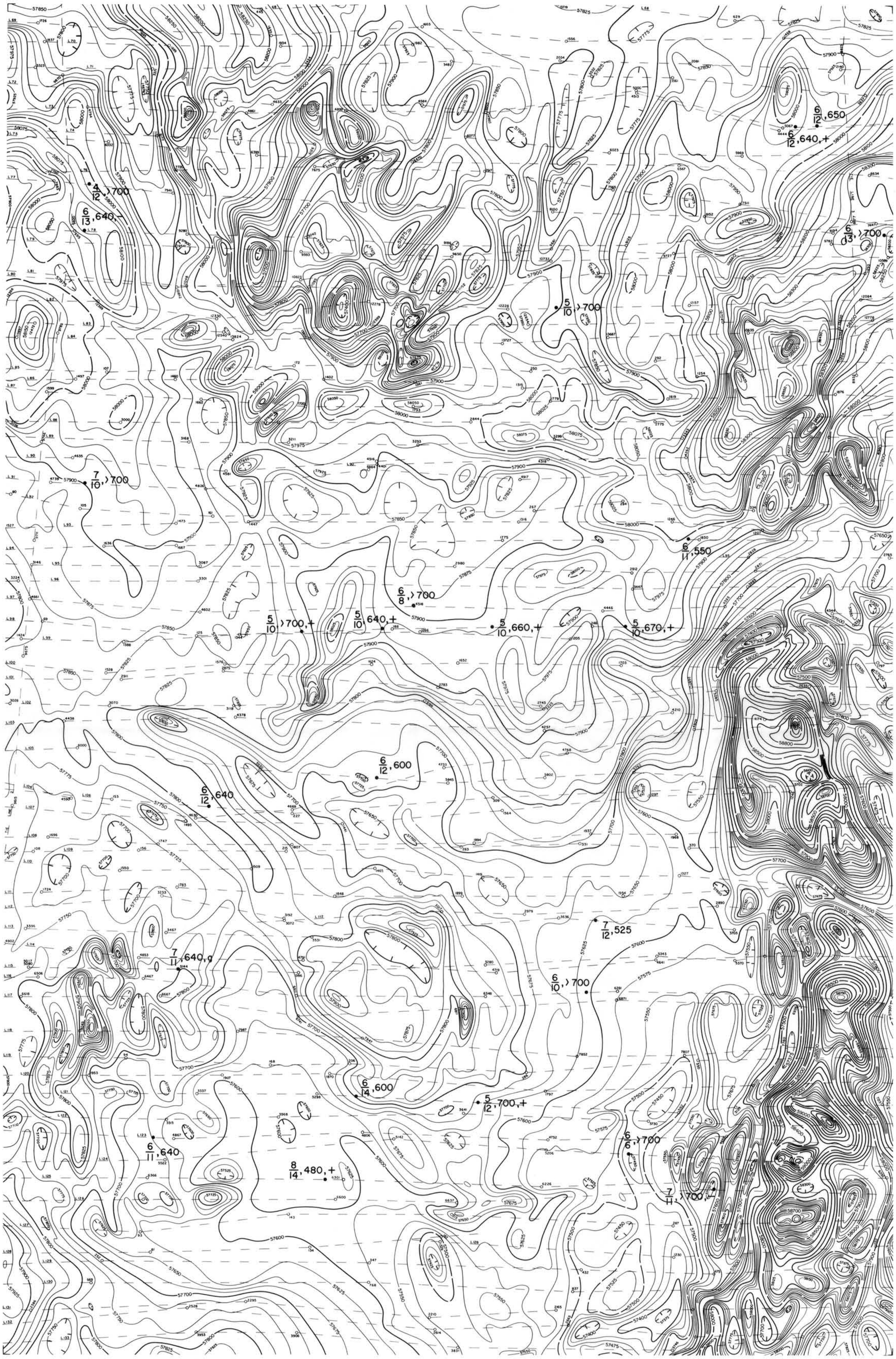


APPROXIMATE MEAN DECLINATION 1958

SCINTILLATION ANOMALIES

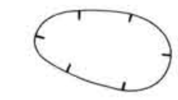
Location • 5/12, > 700, (+, −, g)

- 5 — Peak response 500 counts per minute above local background.
- > 700 — Terrain clearance greater than 700 feet.
- − — Negative topographic correlation.
- g — Anomaly on steep topographic gradient.
- + — Positive topographic correlation.
- 12 — Local background 1200 counts per minute.



EXPLANATION

MAGNETIC CONTOUR INTERVAL — 25 GAMMAS
500 GAMMA CONTOUR
100 GAMMA CONTOUR
50 GAMMA CONTOUR
25 GAMMA CONTOUR

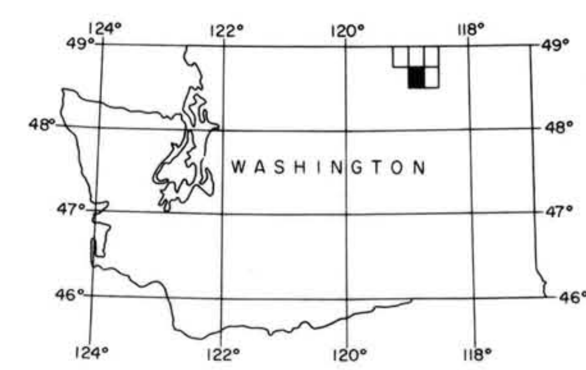


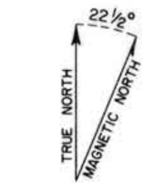
MAGNETIC CONTOUR ENCLOSING AREA OF LOWER MAGNETIC INTENSITY

MEAN FLIGHT LINE SPACING — 1320 FEET
FIDUCIAL POINTS — 3690○
FLIGHT LINES

NOTE

The contours represent absolute values of the total intensity of the earth's magnetic field. The data are obtained continuously along the flight lines and are accurately plotted on these lines. Between flight lines the contours are drawn by interpolation and therefore may be in error. Terrain clearance is nominally 500 feet, but due to sharp variations in ground elevation the clearance is not constant and may locally reach 800 feet.





APPROXIMATE MEAN DECLINATION 1958

SCINTILLATION ANOMALIES

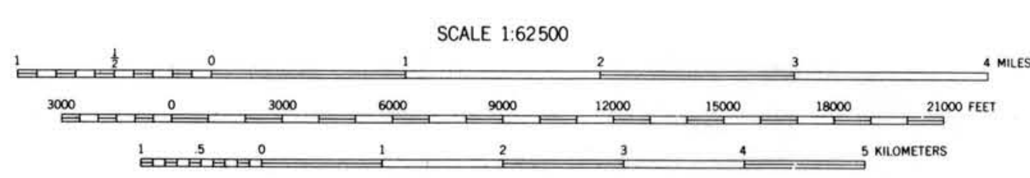
Location • $\frac{5}{12}$, › 700, (+, −, g)

- 5 — Peak response 500 counts per minute above local background.
- 12 — Local background 1200 counts per minute.
- › 700 — Terrain clearance greater than 700 feet.
- + — Positive topographic correlation.
- − — Negative topographic correlation.
- g — Anomaly on steep topographic gradient.

Base from U. S. Geological Survey topographic quadrangle map

Aeromagnetic and scintillometer survey flown 500 feet above ground, 1959
by
HUNTING GEOPHYSICAL SERVICES, INC.

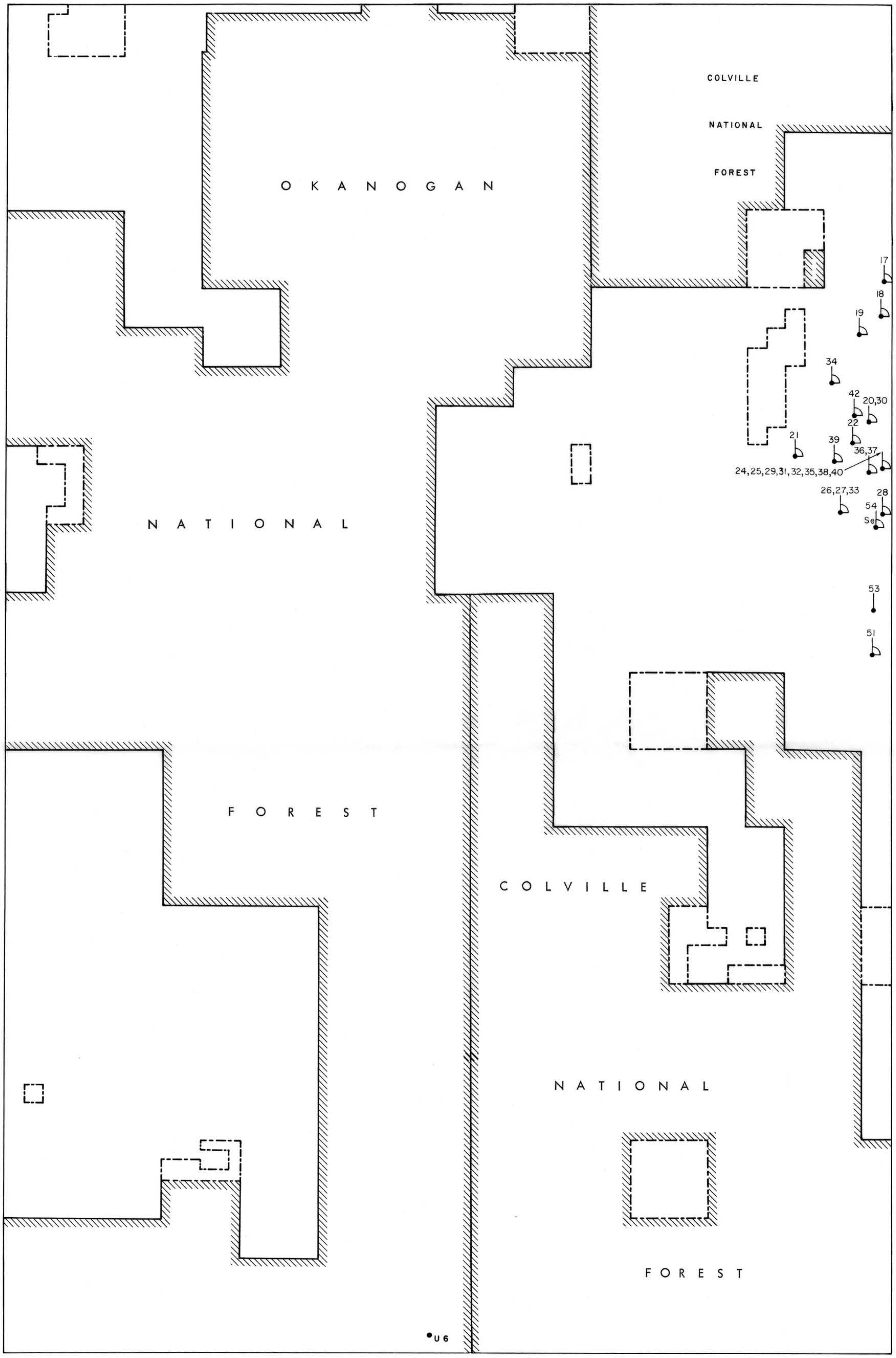
AEROMAGNETIC AND SCINTILLOMETER SURVEY OF AENEAS QUADRANGLE OKANOGAN AND FERRY COUNTIES, WASHINGTON

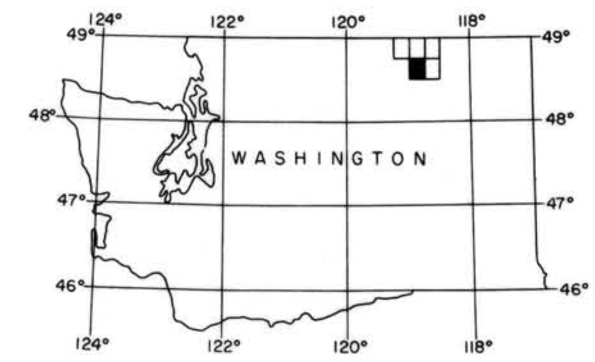


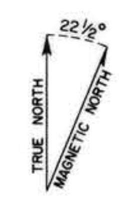
1960

STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY

REPORT OF INVESTIGATIONS NO. 20
PLATE 4 – B



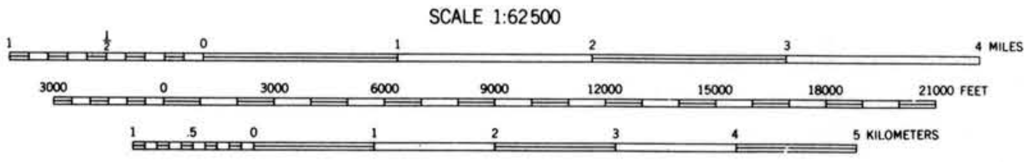




APPROXIMATE MEAN DECLINATION 1958

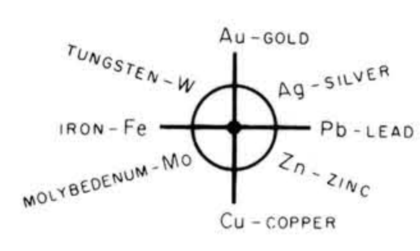
National Forest boundary
State–owned land boundary

MINERAL DEPOSITS MAP
AENEAS QUADRANGLE
OKANOGAN AND FERRY COUNTIES, WASHINGTON



1960

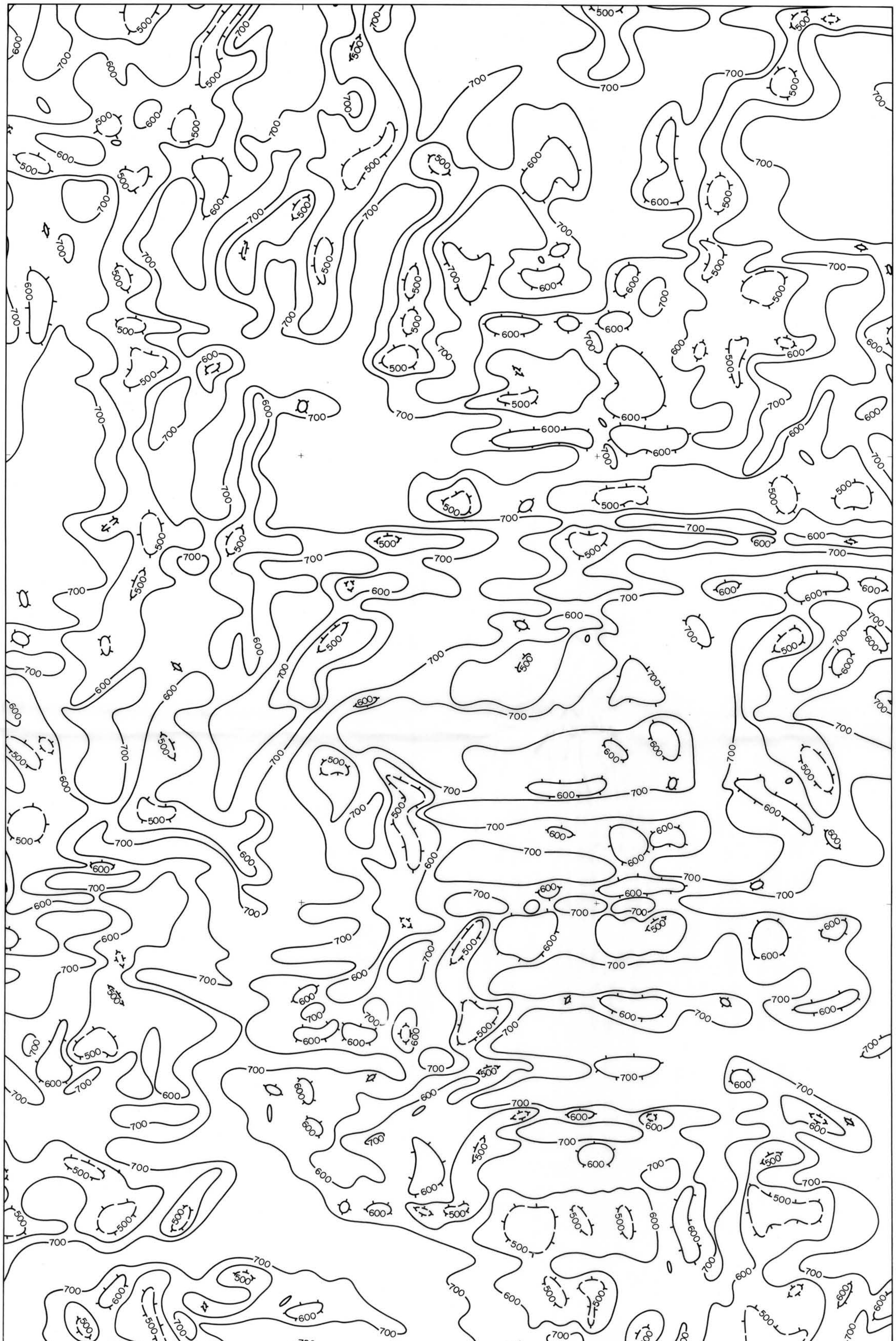
COMMODITY CODE

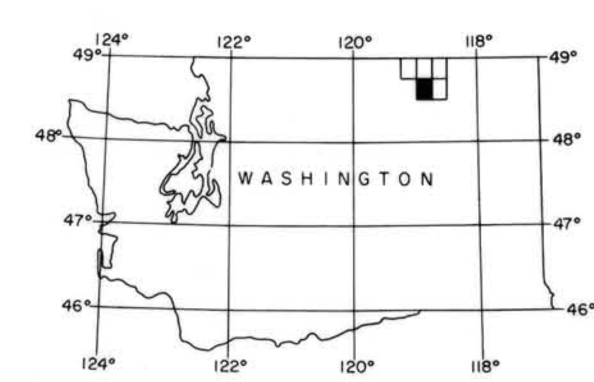


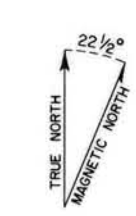
Pt PLATINUM
Se SELENIUM
Sb ANTIMONY
As ARSENIC
Mn MANGANESE
Ni NICKEL
Co COBALT
U URANIUM

NOTE: Numbers are the reference number by commodity and county as listed in Bulletin 37, Inventory of Washington Minerals, Part II Metallic Minerals, Marshall T. Huntting, Division of Mines and Geology, 1956.
e.g. ●—— 6, Occurrence # 6 of Lead in Ferry Co. or in Okanogan Co.

STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY





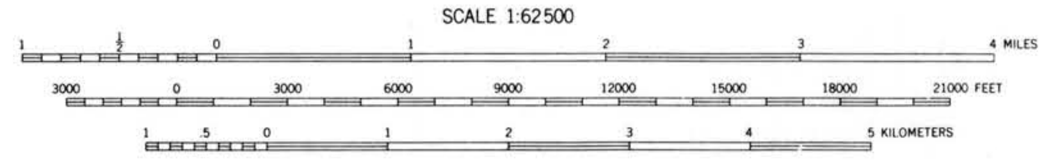


APPROXIMATE MEAN
DECLINATION 1958

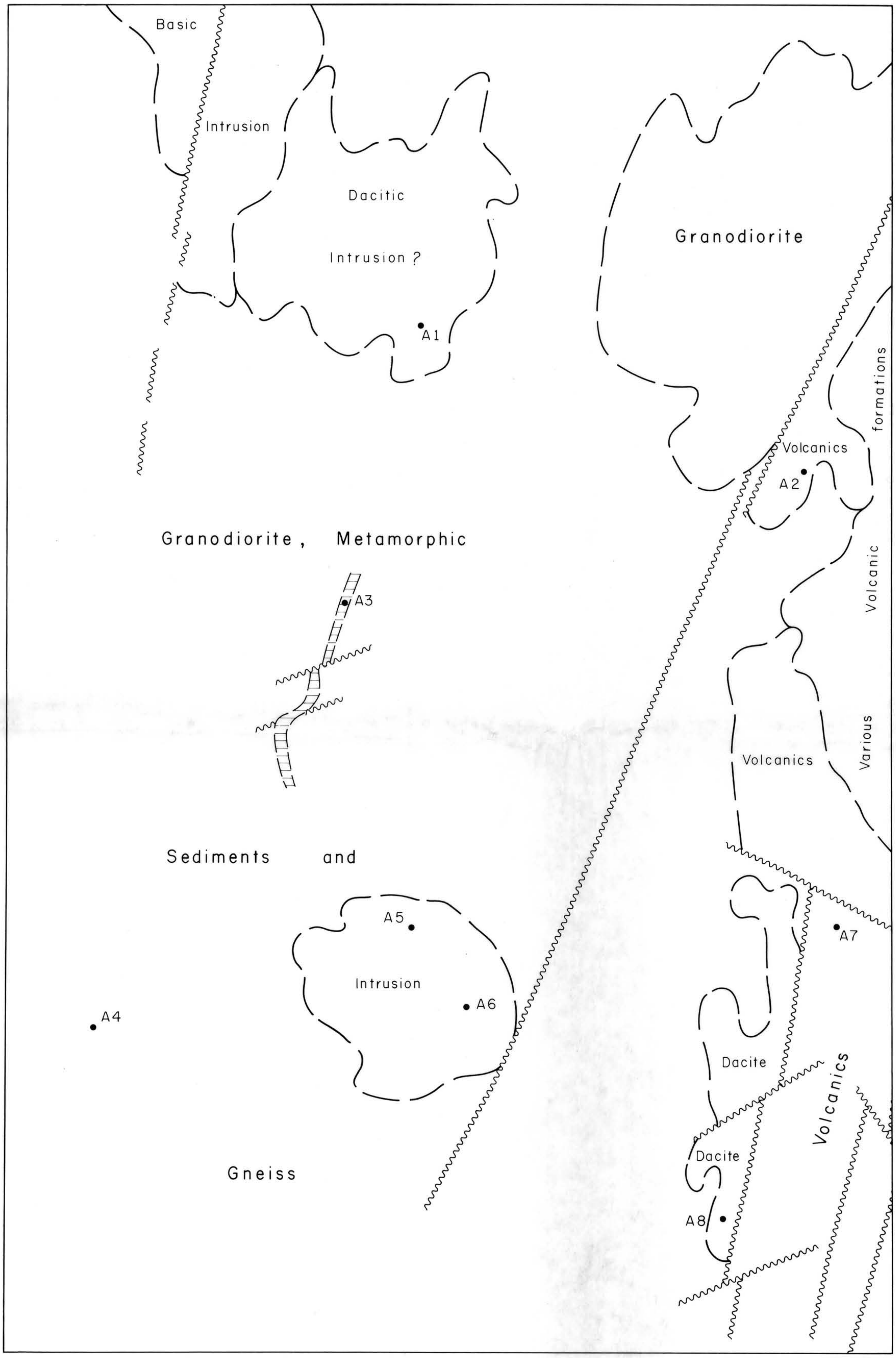
GROUND CLEARANCE MAP
AENEAS QUADRANGLE
OKANOGAN AND FERRY COUNTIES, WASHINGTON

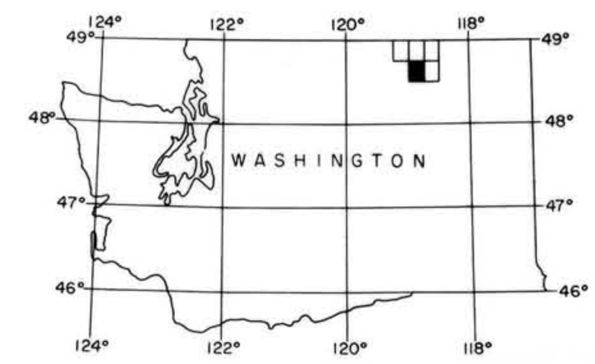
The contours represent the height of the aircraft above ground. The data are accurately plotted along the flight lines but have been drawn by interpolation between the lines. Hachured contours may be indicative of areas of higher topographic relief.
Contour interval 100 feet

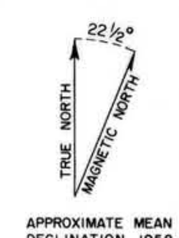
SCALE 1:62500



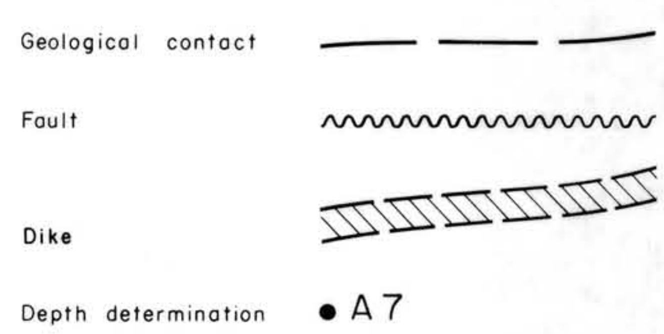
1960





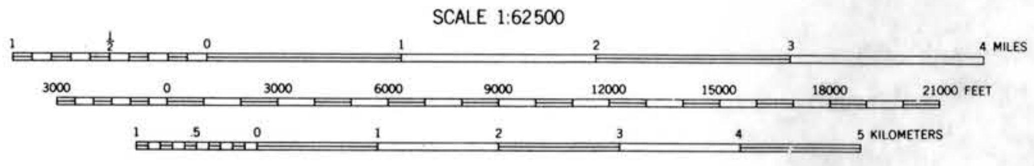


INTERPRETATION



GEOLOGY INTERPRETED FROM AEROMAGNETIC DATA
AENEAS QUADRANGLE
OKANOGAN AND FERRY COUNTIES, WASHINGTON

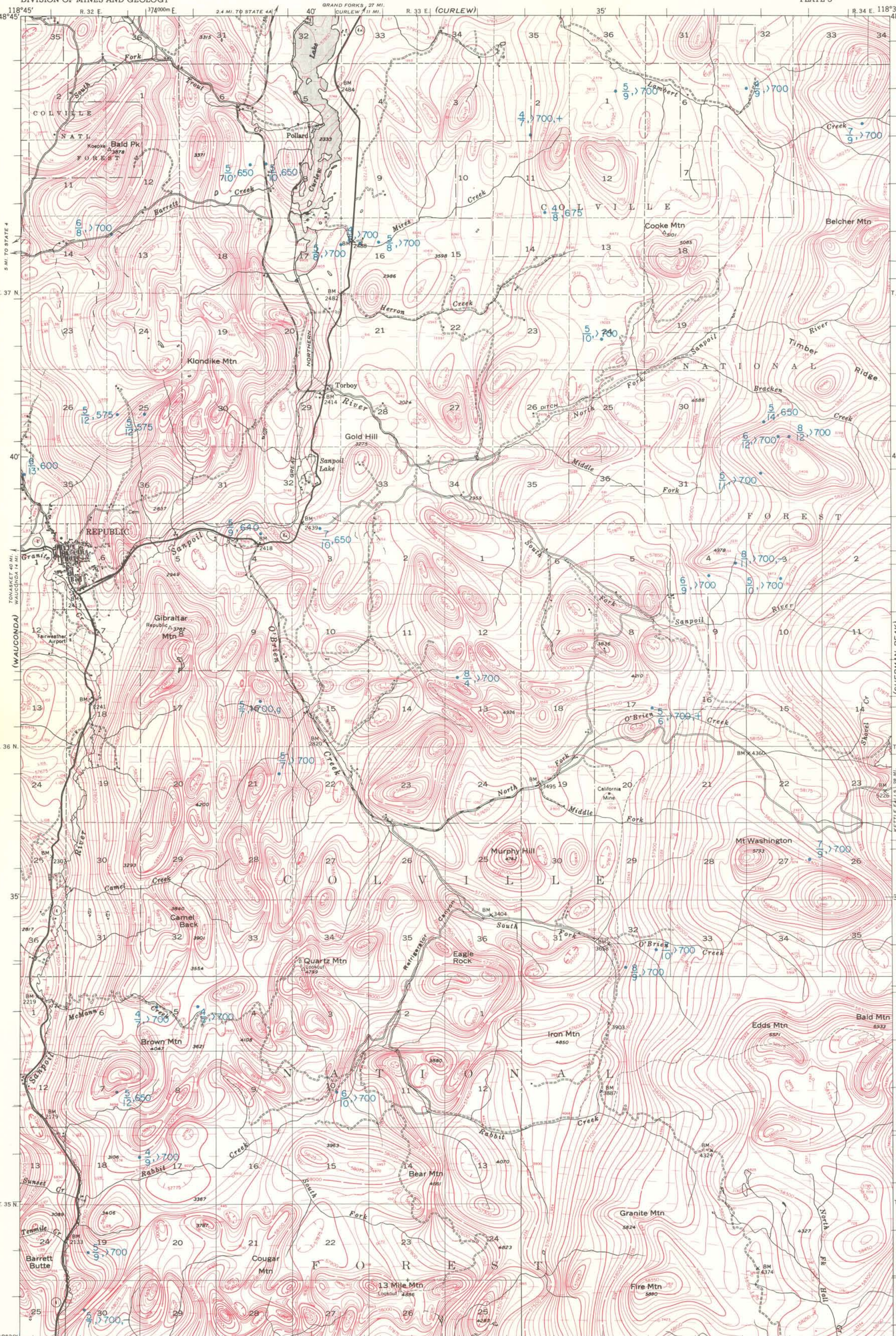
SCALE 1:62500



1960

STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY

REPORT OF INVESTIGATIONS NO. 20
PLATE 5



Base from U. S. Geological Survey topographic quadrangle map

Aeromagnetic and scintillometer survey flown 500 feet above ground, 1959
by
HUNTING GEOPHYSICAL SERVICES, INC.

AEROMAGNETIC AND SCINTILLOMETER SURVEY OF REPUBLIC QUADRANGLE FERRY COUNTY

SCALE 1:62500

0 1 2 3 4 MILES
3000 0 3000 6000 9000 12000 15000 18000 21000 FEET
1 .5 0 1 2 3 4 5 KILOMETERS

EXPLANATION

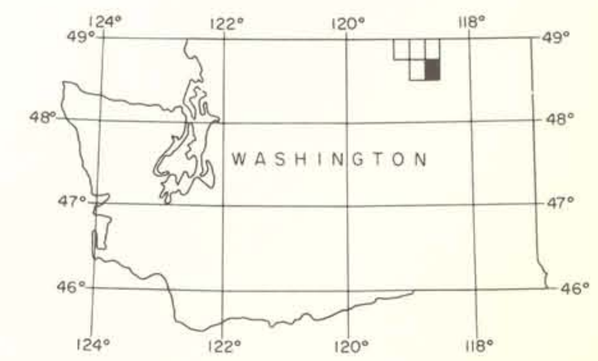
MAGNETIC CONTOUR INTERVAL ... 25 GAMMAS
500 GAMMA CONTOUR
100 GAMMA CONTOUR
50 GAMMA CONTOUR
25 GAMMA CONTOUR

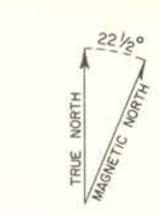
MAGNETIC CONTOUR ENCLOSING AREA OF LOWER MAGNETIC INTENSITY

MEAN FLIGHT LINE SPACING ... 1320 FEET
FIDUCIAL POINTS
FLIGHT LINES

NOTE

The contours represent absolute values of the total intensity of the earth's magnetic field. The data are obtained continuously along the flight lines and are accurately plotted on these lines. Between flight lines the contours are drawn by interpolation and therefore may be in error. Terrain clearance is nominally 500 feet, but due to sharp variations in ground elevation the clearance is not constant and may locally reach 800 feet.



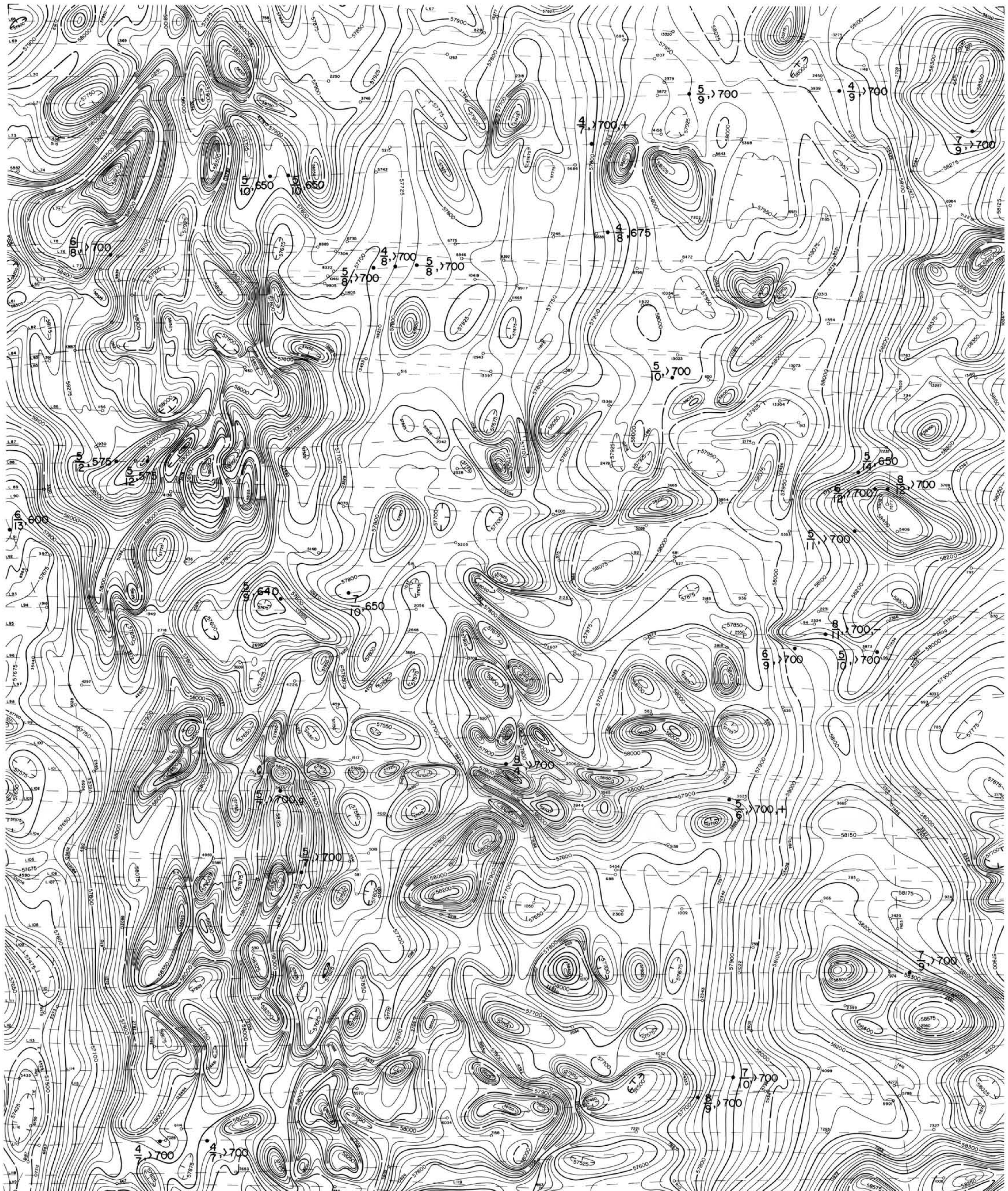


APPROXIMATE MEAN DECLINATION 1958

SCINTILLATION ANOMALIES

Location — 5/12, >700, (+, −, g)
- Peak response 500 counts per minute above local background
- Terrain clearance greater than 700 feet.
- Negative topographic correlation.
- Anomaly on steep topographic gradient
- Positive topographic correlation.
- Local background 1200 counts per minute.

STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY

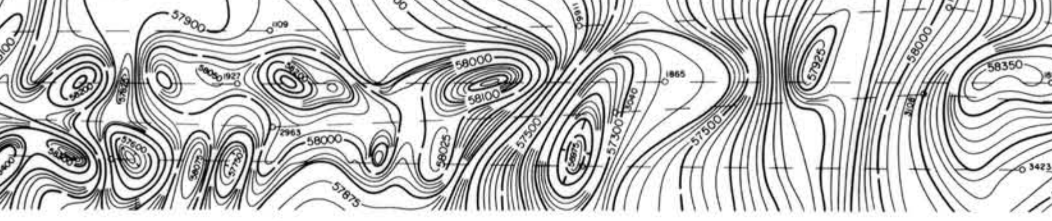


Base from U. S. Geological Survey topographic quadrangle map

Aeromagnetic and scintillometer survey flown 500 feet above ground, 1959 by HUNTING GEOPHYSICAL SERVICES, INC.

AEROMAGNETIC AND SCINTILLOMETER SURVEY OF REPUBLIC QUADRANGLE FERRY COUNTY

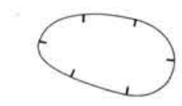
SCALE 1:62500



1960

EXPLANATION

MAGNETIC CONTOUR INTERVAL — 25 GAMMAS
500 GAMMA CONTOUR
100 GAMMA CONTOUR
50 GAMMA CONTOUR
25 GAMMA CONTOUR

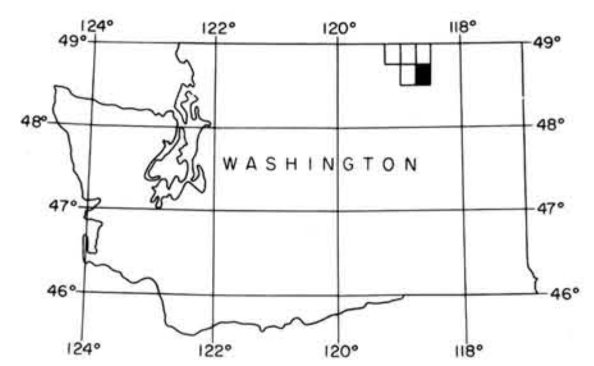


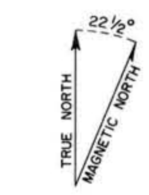
MAGNETIC CONTOUR ENCLOSING AREA OF LOWER MAGNETIC INTENSITY

MEAN FLIGHT LINE SPACING — 1320 FEET
FIDUCIAL POINTS — 36900
FLIGHT LINES

NOTE

The contours represent absolute values of the total intensity of the earth's magnetic field. The data are obtained continuously along the flight lines and are accurately plotted on these lines. Between flight lines the contours are drawn by interpolation and therefore may be in error. Terrain clearance is nominally 500 feet, but due to sharp variations in ground elevation the clearance is not constant and may locally reach 800 feet.





APPROXIMATE MEAN DECLINATION 1958

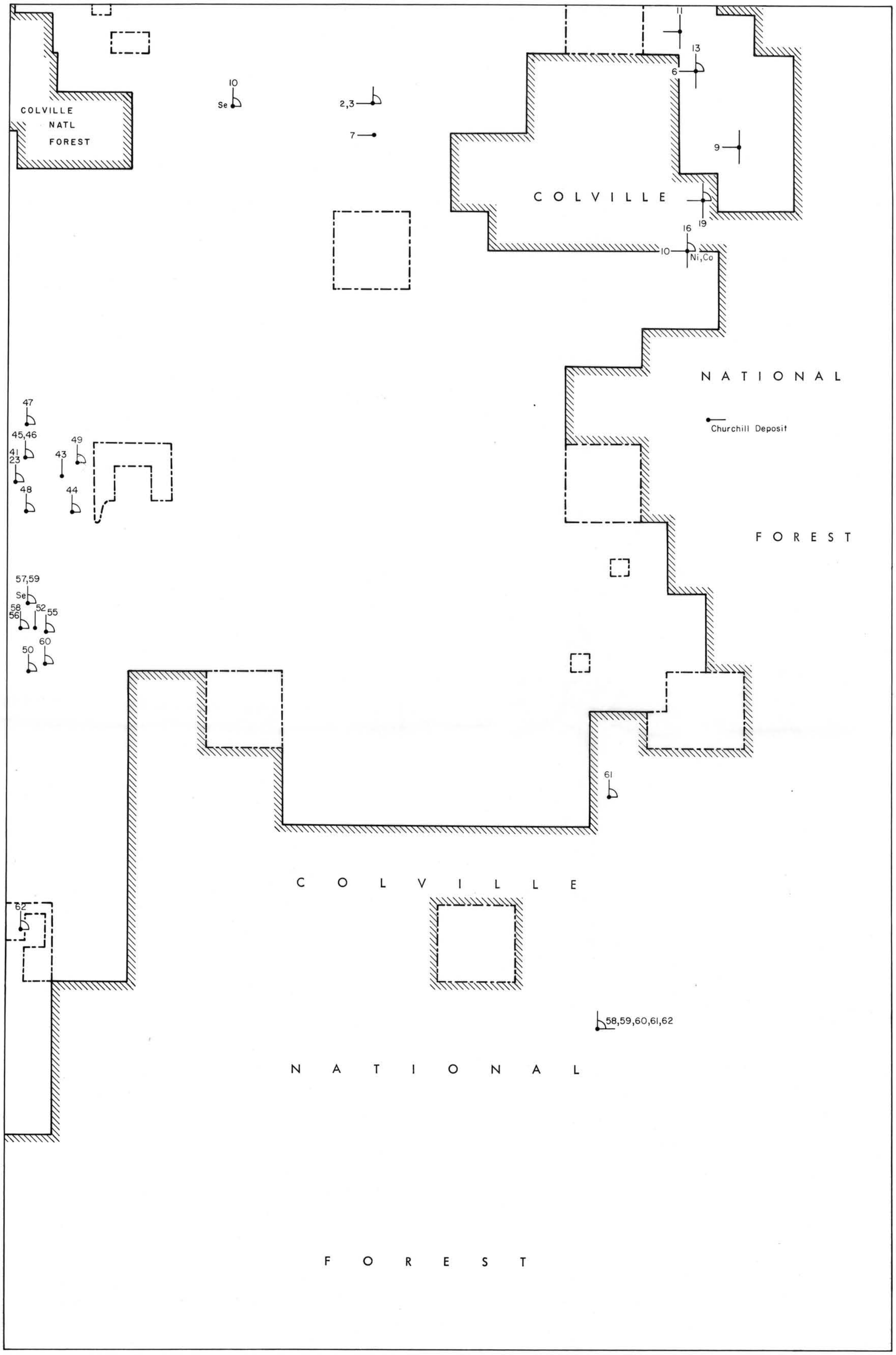
SCINTILLATION ANOMALIES

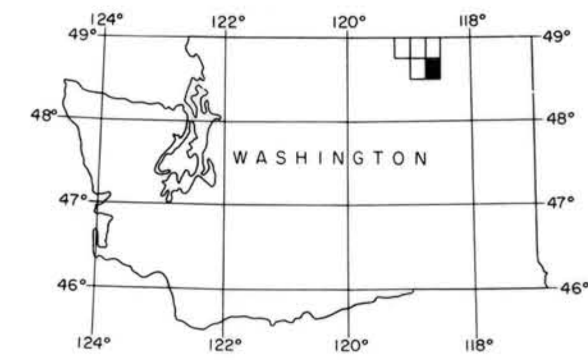
Location • 5/12, › 700, (+, −, g)

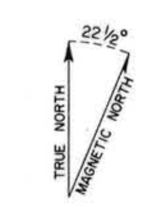
- 5 — Peak response 500 counts per minute above local background.
- 12 — Local background 1200 counts per minute.
- › 700 — Terrain clearance greater than 700 feet.
- + — Positive topographic correlation.
- − — Negative topographic correlation.
- g — Anomaly on steep topographic gradient.

STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY

REPORT OF INVESTIGATIONS NO. 20
PLATE 5 – B



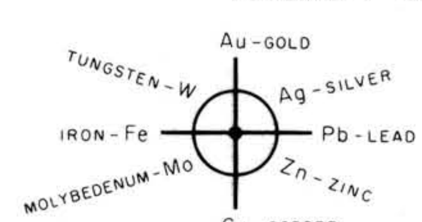




APPROXIMATE MEAN DECLINATION 1958

National Forest boundary
State – owned land boundary

COMMODITY CODE

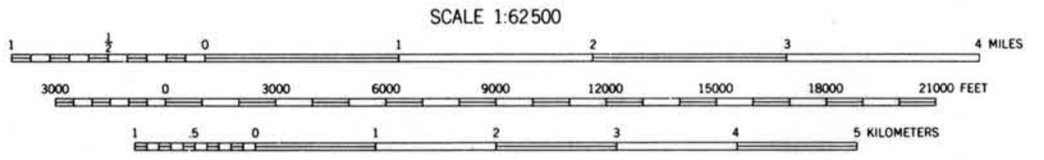


Pt PLATINUM
Se SELENIUM
Sb ANTIMONY
As ARSENIC
Mn MANGANESE
Ni NICKEL
Co COBALT

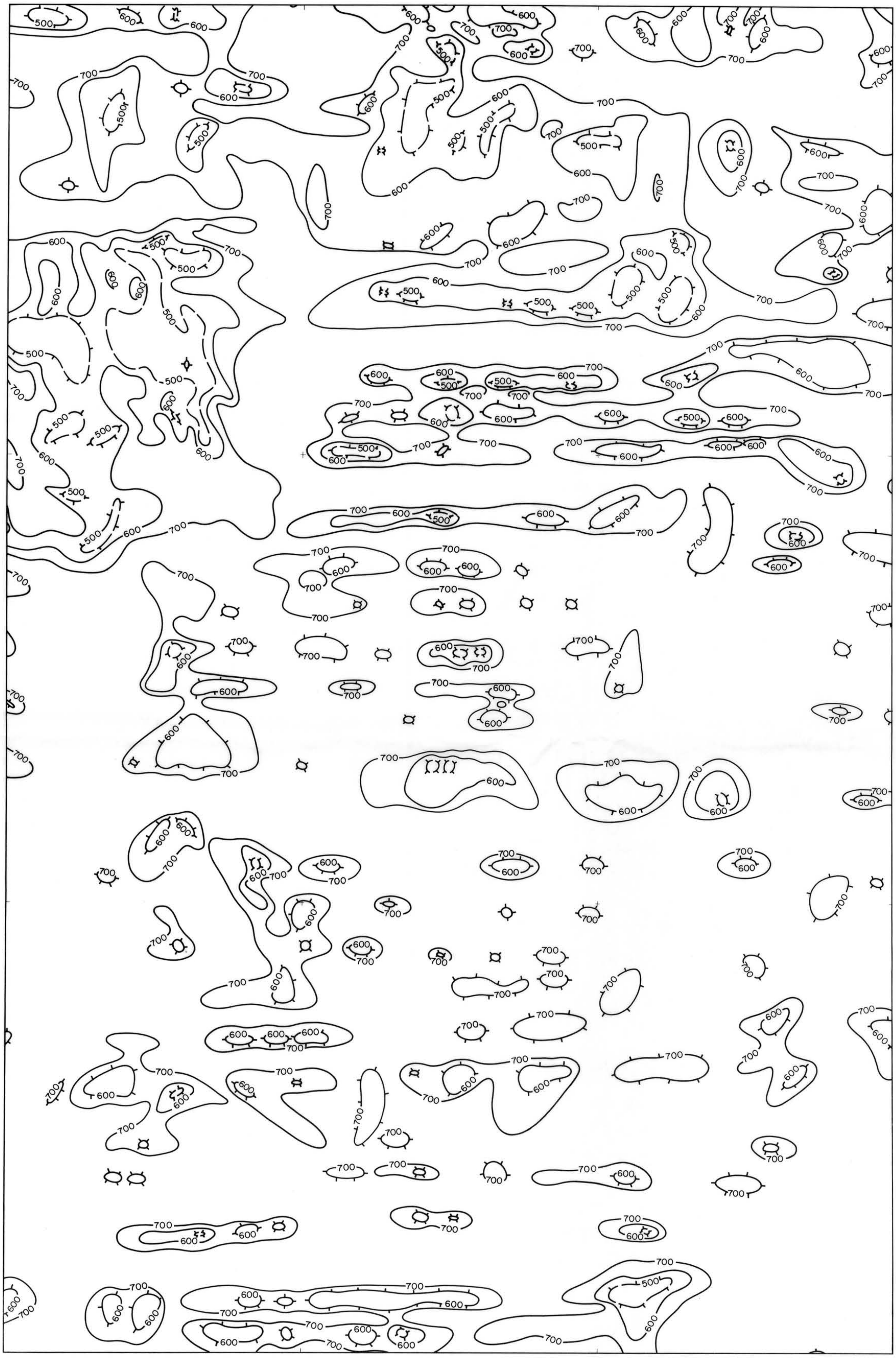
NOTE: Numbers are the reference number by commodity and county as listed in Bulletin 37, Inventory of Washington Minerals, Part II Metallic Minerals, Marshall T. Huntting, Division of Mines and Geology, 1956.
e.g. ●—— 6, Occurrence # 6 of Lead in Ferry Co. or in Okanogan Co.

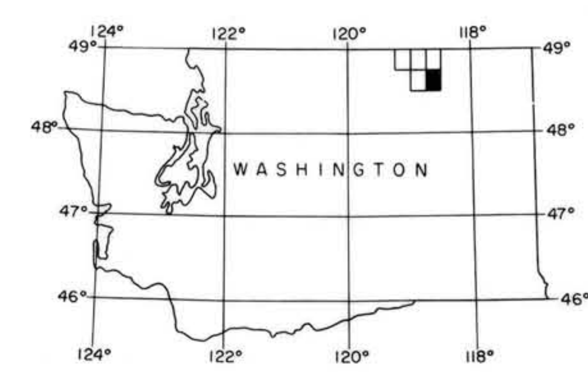
MINERAL DEPOSITS MAP
REPUBLIC QUADRANGLE
FERRY COUNTY, WASHINGTON

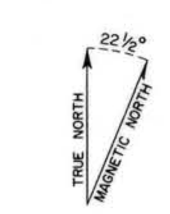
SCALE 1:62500



1960



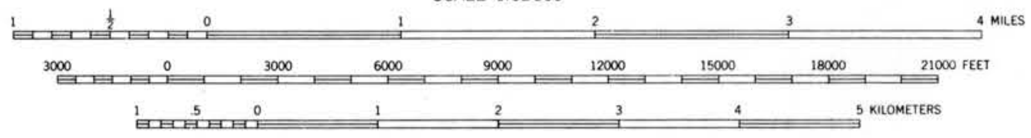




GROUND CLEARANCE MAP
REPUBLIC QUADRANGLE
FERRY COUNTY, WASHINGTON

The contours represent the height of the aircraft above ground. The data are accurately plotted along the flight lines but have been drawn by interpolation between the lines. Hachured contours may be indicative of areas of higher topographic relief.
Contour interval 100 feet

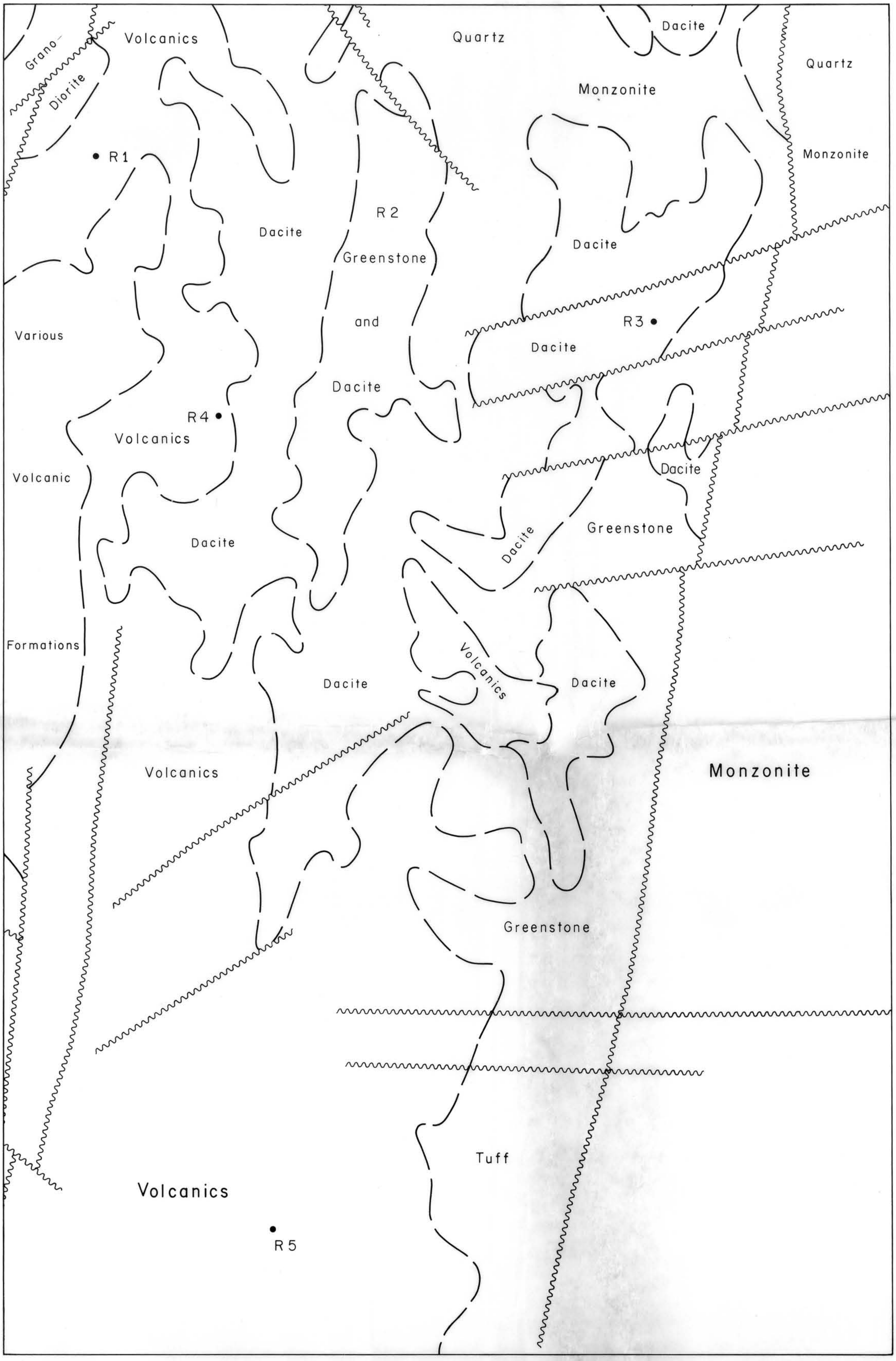
SCALE 1:62500

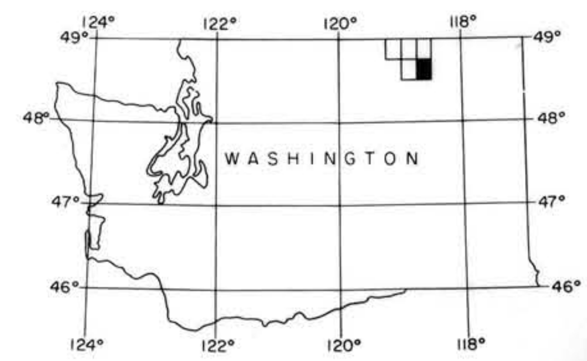


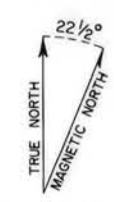
1960

STATE OF WASHINGTON
DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY

REPORT OF INVESTIGATIONS NO. 20
PLATE 5 – D







APPROXIMATE MEAN
DECLINATION 1958

INTERPRETATION

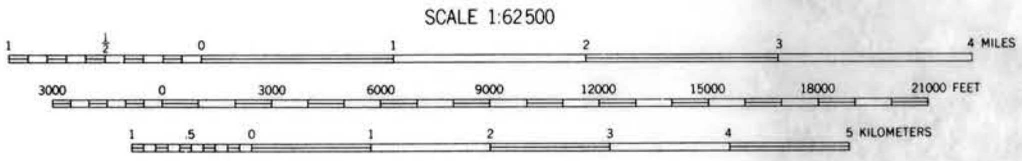
Geological contact

Fault

Depth determination • R5

GEOLOGY INTERPRETED FROM AEROMAGNETIC DATA
REPUBLIC QUADRANGLE
FERRY COUNTY, WASHINGTON

SCALE 1:62500



1960