GEOLOGY OF AN AREA NORTH OF BACON CREEK ON THE SKAGIT RIVER WASHINGTON

by

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GEOLOGY OF AN AREA NORTH OF BACON CREEK ON THE SKAGIT RIVER WASHINGTON

INTRODUCTION

PURPOSE OF INVESTIGATION

This investigation was undertaken in an attempt to explain the tectonic and genetic relationships of certain silica (quartz) and talc deposits occurring in an area on the Skagit River near Marblemount, Washington, to the rock masses of the district, with a view toward predicting the extent of known deposits and the possible location of other deposits.

WORK PERFORMED DURING INVESTIGATION

During the autumn of 1946, while the writer was employed by the U. S. Bureau of Mines, detailed surface maps of three silica deposits in this area were prepared by him as a part of an investigation of Pacific Northwest mineral resources by the Bureau of Mines.

After the area had been selected as the subject of this study, a topographic and geologic reconnaissance map was made. Topography is based on a map prepared by the U. S. Army Engineers from aerial photograph reconnaissance. Because this map included only the surface below 1000 feet elevation, mapping above that contour was done with Paulin altimeter, Brunton compass and aerial photographs.

A total of 42 days was spent in the field during the fall of 1946 and the winter of 1946-47.

Forty-three petrographic thin sections were studied in the laboratory.

ACKNOWLEDGMENTS

This study was conducted under the supervision of Professor G. E. Goodspeed of the Department of Geology, University of Washington, whom the writer wishes to thank for the critical reading of the manuscript and for valuable suggestions.

The writer is indebted to Mr. C. C. Popoff,[12/] mining engineer, U. S. Bureau of Mines, under whose direction the preliminary surveys of the silica deposits were made, for suggesting this investigation and for enlightening discussions regarding the geology of the area.

The assistance, both in the field and in the laboratory, of Mr. L. W. Waterman, has been greatly appreciated.

PREVIOUS WORK IN THE AREA

No published report on this area exists. Wilson, Skinner, and Couch[19/] examined and analysed silica samples from the Bacon Creek and Stoner deposits and Hodge[8/] briefly described a deposit on the Pressentin property. There are two unpublished reports on the Stoner deposit.

Reconnaissance parties, one under I. C. Russell[13/] and another under G. O. Smith[14/] passed this way nearly a half-century ago, but no information directly pertaining to this area was published in the subsequent reports.

CONCLUSIONS OF THE WRITER

The silica deposits are quartz veins, formed partly by fissure filling and partly by replacement of the country rock acted upon by hydrothermal solutions, probably at a moderate depth in the lithosphere. Their occurrence is structurally controlled: the larger veins are more or less concordant with the regional cleavage in the surrounding schist; the smaller veins appear to follow transverse fractures in this schist.

This view is not in accordance with the theory advanced in two unpublished reports that the Stoner deposit, at least, is a product of pegmatitic differentiation.

The origin of the talc deposits is obscure. They occur in the same schist as do the quartz veins, although not in juxtaposition; a well-developed schistosity in the talc parallels that of the country rock. The talc appears to be in disturbed zones, either in zones of faulting or near intrusive igneous bodies. It may have been derived from the enclosing schist, through the agency of hydrothermal solutions.

GEOGRAPHY

LOCATION OF AREA

The area under investigation, comprising about six square miles, lies on both sides of the Skagit River in Skagit County, Washington; it is bounded roughly on the northeast by Damnation Creek and on the southwest by Bacon Creek, both of which are tributary to the Skagit from the northwest about midway between the towns of Marblemount and Newhalem, Washington.

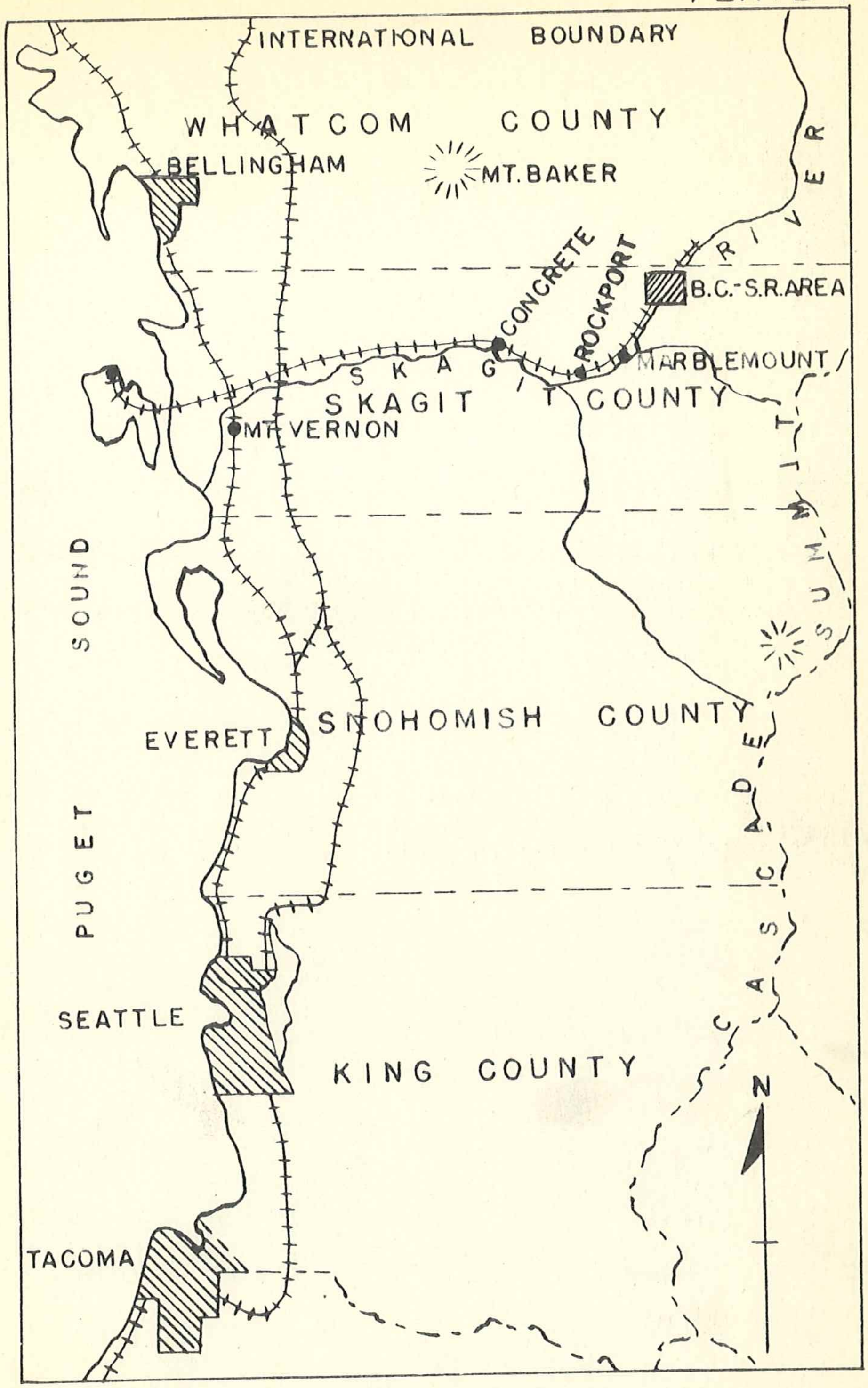
A graveled road, whose northern end is at Newhalem, leads to the nearest community, Marblemount, on State Highway 17-A. Distances from Bacon Creek by highway are: Marblemount, 5 miles; Rockport, 14 miles; Mt. Vernon, 47 miles; Seattle, 120 miles.

The Skagit River Railway, owned and operated by the City of Seattle Lighting Department, passes through the area; at Rockport, this railroad connects with the Anacortes-Rockport branch of the Great Northern Railway.

THE SKAGIT MOUNTAINS

The northern Cascade Mountains, which extend from near Snoqualmie Pass to the international boundary, may be subdivided, on a physiographic basis, into three ranges. The eastern portion is called the Okanogan Mountains. To the central portion, lying between the Pasayten River, which belongs to the Columbia drainage and the Skagit, which flows into Puget Sound, the name Hozomeen Range has been given. The most western of the three subranges is known as the Skagit Mountains.

PLATE I



INDEX MAP

SCALE: 1 IN = 20 MILES

Physiography

The axis of the Skagit Mountains strikes northwesterly from the main Cascade summit line, passes just east of Mt. Baker and continues into British Columbia. The American portion of the range is about 50 miles long and about 20 miles wide--although lateral boundaries are largely arbitrary because of the wide extent of ramifying foothills.

A complex system of serrate ridges and peaks, many of which rise to about 7500 feet elevation, the Skagit Mountains are deeply dissected and strongly glaciated. The existing relief is near the maximum possible in the present erosion cycle.[3/] Slopes are precipitous, near-vertical faces being far from uncommon. Small glaciers flank the higher mountains.

West of the main range, the Skagits consist of somewhat lower, broad timbered ridges. Mt. Baker, a dormant Pleistocene volcano, rises nearly 5000 feet above these foothills and stands somewhat apart from the main peaks of the range.

The Skagit River drains a large portion of this mountain mass. This river, which flows gently southward from Canada in a broad valley, on meeting the Skagit Mountains turns slightly west and, in a wild canyon, cuts through the range; it then veers directly west and pursues a leisurely course to Puget Sound. The tributaries of the Skagit are, for the most part, short streams with steep grades.

General geology

The geology of a limited area such as the Bacon Creek-Skagit River district cannot be fully understood without a knowledge of the geology of the region or province of which it is a part; for this reason, the general and historical geology of the Skagit Mountains will be discussed.

The range consists of altered sedimentary and volcanic rocks, including all systems from the Carboniferous to the Cretaceous, mostly much deformed, and lying on both sides of a central granodiorite ridge of batholithic proportions, probably mid-Cenozoic in age. Smaller intrusive bodies of Jurassic age may also be present.

Some Paleocene sediments occur in the western foothills. Small intrusives of varying form and composition represent the mid-Cenozoic, both preceding and following emplacement of the batholith.

The Pleistocene lavas of Mt. Baker and the Quaternary glacial and alluvial deposits complete the geologic column.

The older lithologic units are complexly folded and faulted and have undergone metamorphism in varying degree. The most striking structural feature in these rocks is a regional cleavage which parallels the main axis of the range, approximately N 30° W.

Age relations in the Skagit Mountains are not definitely known, because of the dearth or absence of fossil remains in most of the strata. Correlation has been based largely on lithology, degree of metamorphism and structural relations, all of which are realms of interpretation.

Historical geology

The oldest rocks are probably contained in the Hozomeen series which lies on the eastern edge of the range. This series, in the Skagit Mountains consists of cherty quartzite and interbedded phyllites; it is unfossiliferous and was assigned by Daly[3] to the Carboniferous on the basis of lithologic similarity to known Carboniferous formations.

The Chilliwack series, on the western side of the range, consists of argillites and limestone, and has been placed in the Carboniferous on the evidence of Pennsylvanian fossils found in the limestone. Fossils from the Pennsylvanian have also been found at Concrete, on the lower Skagit River.17/

Limestone at Granite Falls, some 50 miles to the southwest of the Skagit Mountains, as well as limestone in the Cache Creek series of British Columbia, was deposited in late Guadalupe time of the Permian period.16/

In the late Paleozoic, this region was a scene of deposition of fine clastic sediments and limestone in a rather shallow, quiet sea. This sea, in the form of a long arm which came down from the north, was probably the last Paleozoic marine invasion of North America.16/

A series of conglomerates, grits, quartzitic sandstones and shales apparently represents the Mesozoic in the vicinity of Mt. Baker. Farther to the northwest, a thick series of schists, argillites and greenstones is called Mesozoic by Crickmay.2/ According to him, some of the greenstones and schists are of pyroclastic origin and some were derived from extrusive igneous rocks.

A banded granodiorite or granite gneiss on the eastern border of the batholith has an older appearance than the unaltered granodiorite and was tentatively placed in the Jurassic by Daly.

In the Mesozoic rocks, the absence of limestone, the predominance of the coarser sediments, the angularity of the fragments, the presence of feldspars--all these indicate rapidly changing conditions of deposition in a geosynclinal basin or trough, with the source landmass nearby.

Considerable volcanism took place in the Mesozoic, probably centering in the Jurassic and perhaps connected with the large Jurassic intrusions elsewhere in the Pacific Coast area.

Paleocene sediments, consisting principally of sandstone with some shale and conglomerate, occur at the western edge of the Skagit Mountains. According to Crickmay, these rocks, in some places intensely deformed, were involved in the orogeny which formed the range; he believes that selvages of Paleocene rocks, affected by folding and thrust faulting, show that the mountain building was of post-Paleocene date.

Both Crickmay and Daly suggest that these mountains were formed as a phase of the Laramide orogenic revolution in the early Eocene, with compression from the east folding and overthrusting toward the west.

Possibly in the Miocene the granodiorite batholith invaded the Skagit Mountains along the principal axis of folding, producing local, often severe deformations. In the Pliocene, a general uplift probably occurred, to which many of the present canyons are due.

During the Pleistocene a great glacier in the Skagit valley flowed down the stream to Puget Sound; tributary glaciers, some of them of large size, came in from lateral canyons. On the retreat of the glaciers, streams in these mountains became overloaded with glacial outwash, upgraded their channels and afterward cut through the material previously deposited, leaving high gravel terraces along their borders.

The eruptions which formed Mt. Baker occurred in the Pleistocene, both before and after glaciation.1/

Recent time is represented by insignificant alluvial deposits.

THE BACON CREEK-SKAGIT RIVER AREA

This Bacon Creek-Skagit River area is rugged, although not so precipitous as the country a few miles farther up the Skagit. The mountains rise to about 7000 feet elevation on both sides of the river; however, the area mapped has a maximum relief of 2000 feet and an average relief of 1000 feet. The chief hindrance to prospecting or geologic reconnaissance is not the steepness of the slopes, but the almost luxuriant vegetation which grows upon them.

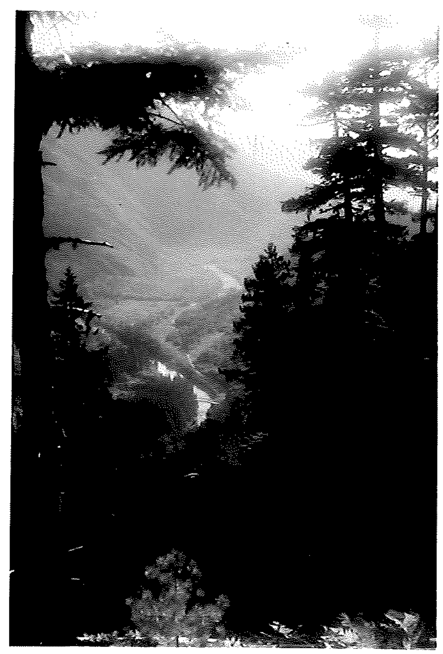
The Skagit River is here a swift-flowing, impetuous stream confined to a rather restricted channel. Bacon Creek flows in from the northwest in a prominent, glaciated valley with a comparatively low gradient; rapids replace the cascades of shorter tributaries. Other streams in the area are steep and short, torrential during the rainy season, often disappearing in the summertime.

The summers are warm and dry, but short. The winters are periods of mild temperature and copious precipitation. At high altitudes the snowfall is heavy; at the level of the silica and talc deposits, the snow on the ground never becomes deep, but it may remain for five months or longer.

Good timber grows in patches throughout the area; the remainder of the surface is covered by stumps, underbrush and scrub timber.

PLATE 2

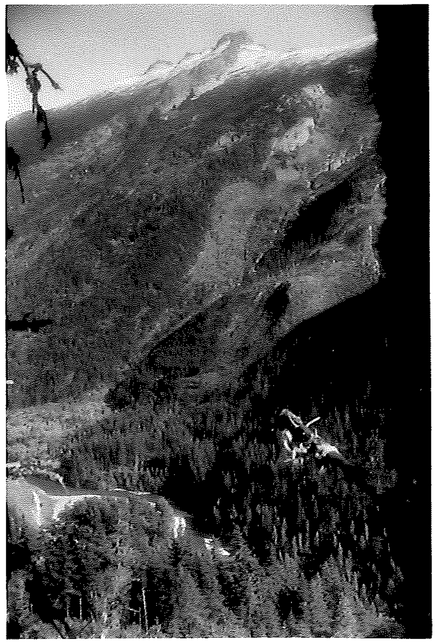
A View northeast (upstream) from hill above Silica Camp. Stoner deposit is in right foreground.



B Looking south (downstream) from hill above Silica Camp; Skagit Talc Company bridge across river.

SKAGIT RIVER VALLEY

PLATE 3



A Teebone Ridge seen from hill above Stoner deposit. Looking east across the Skagit River.

B Looking north from Bacon Point Lookout, across west central part of mapped area.

TOPOGRAPHY OF BACON CREEK-SKAGIT RIVER AREA

GENERAL GEOLOGY

STRATIGRAPHY

The lithologic units of the area will be discussed in sequence according to relative age. No evidence exists to warrant definite geologic age assignments to any of the rocks. No existing formational names can be, and no new names will be, given to these rocks. Each rock will be described under a general descriptive name, one which best seems to fit the bulk of the exposures, although individual outcrops may vary considerably from the norm denoted by the general name.

Quartz-mica schist

The quartz-mica schist, the oldest rock in the area, varies in appearance from a brown schistose shale to a blue-black phyllitic schist. It appears to have been derived from sediments by dynamothermal metamorphism which has produced the mica as well as the schistose structure. All of the rocks of igneous origin in the area are intrusive into it.

The schist is composed of thin, alternating dark and light laminae. Cleavage surfaces exhibit a micaceous sheen; these surfaces are usually planar, except in parts of the dark phyllitic schist where the layers are ptygmatically folded.

Hardness varies greatly; some of the schist can be pulverized with the fingers, yet other specimens are difficult to break with a hammer. In places along fault zones or near quartz veins, the schist appears to be desilicified and the mica is soft, greasy and silvery, suggesting alteration to talc. In one locality the schist is calcareous.

The schistose shale fractures blockily and only on weathered surfaces can the schistose structure be seen megascopically.

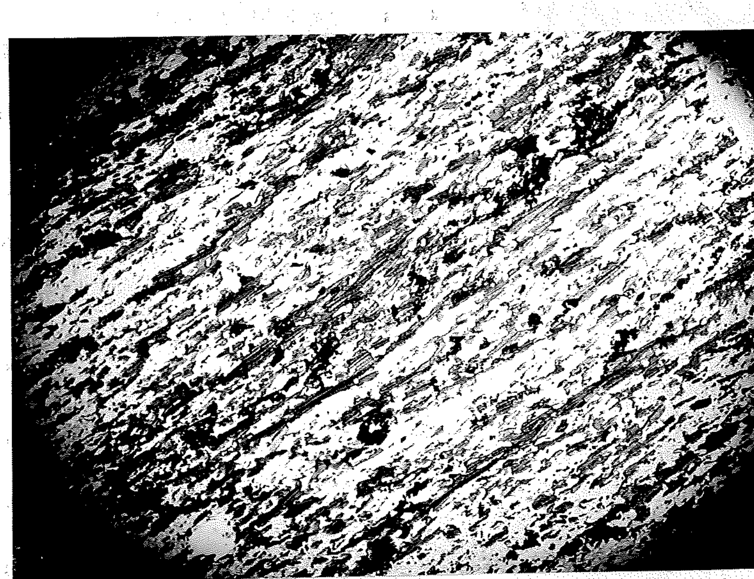
Under the microscope, the lighter layers are seen to be almost pure quartz; the darker layers are usually biotite, but often sericite with minor amounts of graphitic material forms the laminae between the quartz layers. Occasional accessory minerals are sphene, chlorite, magnetite, ilmenite and leucoxene. Quartz usually comprises about 80 to 90 per cent of the rock, a fact not readily apparent in the field. However, the amount of micaceous material sometimes markedly increases; in one outcrop, the schist is almost pure biotite.

Other metamorphosed sediments of minor thickness have been mapped with the schist. Two of interest occur near the Bacon Creek silica deposit. One is a schistose marble, the other a feldspathic granulite.

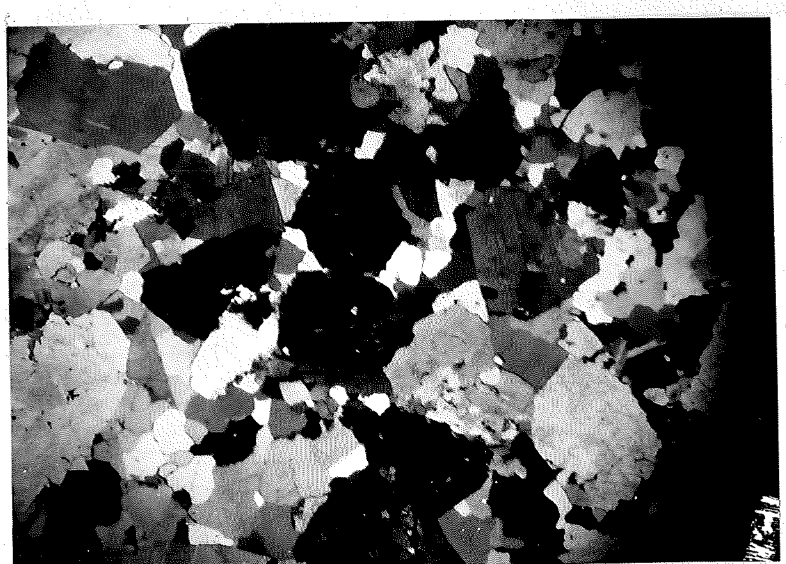
The blue-gray to dark blue marble has, by recrystallization under differential stress, acquired a schistose structure. It occurs in a layer ten feet wide, interbedded with the schist.

The granulite is light gray, compact and hard, fine-grained, and has a faint lineation of the darker constituents. The primary microscopic texture is crystalloblastic. Feldspar porphyroblasts comprise about sixty per cent of the rock; they are crowded with inclusions which show a palimpsest structure. Quartz is the next most abundant mineral, with biotite, diopside, chlorite and magnetite as accessories. The mica, both between grains and as inclusions, is well-aligned, bringing out the blasto-psammitic modifying texture. This rock was originally a sediment, probably an impure sandstone, which has been feldspathized, possibly by hydrothermal solutions.

PLATE 4



A Quartz-mica schist near Rainbow talc mine; contains quartz, biotite, sphene (high relief), ilmenite and leucoxene. Plane light, x17

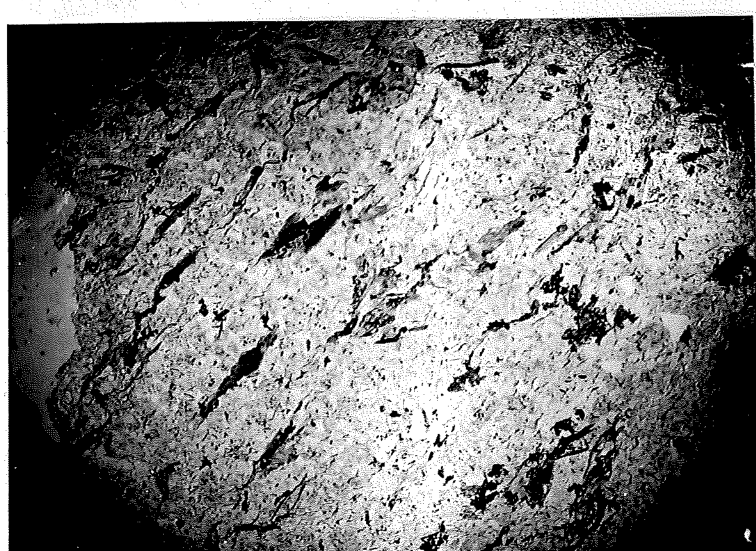


B Mafic-free granodiorite near Stoner Silica deposit; contains sodic feldspar and quartz. Crossed nicols, x10.

QUARTZ-MICA SCHIST AND GRANODIORITE

PLATE 5

A Crystalloblastic feldspathic granulite near Bacon Creek silica deposit, containing feldspar, quartz, biotite, and diopside. Crossed nicols, x17.



B Same section in plane light, showing palimpsest structure represented by aligned biotite. x17.

FELDSPATHIC GRANULITE

Amphibole-pyroxene gneiss

An amphibole-pyroxene gneiss is the next younger rock. It is probably a metamorphosed igneous rock, originally a diorite or quartz diorite. It varies greatly in appearance from place to place but is characterized everywhere by the green color imparted by the ferromagnesian minerals. The rock is resistant to weathering and forms bluffs in which chloritized, slickensided joints are common.

In one outcrop the rock is fine-grained, dark green and structureless; here it consists microscopically of about equal amounts of turbid plagioclase (principally andesine) and hornblende with subsidiary augite, chlorite, and a little quartz; this composition is that of a quartz diorite.

Elsewhere the rock is greatly altered. As necrystallization becomes more evident, it takes on a coarse-grained appearance, and a secondary foliation which at first is barely distinguishable becomes well-developed. The plagioclase appears to break down rapidly and then recrystallize; plagioclase porphyroblasts in the more gneissic specimens are abundant. The hornblende alters to diopside, chlorite, actinolite-tremolite, chloritoid and magnetite, the first four uniting to give the rock its green color.

The more gneissic rock, near the contact with the quartz-mica schist, contains much quartz. There is some microscopic indication that part of the quartz in the more altered rock was derived from the destruction of the original minerals; however, most of it probably came from external sources, possibly from the same hydrothermal solutions that deposited the Bacon Creek quartz veins in the schist nearby. Vuggy quartz veinlets, in places mineralized with pyrite and chalcopyrite, fill many fractures in the gneiss.

The contact between the gneiss and the schist has been seen in but one place, although it can be mapped within ten feet over a long distance. In this one place the contact is sharp and pieces of the schist appear to be included in the border of the gneiss. From the map, the contact appears to be nearly vertical. The cleavage in the schist steepens near this contact and becomes nearly vertical.

The field relations, the petrographic evidence and the abundance of the ferromagnesian constituents in the rock, suggest that the amphibole-pyroxene gneiss represents a basic igneous rock intrusive into the quartz-mica schist and profoundly altered by both dynamothermal metamorphism and hydrothermal solutions.

Peridotite

A dark crystalline rock, which is apparently an altered peridotite, was found in two small bodies near the Stoner silica deposit. On fresh surfaces it has a waxy luster and contains radiating fibrous or acicular, olive-green crystals. A peculiar feature of the red-brown weathered surface of this rock is a planar structure indicated by small, narrow, parallel, light-colored ridges, produced by differential weathering. These ridges are not prominent but they are apparent. They have a uniform attitude which is the same as the strike and dip of the schistosity in the quartz-mica schist 200 feet away on the other side of the Stoner deposit.

Microscopically, the rock consists mainly of radiating crystals of anthophyllite embedded in a groundmass of antigorite, serpentine and talc. Olivine and some augite are less abundant constituents, with magnetite as an ever-present accessory. The olivine has subparallel parting across all grains, irrespective of orientation; this probably causes the peculiar weathering.

The two bodies are singularly free of inclusions, even of quartz veinlets. Despite this, the writer believes the peridotite may be older than the granodiorite which almost envelops it, both because of the micro-fracturing parallel to a schistosity which was probably pre-granodiorite and the fact that some of the peridotite is found inside the Stoner quartz body, indicating that the quartz does cut the peridotite, at least once. Of course, by the latter evidence alone, the peridotite could still be younger than the granodiorite.

Granodiorite

The batholith which forms the higher portions of the mountains on both sides of the Skagit and which sends large sills upward and outward into the quartz-mica schist is composed of a medium-grained granodiorite, consisting of plagioclase, quartz, and minor biotite. Unaltered and fresh-appearing, it forms conspicuous cliffs.

In the few slides studied, biotite was the only mafic in the granodiorite, ranging from zero to as high as 15 per cent of the rock. In some small sills near the Rainbow talc mine, the biotite occasionally forms rounded clumps or segregations up to one-half inch in diameter. Time did not permit determination of the mechanism of emplacement of these sills.

PLATE 6

A Small, faulted granodiorite sill (behind hammer) in soft mica schist near Rainbow talc mine. Alluvial terrace in foreground.

B Dialation dike of diorite porphyry cutting and displacing quartz veinlet in granodiorite near Stoner silica deposit.

GRANODIORITE SILL AND DIORITE DIKE

Along the west side of the granodiorite sill which passes near the Stoner silica deposit the biotite, always minor in amount, gradually disappears, leaving a rock composed entirely of quartz and feldspar.

This mafic-free granodiorite was channel-sampled by the U. S. Bureau of Mines. A partial chemical analysis gave SiO_2, 74.9 per cent; Al_2O_3, 13.91 per cent; and Fe_2O_3, 0.33 per cent. This rock is white, medium-grained, equigranular, hard and compact, with no visible dark minerals. Under the microscope, it is seen to consist of 25 per cent quartz and 75 per cent feldspar, with orthoclase at least as abundant as plagioclase. This somewhat resembles the "soda-syenite" described by Smith and Calkins[14/] and ascribed by them to an exceptional kind of differentiation from a granitic or granodioritic magma. In the field a progressive increase in biotite can be traced from this white rock to a normal granodiorite. A prominent light-colored cliff near the highway at the Stoner property is the face of an almost biotite-free granodiorite body.

Alluvium

Alluvium mapped consists of Recent stream silts, sands, and gravels as well as remnants of a well-defined terrace on both sides of the river, composed of coarse, roughly-stratified glacial outwash. The top of this terrace is about 500 feet elevation.

STRUCTURE

The bulk of the area mapped consists of schist partially enclosed on the north and east by the granodiorite batholith and intruded by several large sills. The schist is apparently of relatively shallow vertical extent, lying upon an irregular surface of granodiorite. It has been faulted but tight folding is not evident.

In 1938 a road nearly one mile long was built to this deposit from the Bacon Creek road of the U. S. Forest Service and from 1938 to 1941 two to three thousand tons of quartz were mined. Some of the quartz was used in the manufacture of abrasive stones and some was shipped to the Tacoma smelter for flux. The road has now become impassible due to the growth of small trees during recent years. At the deposit, two storage bunkers are in good condition but there is no mining equipment.

Three irregular quarries or pits have been advanced a short distance into the hillside along the strike of the veins. Most of the production came from the south pit.

The Bacon Creek deposit consists of several closely-spaced, parallel, relatively thin quartz veins in a zone about 500 feet wide and about 1200 feet long in the quartz-mica schist near the contact with the amphibole-pyroxene gneiss. The veins are parallel to the cleavage of the schist in which they occur. Vein walls are remarkably linear; no lensing or bulging is evident. Inclusions of schist in the veins likewise have rectilinear boundaries and are parallel to the walls. Although some veins can be traced by outcrops, correlation of the outcrops is difficult because of overburden, the attitude of the veins and disturbance by landslides and mining.

The largest vein lies farthest from the contact between the schist and the gneiss. In the middle pit this vein (see plate 8) is exposed for 200 feet along its dip, which is 55 degrees to the southwest. On the strike, N 20° W, the vein has been traced about 1200 feet. The visible thickness varies from ten to 20 feet. Long rectangular stringers of schist up to two feet in thickness are characteristic inclusions.

The regional cleavage or schistosity of this rock has controlled the direction and form of intrusions, especially of the large granodiorite sills and it has also determined the position and form of the major silica deposits. The rectilinear boundary of the amphibole-pyroxene gneiss shows the influence of this structure.

In the three places where it has been recognized, bedding is parallel to schistosity. Not only does this schistosity or cleavage have a regional strike, N 20-30° W, but also a fairly constant dip, averaging about 55° SW. That this structural feature is not confined to the Bacon Creek-Skagit River area is indicated by the attitudes of strata at Rockport and Concrete, 10-15 miles to the southwest, where the prevailing strike is N 45-60° W and the sip about 45° SW. The dip, although quite variable, does not reverse; therefore, compressed anticlinal folding, supposedly typical of the Skagit Mountains, is not characteristic of this particular district.

Several subparallel, high-angle faults striking about N 25° E have been mapped; in those cases where it can be determined, the down-dropped block is on the east. Considerable strike-slip faulting has probably taken place but is not easily discernible. Faulting has produced local zones of softened and broken schist, grading into an unconsolidated blue gouge in several places, such as in a road cut just north of the McMyrl-Wilson talc mine.

All the silica deposits occur in this schist. The larger deposits are concordant with the schistosity; some of the smaller appear to follow transverse fractures or even faults.

The amphibole-pyroxene gneiss which bounds the quartz-mica schist on the southwest has rather widely-spaced joints, along many of which some slipping has taken place, producing chloritized, slickensided surfaces. Into many of these quartz has come; the quartz veinlets usually show signs of subsequent shearing and some mineralization. The gneiss is believed to be intrusive into the schist. In the area mapped, no rock was found intruding the gneiss.

The granodiorite is unjointed, but near its contacts with the quartz-mica schist it is often cut by quartz veinlets and, near the Stoner property, by small diorite dikes. The granodiorite sills have been cut by transverse faulting which does not appear to extend into the batholith. These sills vary from one foot to 1000 feet in thickness and rather closely conform to the cleavage of the enclosing schist, striking northwesterly and dipping 55-70° to the southwest.

The larger quartz veins, all of which are in the schist, also follow this regional schistosity. The smaller veins which do not have this attitude appear to have followed transverse fractures or even faults in the schist.

HISTORICAL GEOLOGY

The oldest rocks in the Bacon Creek-Skagit River area are the metamorphosed sediments which comprise the quartz-mica schist. These sediments were probably deposited during the late Paleozoic, possibly in the Carboniferous.

The schist is lithologically similar to other metamorphics of late Paleozoic age in this province, such as the Peshastin formation of Smith,[15/]

parts of Daly's Chilliwack series,[5] and a portion of the Leech River group as described by McLellan.[11] The amount and character of the metamorphism equal that reported for Paleozoic rocks of similar composition in the northern Cascades.

No limestone has been recorded from post-Paleozoic rocks in the Skagit Mountains; consequently, the presence of schistose marble interbedded with this quartz-mica schist is a further indication of pre-Mesozoic age.

Recent work by the U. S. Bureau of Mines indicates that the limestone beds on Sauk Mountain, about eight miles southwest of Bacon Creek, are a continuation of the Concrete deposits which are known to be of Pennsylvanian age. These beds strike N 60° W; on Sauk Mountain near Rockport, they dip 45° SW. By interpolating the known structure (assuming a regional strike and dip) and disregarding possible repetition of strata and intervening intrusions, the maximum possible stratigraphic separation between the Pennsylvanian deposits and Bacon Creek may be calculated. It cannot be greater than 30,000 feet and may be much less. By this assumption, the Bacon Creek strata would be stratigraphically lower than the Concrete beds and therefore would be pre-Permian.

Lithologic dissimilarity between this schist and the oldest known sediments in the region, namely the Hozomeen series of Daly and the Orcas group, Devonian-Pennsylvanian in age, described by McLellan, suggests an extremely tentative assignment to the Carboniferous.

The age of the amphibole-pyroxene gneiss is a problem of interpretation. The contact between the gneiss and the schist is rectilinear and the schistose planes near this contact are distorted; therefore, the regional cleavage was apparently well-developed at the time of the intrusion. Evidence that strong forces, oriented similarly to those which produced the schistosity, contined to act or were renewed after the intrusion of the gneiss (quartz diorite?) is given by the gneissic structure in the gneiss and by the texture and structure of the nearby Bacon Creek quartz veins. The gneissic structure parallels the nearly-vertical contact in strike, but dips about 45 degrees to the southwest, thus conforming to the regional dip and indicating that the structure is secondary. The Bacon Creek quartz veins, younger than the gneiss, also show stress and strain effects which conform to the regional structure. The extreme alteration of the gneiss argues for an old age, at least one considerably older than that of the granodiorite.

A dating of the granodiorite batholith would be pure conjecture based upon the literature. However, it is believed that a study of the structure in the Bacon Creek-Skagit River area supports the contention that the batholith is younger than the mountains. Where bedding in the schist has been observed it parallels the schistosity; from this, and from the wide extent of this uniform schistosity, it is concluded that this structure is a regional cleavage developed by lateral compressive forces of regional scope. These forces probably built the Skagit Mountains. Although the granodiorite sills faithfully follow the cleavage, the edges of the batholith often cut across it at a sharp angle, proving that the structure in the schist is pre-granodiorite. The cleavage parallels the main axis of the elongate batholith. From these field relations it is inferred that the granodiorite invaded a mountain range already formed by compressive orogenic forces.

The quartz, which cuts all rocks in the area except some small diorite dikes, appears to have formed over a considerable period of time. The quartz intricately veins and partially replaces the gneiss, invades the borders of granodiorite bodies, and forms larger veins in the schist which follow both the cleavage and later fractures. The quartz veins at Bacon Creek show the cataclastic effects incident to formation under great directed stress and moderate temperature, yet quartz in other deposits has merely been fractured by earth movements subsequent to formation.

The geologic history of the area is an interpretation of these facts. Impure arenaceous sediments laid down in the Paleozoic (Carboniferous?) were later metamorphosed with the development of a regional cleavage. A quartz diorite(?) and a peridotite intruded (Mesozoic??) the now-schistose sediments. Orogenic forces continued to act or were renewed and the present Skagit Mountains were formed (Eocene?). Sometime later (Miocene?) a granodiorite batholith invaded the mountains along their major axis, forming large sill-like bodies in the schist. Rather late in the geologic history (Tertiary?) hydrothermal solutions, following fissures and cleavage planes, started to deposit silica as quartz veins; this continued for some time.

As the Skagit Mountains rose, the Skagit River maintained its right of way across them and cut down into the range. In the Pleistocene a glacier which filled the valley of the Skagit greatly aided erosion in producing the present topography. The glacier was not less than 1200 feet thick in this area; glacial striations and erratic boulders have been found at an elevation of 1600 feet in a section where the base of the post-glacial terrace is about 400 feet elevation. After the glacier retreated this terrace was formed; later the river cut down through it and slightly beyond, to its present level.

Erosion, by streams and frost action, is the primary physiographic agent at work today in the Skagit Mountains. The schist erodes easily to a fine material which is either carried away or forms soil; the granodiorite and, to a lesser extent, the gneiss, form barren talus slopes composed of angular blocks often of great size. An example of what Daly terms a "winter-talus ridge" occurs in the north central part of the area where the position of a large granodiorite sill is indicated for 2000 feet by a ridge of blocky talus, increasing in size and depth as the cliff which marks the subaerial beginning of the sill is approached.

ECONOMIC GEOLOGY

The first mining claims in the district were staked on quartz veins by gold prospectors before the end of the last century. The veins were found to contain little or no gold and were abandoned. The present claims on quartz veins, consisting of one patented and about a dozen unpatented claims, were located for silica about twenty years ago. The three deposits which have been exploited have produced between eight and ten thousand tons of quartz.

Talc was first mined shortly after the turn of the century and talc mining has continued sporadically since that date. From the few available production figures, it is estimated that about fifteen to twenty thousand tons of impure talc have been shipped from three talc mines. There are five patented and several unpatented claims in the area.

SILICA DEPOSITS

Local custom and commercial usage demand that the term silica be used in speaking of deposits which, although composed of quartz, are valued for their SiO_2 content. When deposits are mentioned in this report, silica is employed as a general name; quartz is used when mineral or rock descriptions are given or intended.

Bacon Creek deposit

The Bacon Creek deposit, lying between the elevations of 850 and 1300 feet, in the southwestern part of the area, consists of one claim, Doris No. 1, owned by Mr. H. P. Scheel. This is an unpatented claim located in the north half of section 21, T. 36 N., R. 11 E. W. M.

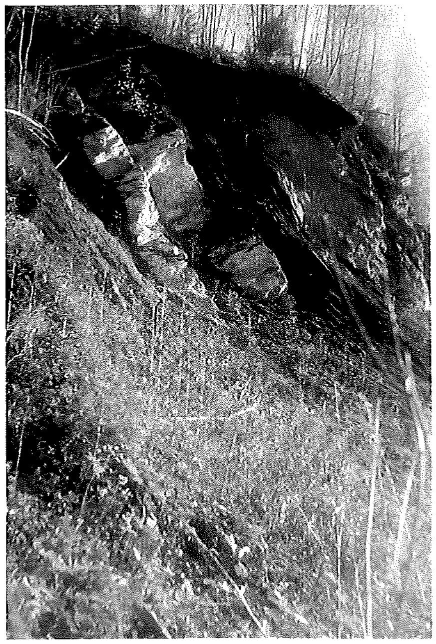
PLATE 8

A Outcrop of principal vein with inclusions of quartz-mica schist.

B Outcrop of principal vein, showing section perpendicular to strike.

MIDDLE PIT AT BACON CREEK DEPOSIT

PLATE 9



A Closely-spaced, parallel veins in south pit, separated by talcose schist.

B Thin, parallel quartz veins in north pit.

QUARTZ VEINS AT BACON CREEK DEPOSIT

Southwest of this vein, numerous outcrops of quartz on the steep hillside mark the position of a parallel vein which has been traced about 700 feet, both north and south of the south pit. West of this vein, near the contact with the gneiss, another vein has been exposed in the south pit; this vein is nearly vertical.

In the north pit, three narrow veins, varying in thickness from one to three feet and separated by schist less than two feet in thickness, have been partially removed by mining.

The Bacon Creek quartz contains shadowy blue or dark gray bands of varying width which are everywhere parallel to the walls of the vein. It fractures easily along three distinct planes, so readily along one plane that it forms flat slabs. The quartz is white to bluish-white, has a subvitreous luster and is subtranslucent. It breaks with a peculiar metallic or porcelaneous sound.

The silica content of the vein exceeds 99 per cent when no country rock is included in the sample; individual samples range from 95 to 99 per cent SiO_2. The chief impurities are alumina and iron oxide.

Galena is found in places in the quartz and was sorted out during mining. It occurs in fractured zones and is later than the quartz.

Near the walls of the veins and in inclusions, the schist is soft and apparently contains little quartz; it separates readily from the quartz during mining. Between two closely-spaced veins in the south pit much of the schist is talcose.

On the borders of the principal vein and surrounding inclusions of the country rock, a milk-white band of feldspar, ranging from one-quarter inch to four inches thick, extends into the vein, making an irregular contact with the quartz. Structurally, these bands are part of the vein material.

Under the microscope, the quartz is seen to be extremely cataclastic, following Goodspeed's classification of quartz as either aclastic or cataclastic.[7/] As defined and illustrated by White,[18/] cataclasis, a progressive morphological change in vein quartz, is a process of micro-brecciation and simultaneous recrystallization brought about by the application of local differential stress at somewhat elevated temperature to complete sections of the vein structure. Below a certain temperature, probably 200° to 300° C., cataclasis gives way to purely mechanical breaking or pulverization.

The Bacon Creek quartz represents the final stage in cataclasis. Almost completely crystalloblastic, the quartz has recrystallized in flattened, elongated grains, averaging 0.33 mm in length, oriented normal to the direction of applied stress. Strain shadows and wavy extinction are characteristic of the original crystals which remain; these are up to 2 mm in length. Many of the larger elongate grains are glomeroblasts with several grains of varying optical orientation uniting to form one grain. Zones of more intense cataclastism, arranged in en echelon streaks parallel to the plane of the vein, have produced a banding in the quartz due to lateral variation in grain size. This structure appears megascopically in the shadowy gray or blue bands which parallel the walls of the vein.

The feldspar border of the vein is clear, coarse-grained plagioclase (mainly oligoclase) which has been considerably fractured. Twin lamellae are bent and twisted, and microfaulting has offset lamellae, even to the production of drag. The feldspar is not oriented in any particular

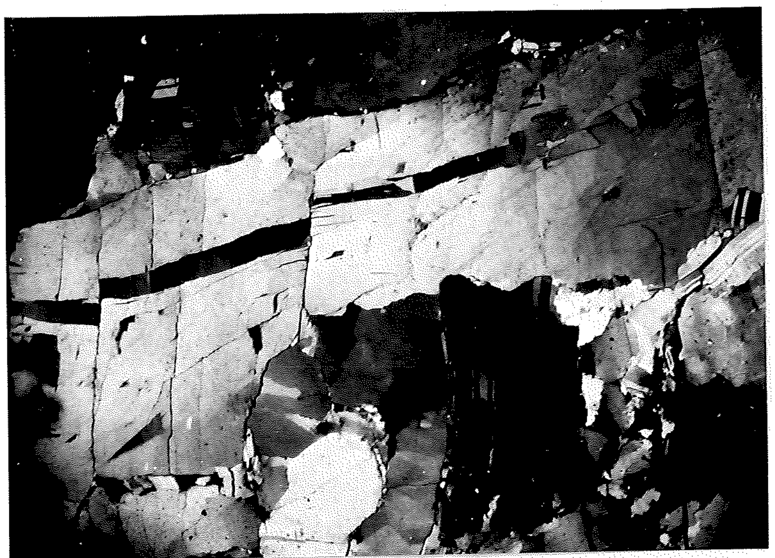
PLATE 10

A Tabular, crystalloblastic quartz oriented parallel to plane of the vein. Crossed nicols, x10.

B Lateral variation in grain size which produces shadow banding. Crossed nicols, x10.

BACON CREEK CATACLASTIC QUARTZ

PLATE 11



A Microfaulted plagioclase in principal vein near hanging wall. Crossed nicols, x10.

B Original quartz (strain shadows) and recrystallized quartz near hanging wall of principal vein. Crossed nicols, x10.

BORDER FEATURES OF BACON CREEK VEINS

PLATE 12

A Plagioclase porphyroblast, showing sieve structure, excluding mica. In amphibole-pyroxene gneiss. Crossed nicols, x43.

B Complex quartz-feldspar cumuloblast in feldspathised quartz-mica schist. Crossed nicols, x43.

CRYSTALLOBLASTIC FELDSPAR AND QUARTZ

direction. Galena occurs more commonly in the feldspar than in the quartz, probably because of the greater fracturing in the feldspar.

The writer's interpretation of these features is as follows: A hydrothermal solution carrying silica under moderate pressure and temperature (mesothermal) followed the cleavage of the schist, which provided the easiest passageways, and deposited quartz in the more favorable portions of each channel. Some of the silica probably was derived from the schist, an interpretation given by Knopf[9/] for the Mother Lode of California. As the quartz deposited, still under rather elevated temperature, it reacted with the biotite in the schist, and formed feldspar on the borders of the veins. The by-products of this chemical reaction are magnesia, iron oxide and water. The water was added to the solution, the iron oxide and magnesia remained in the schist. In some cases, silica appears to have combined with the magnesia and water to form a talcose schist. During the time of formation and cooling, the veins were under continuous or intermittent differential stress. At the more elevated temperature, this produced cataclasis; as the temperature fell below that required to produce cataclasis, mechanical fracturing took place, allowing later solutions to deposit galena here and there. The peculiar fracture cleavage in the quartz is due to the continued stress during the formation of the vein.

The authors of Silica Sands of Washington[10/] examined a sample from the Bacon Creek deposit and reported the following:

> Skagit 7 (Scheel) This composite sample was taken from a quartz vein 450 feet above Bacon Creek (may be a continuation of that found on the Stoner property). Occasionally nodules of sulphides are found which are handpicked from the crushed rock. Pulpstones are made by adding the crushed rock to cement and then molding the mixture. A glass company is using the crushed and sized rock as a glass sand, and several foundries are using it

as a foundry sand. The crushed rock is passed over magnetic pulleys to remove tramp iron. This sample contained 99.0 SiO_2, 0.47 Fe_2O_3, 0.4 Al_2O_3. Pyrometric cone equivalent test gave a clear fusion at cone 32. The sample obtained from the glass company had contained only 0.05 Fe_2O_3. Petrographic examination showed 99 per cent quartz with traces of fresh and turbid feldspar, chlorite, muscovite and iron minerals. The first sample was slightly iron-stained, the second was not stained.

Table 1 gives the chemical analyses, by the U. S. Bureau of Mines, of the five samples from the Bacon Creek deposit. By a comparison with the results of sampling other deposits, it will be noted that the alumina percentage is much higher in the Bacon Creek samples; this is probably due to the feldspar being sampled with the quartz.

TABLE 1 CHEMICAL ANALYSES OF BACON CREEK SILICA

Sample number	Length in feet**	Per cent, dry basis				
		SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO
1	9.7	96.1	0.54	2.09	0.05*	0.01*
2	5.5	98.0	0.43	0.13	0.05*	0.01*
3	6.7	98.8	0.60	0.16	0.05*	0.01*
4	15.5	97.0	0.45	1.14	0.05*	0.01*
5	4.0	98.2	0.64	1.05	0.05*	0.01*
Weighted average		97.3	0.49	1.15	0.05*	0.01*

* less than
** horizontal thickness, perpendicular to strike

Pressentin deposit

In the central part of the Bacon Creek-Skagit River area there occur boulders and outcrops of quartz from the river level up to an elevation of 2500 feet. In this area are eight unpatented claims owned by Edward Pressentin and Henry A. Martin. The Pressentin deposit as herein described is encompassed by one of these claims, presumably Silica No. 2, in the northwest quarter of section 15, T. 36 N., R. 11 E. W. M., between the elevations of 675 and 875 feet.

Hodge[8/] briefly described another deposit in this group of claims:

> The deposit appears to be a lens on top of a hill which stands 750 feet above the valley floor. The lens has an average width of about 27 feet, strikes N 15° E and dips 78° easterly. The walls are a micaceous slaty schist. Several small seams of schistose material run through the quartz deposit, making sorting necessary.

About 2000 tons of quartz were taken from this deposit, lowered by a tramway to a small mill near the highway, where the quartz was ground for the production of abrasive stones. A small mining camp, the remains of which are today known as Silica Camp, was built nearby.

The Pressentin deposit on the Silica No. 2 claim can be reached from the road and railroad by a trail about 500 yards long. An old open cut and several prospect holes are partly caved in and overgrown with underbrush.

Quartz outcrops in two small areas about 700 yards apart. In the northern part of the claim two veins outcrop; they lie in a soft, porous, blue gray to blue-black schist and are separated by eight to ten feet of the schist. If the apparent attitude, a N 45° E strike and a 40° SE dip, is the true attitude, one vein is 14 feet thick and the other is 23 feet thick.

Outcrops of quartz are numerous on the southern part of the claim, north of Pettit Creek, but the structural features of the bodies have not been determined. The outcrops may represent two or three closely-spaced, parallel veins striking northeast and dipping flatly southeast.

Between these two localities, only one large outcrop and some small fragments of quartz have been found. The veins may have been eroded along the slope of the hill, they may be concealed by overburden or they may not exist.

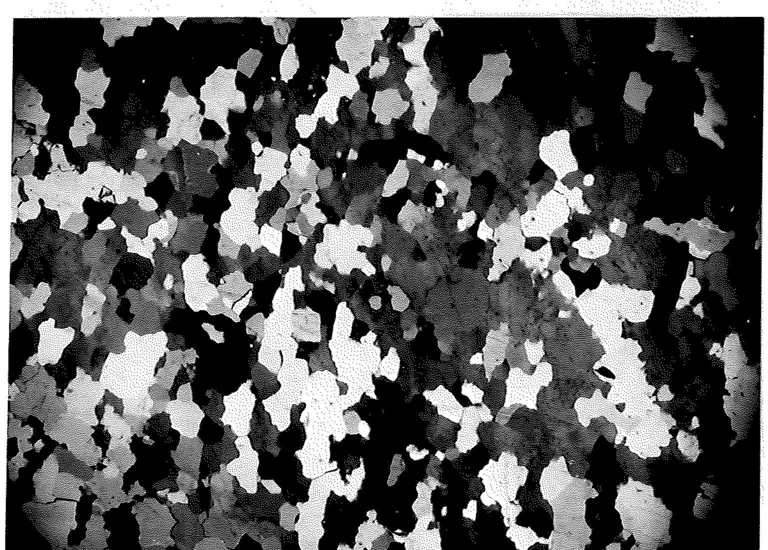
It is believed that the deposit consists of two or more veins, striking N 45° E and dipping 25-40° SE. This is a radical departure from the attitude of other veins studied and is presumed to be controlled by fractures or a fault zone, instead of by the regional cleavage.

The Pressentin quartz is white, has a vitreous luster and fractures irregularly but easily. In fact, much of it is fractured in place and pieces may be picked out by hand. The veins contain lenticular pods, up to four inches in maximum diameter, of twisted micaceous talc schist which is gray to gray brown, is extremely soft and has a soapy feel. The talc schist separates readily from the quartz, leaving smoothly-rounded cavities. The individual lenses are roughly aligned parallel to the plane of the vein.

Microscopically, the Pressentin quartz is hypidiomorphic granular, the grains ranging from four to six millimeters in diameter and showing random orientation. However, a small percentage of the rock consists of recrystallized grains about 0.4 mm in diameter; these occur in discontinuous, subparallel chainlets both across and along the borders of the original grains. This is the primary stage of cataclasis. Incipient cataclasis may be seen in the larger crystals, which show irregular extinction and other strain effects. (see plate 12, A) No feldspar was found in the quartz veins.

PLATE 13

A Coarse-grained Pressentin quartz, showing incipient cataclastism. Crossed nicols, x10.

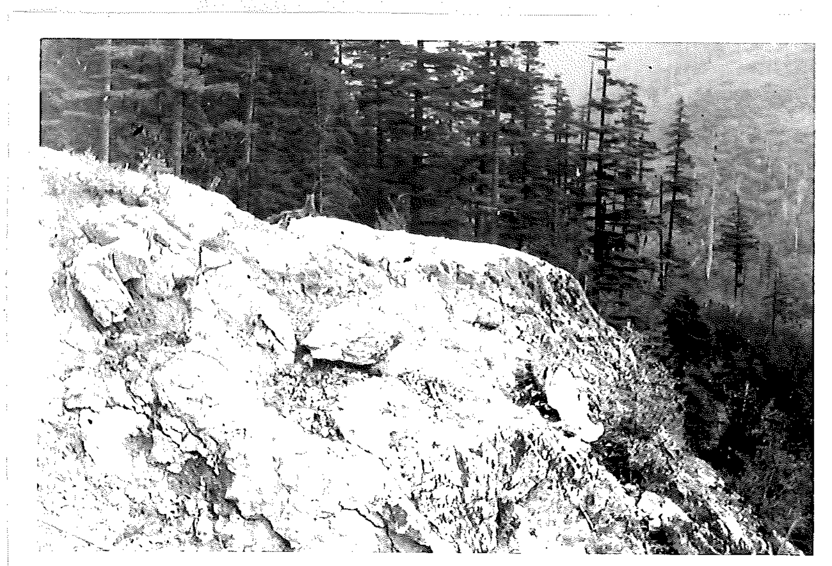


B Stoner quartz, well-advanced cataclastism. Crossed nicols, x10.

PRESSENTIN AND STONER QUARTZ

PLATE 14

A Outcrop as seen from quarry floor, looking northwest.



B Top of quartz outcrop, looking northeast across strike.

STONER SILICA DEPOSIT

Chemical analyses of the three samples taken by the U. S. Bureau of Mines at the Pressentin deposit are given in Table 2.

TABLE 2 CHEMICAL ANALYSES OF PRESSENTIN SILICA

Sample number	Length in feet**	Per cent, dry basis				
		SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO
1	7.2	97.8	0.53	0.70	0.08	0.20
2	15.5	98.9	0.42	0.20	0.05	0.01*
3	14.0	98.6	0.36	0.32	0.05*	0.15
Weighted average		98.6	0.42	0.34	0.06	0.09

* less than
** horizontal thickness, perpendicular to strike

Stoner deposit

In the northeastern part of the area, between 850 and 1100 feet elevation, lies the Stoner deposit. This deposit, in the northeast quarter of Section 10, T. 36 N., R. 11 E. W. M., was discovered by Mr. R. J. Stoner, the present owner, and patented in 1938 by his wife, Mrs Mary A. Stoner, under the name Silicon Quartz Lode Mining Claim No. 1.

Small scale mining was started in 1941 by H. P. Schoel and later continued by the Skagit Mineral Products Company. Most of the output was shipped to the Northwest Glass Company in Seattle; some was ground to silica flour and grit for the local market. The total production does not exceed six thousand tons.

In 1944 the deposit was leased by the Bellingham Iron Works and explored by hydraulicking. The present lessee is the Skagit Mineral Products Company, which has subleased the deposit to the present operator, Mr. J. O. Newton. Mr. Newton is completing installation of equipment (crusher, rolls, screen, compressor, pipeline, etc.) for an estimated production of 20,000 tons of quartz per year.

The deposit, which lies 400 to 600 feet above the road and railroad, is connected by a rude tramway with a camp at the road level. A pipeline through which the quartz will be washed connects a crusher at the quarry level with a bunker at the road.

The quarry floor, at about 870 feet elevation, is 30 to 50 feet wide and has advanced 40 to 50 feet northerly along the apparent strike of the vein. The body has been explored for 200 feet north of the quarry by trenches and by hydraulicking.

The Stoner deposit is a lenticular quartz vein ranging from 80 to 120 feet in horizontal thickness (including horses) which has been traced by mining and surface exploration along its N 25-30° W strike for 350 feet and on its 55° SW dip about 120 feet. The vein occurs in feldspathized quartz-mica schist along its contact with a large granodiorite sill. In places this sill appears to form the footwall, in other places an altered peridotite lies beneath the quartz. In the northern part of the body, the schist is on both walls; everywhere, the hanging wall is in schist.

The vein contains several large, elongated, parallel horses of altered schist ranging from a fraction of a foot to ten feet in thickness. These may wedge out in a short distance or continue without break into the quartz-mica schist outside the quartz body. The horses have the same strike and dip as the vein, which agrees with the regional schistosity. They are less resistant to erosion than the quartz and, consequently, they form long, narrow depressions on the surface of the vein outcrop. The quartz between the horses is free of inclusions except near the walls of the vein where small lenses of altered, whitened schist become numerous. Also near the borders of the quartz mass there occur, in the quartz, lenticular vugs up to five inches in length, lined with idiomorphic quartz crystals. Small lenses and stringers of quartz, parallel to the main body, occur in the schist on the hanging wall.

Quartz veinlets cut the granodiorite and the schist but not the peridotite; however, a wide part of the vein on the footwall appears to penetrate the peridotite near the quarry level. The only rock later than the quartz is a diorite which is represented by two small dikes near the deposit.

The quartz-mica schist has been altered and varies greatly in appearance near the Stoner deposit. Near the hanging wall, it grades from the common, dark-brown quartz-biotite schist through a lighter, hornfelsic rock to a bleached biotite gneiss on the hanging wall and in the horses. In one place the quartz has apparently been removed from the schist and a biotite schist remains, considerably crumpled and distorted. In the smaller vein inclusions, the biotite often completely disappears; the inclusion is visible only because of its clayey, dull whiteness which contrasts with the subvitreous luster of the quartz.

The Stoner quartz is creamy white, has a subvitreous luster and an irregular to subconchoidal fracture. Some of it has a rock candy texture, and all of it is difficult to break.

Under the microscope, a stage of cataclasis more advanced than that of the Pressentin quartz, but much less advanced than in the Bacon Creek quartz, is apparent (see plate 12,B). The original grains are subhedral and average three millimeters in diameter. These grains, which show the usual strain shadows, are everywhere breaking down and recrystallizing into grains which average 0.2 mm in diameter. Less than half the rock has recrystallized in this manner.

Near the walls of the vein and in the horses, the quartz-mica schist has been greatly feldspathized, apparently at the expense of the biotite which disappears in some places. The feldspathized schist is completely crystalloblastic with porphyroblasts of sodic feldspar growing in a granoblastic quartz groundmass and pushing aside the biotite grains which struggle to retain their original alignment (see plate 14,B). Goodspeed's designation of composite porphyroblasts as either glomeroblasts or cumuloblasts[6/] is particularly applicable to this rock, which contains numerous feldspar glomeroblasts as well as quartz-feldspar cumuloblasts (see plate 15).

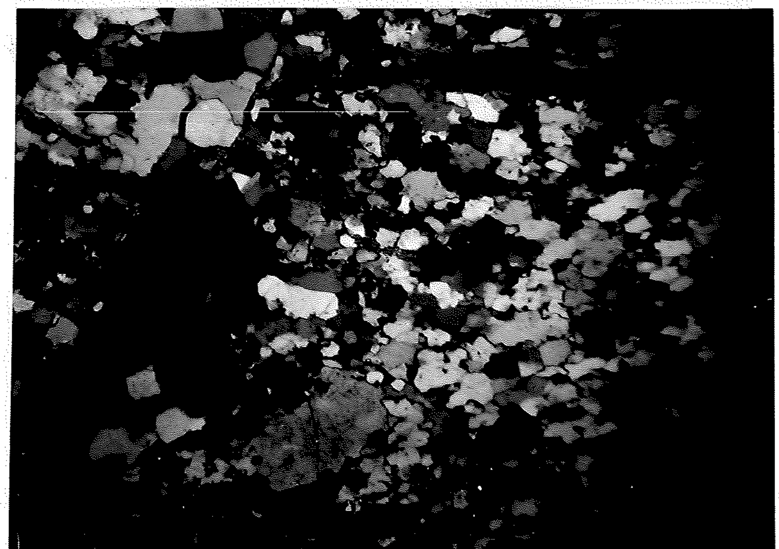
Veins of quartz which appear to cleanly transect the schistosity are seen under the microscope to partially surround original biotite grains without disturbing them. Occasional feldspar crystals are found in these veinlets, which are often discontinuous. The texture is crystalloblastic.

The feldspar in the rock from the hanging wall is usually clear and includes nothing but quartz; in specimens of a feldspar-rich rock taken from the footwall, the feldspar is extremely turbid and contains small quartz grains and sericite.

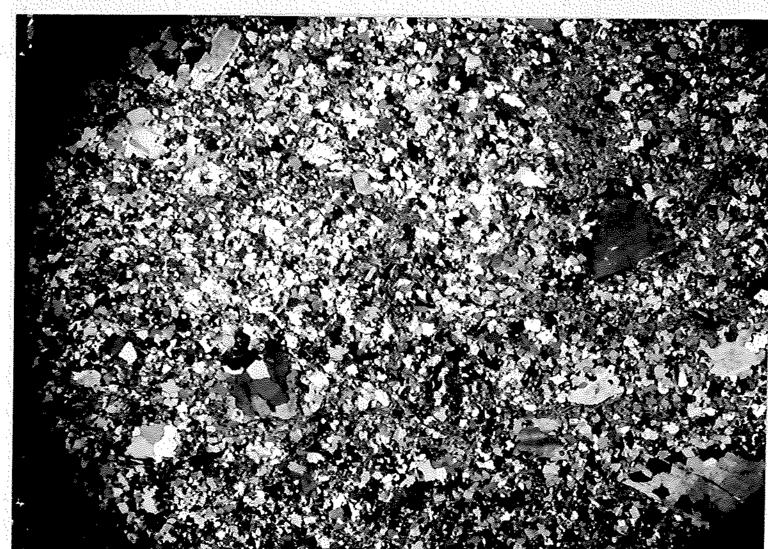
Near the hanging wall, a few biotite grains have been discovered altering to limonite which is apparently escaping along minute fissures in the quartz.

The interpretation placed upon these field and microscopic relations by the writer is: The granodiorite sill intruded the quartz-biotite

PLATE 15



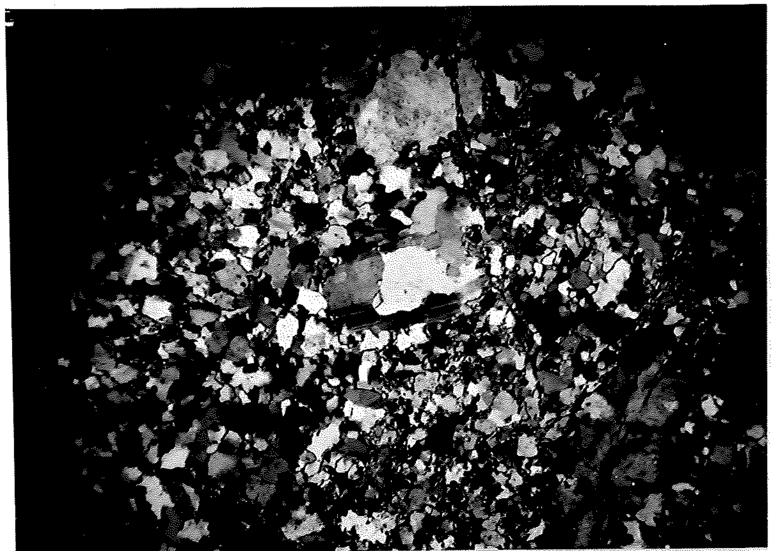
A Quartz-feldspar veinlet (on left) forming by replacement of quartz-biotite schist. Crossed nicols, x43.



B Composite porphyroblasts in feldspathized schist. Faint palimpsest structure. Crossed nicols, x10.

FELDSPATHIZED QUARTZ-MICA SCHIST

PLATE 16



A Quartz-plagioclase cumuloblast and feldspar glomeroblasts in feldspathized schist. Crossed nicols, x43.

B Feldspar porphyroblast including quartz and quartz glomeroblast in feldspathized schist. Crossed nicols, x43.

COMPOSITE PORPHYROBLASTS

schist, which, in the vicinity of the Stoner deposit, had possibly been already weakened by a peridotite intrusion. In any case, a small zone of structural weakness was developed in the schist at this place. Silica-bearing hydrothermal solutions, rising along the planes of schistosity, migrated to this area and deposited the quartz vein by fissure-filling and replacement. As in the Bacon Creek deposit, the silica in the hydrothermal solution reacted with the biotite to form feldspar, especially along the borders of the growing veins. In parts of the schist which became completely surrounded by quartz, the porphyroblastic feldspar and the remaining biotite were leached out, leaving vugs which became lined with small idiomorphic quartz crystals. In the schist on the walls, sodic feldspar formed, biotite decreased, and part of the quartz migrated into the veinlets, some of which eventually became part of the large quartz deposit.

On the footwall, the quartz probably replaced some of the granodiorite, by reduction of the feldspar to quartz and sericite, the latter being leached out along with the biotite. There is some indication in all these deposits that a moderately elevated temperature is required for the formation of feldspar from quartz and mica, and that below the temperature required to initiate this reaction simple leaching of the micas and alteration of the feldspars to quartz and sericite is predominant.

There is no evidence to relate the hydrothermal solutions to the nearby granodiorite batholith.

The evidence is conclusively against the pegmatite theory of the formation of the Stoner deposit; it all points to deposition of quartz from a hydrothermal solution and replacement along cleavage planes in a receptive schistose rock.

Table 3 shows the chemical analyses of thirteen samples taken from the Stoner deposit by the U. S. Bureau of Mines. The silica content of the body is high and uniform, averaging 98.8 per cent; variations in individual samples are probably due to small inclusions of the feldspathized and micaceous schist. Near the walls the analyses are high in magnesia and alumina, bearing out this hypothesis.

TABLE 3 CHEMICAL ANALYSES OF STONER SILICA

Sample number	Length in feet**	Per cent. dry basis SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO
1	12.0	99.0	0.41	0.12	0.05*	0.02
2	12.0	98.6	0.43	0.05	0.05*	0.01*
3	7.0	98.2	0.31	0.06	0.05*	0.01*
4	11.0	99.7	0.33	0.02	0.05*	0.01*
5	16.0	98.4	0.42	0.02	0.05*	0.01*
6	13.1	99.1	0.41	0.02	0.05*	0.01*
wtd avg samples 1-7		99.0	0.39	0.02	0.05*	0.01*
7	20.5	98.2	0.40	0.17	0.05	0.22
8	8.5	98.9	0.50	0.05	0.05*	0.01*
9	16.5	99.7	0.25	0.06	0.05*	0.01*
10	26.0	98.3	0.26	0.03	0.05*	0.01*
11	14.9	98.8	0.50	0.59	0.05*	0.33
wtd avg samples 7-11		98.7	0.36	0.17	0.05*	0.11
13	12.5	99.2	0.39	0.06	0.05*	0.01*
14	13.0	99.1	0.20	0.03	0.05*	0.01*
wtd avg 13 samples		98.8	0.39	0.10	0.05	0.05

* less than
** horizontal thickness, perpendicular to strike

A report on the examination of a sample from the Stoner deposit was published by Wilson, Skinner, and Couch:[19]

> Skagit 6 (Stoner) This composite sample represents samples taken from three five-foot quartz veins in metamorphic rocks. The sample contained 99.6 SiO_2, 0.13 Fe_2O_3, 0.2 Al_2O_3

and 0.2 ignition loss. The pyrometric cone equivalent test gave a glassy fusion at 32½. Petrographic examination showed 99 per cent quartz with traces of fresh and turbid feldspar.

As mined, the quartz is suitable for the manufacture of amber glass and for many other industrial uses. Some method of beneficiation, probably one of those suggested for silica sands by Dasher and Ralston[4] might produce low-iron silica for the manufacture of high-grade glass. Table 4, taken from Silica Sands of Washington[19] gives the specifications for silica to be used in various grades of glass. These requirements were set up by the American Ceramic Society.

TABLE 4 CHEMICAL COMPOSITION REQUIRED OF VARIOUS GLASS SANDS

		Per cent, dry basis			
Quality	Type of glass	SiO_2 min.	Al_2O_3 max.	Fe_2O_3 max.	CaO-MgO max.
1	Optical	99.8	0.1	0.02	0.1
2	Flint, tableware	98.5	0.5	0.035	0.2
3	Flint	95.0	4.0	0.035	0.5
4	Sheet, rolled and	98.5	0.5	0.06	0.5
5	polished window	95.0	4.0	0.06	0.5
6	Green containers	98.0	0.5	0.3	0.5
7	Green	95.0	4.0	0.3	0.5
8	Amber containers	98.0	0.5	1.0	0.5
9	Amber	95.0	4.0	1.0	0.5

This table originally published in the Bulletin of the American Ceramic Society, volume 2, 1923, pages 182 to 184.

TALC DEPOSITS

Not enough field work was possible on the talc deposits to permit the substantiation of any hypothesis as to their origin. However, from the field relations an idea of the genesis was formulated; it will be presented purely as a suggestion.

There are three deposits in the Bacon Creek-Skagit River area which have at some time produced talc: the McMyrl-Wilson mine in the northeast quarter of section 21; the Rainbow mine in the southwest quarter of section 18; and the Skagit mine in the northwest quarter of section 14, T. 36 N., R. 11 E. W. M.

At the McMyrl-Wilson mine, there are three adits, one of which is 140 feet long, and a quarry about 20 feet wide and 30 feet long. Blocks of talc were sawed from the quarry and shaped into smaller pieces in a mill at the highway nearby. The production was possibly 2000 tons.

The deposit is enclosed in quartz-mica schist, with which the schistose talc agrees in strike and dip. The strike is N 8° W and the dip is steep to the southwest. Talc schist seams are the rule rather than the exception for several hundred feet horizontal distance in a section normal to the strike. There appears to have been considerable strike-slip faulting, possibly of minor displacement, along this zone. The quarry face shows rounded to subangular brown spots from one inch to four inches in diameter, with a limonitic halo surrounding each one. These spots are darker and harder than the enclosing soft, light-colored talc. Smaller and more angular inclusions with a similar megascopic appearance occurring in the Skagit mine, proved, on microscopic examination, to be large ankerite porphyroblasts. On the south side of the quarry a four-foot seam of serpentine outcrops.

Openings at the Rainbow mine consist of two adits and several hundred feet of underground workings. Several large rooms have been stoped out. Total production has been about 7000 tons. The mine is near or in a probable fault zone. The strike in the green talc schist is almost north, the dip 45° to the west. Irregular chunks of a rather soft, massive, dark-green rock, which is probably serpentine or soapstone, are scattered throughout the talc schist in the Rainbow. About 200 feet south of the mine, on the surface, there is an interesting outcrop. A biotite-rich schist grades rapidly into massive, fine-grained biotite which then passes abruptly into a green micaceous mineral (chlorite?); this occurs within a distance of ten feet in a single outcrop. The concentrated micaceous minerals are on the north end of the outcrop, nearer the mine.

At the Skagit talc mine, the most recently operated, the workings are the most extensive, consisting of four adits, several hundred feet of crosscuts, and stoped-out rooms on two levels. Production is estimated at ten thousand tons or more. All of the workings are in schistose or massive talc, the former greatly predominating.

At the head of one crosscut thin layers of biotite were found interstratified with green schistose talc. In some of the schistose talc chalcopyrite is smeared in thin films along many of the parallel cleavage planes. In the massive talc ankerite forms large, white, euhedral crystals which weather to a brown color on cut surfaces. Although the workings nowhere intersect it, a small granodiorite body, probably sill-like, occurs near the deposit; caved material at the ends of two of the crosscuts on the north side of the mine is composed principally of granodiorite boulders. The talc schist strikes northwesterly and is nearly vertical. South of the mine the quartz-mica schist outcrops.

According to the literature, talc may be formed in any of several ways. It is commonly considered to have been derived from the alteration of basic igneous rocks such as pyroxenite or peridotite to serpentine and then to talc. Lindgren[10/] states that talc is a product of the later stages of pyrometasomatism, but may also be formed during dynamometamorphism and perhaps in part by the action of the deeper groundwater; he also notes that E. Weinschenk, in describing Austrian talc deposits, holds that the mineral develops by replacement of schist composed of quartz, chlorite, chloritoid and graphite, along its contact with limestone, and believes that this transformation is due to waters following the irruption of large igneous bodies. Diller[4/] remarked that the long, narrow belts which talc forms approximately parallel to the general trend of the neighboring rocks may suggest derivation by alteration from sedimentary rocks, but he believes that such rocks are probably intrusive and that the rock bodies are dikes rather than strata.

The writer favors the hypothesis that the talc in the Bacon Creek-Skagit River area has been derived in place from the alteration and replacement of the quartz-mica schist, acted upon by hydrothermal solutions percolating in localized zones of structural weakness. It is further suggested that biotite, necessary for the formation of feldspar in the schist, has again acted a principal role and has, by progressive alteration, formed talc. By some process, as yet undetermined, small areas of schist have had the quartz removed, leaving almost pure biotite. This mica may have changed to chlorite, which then broke down into anthophyllite and talc (optically indistinguishable); where the solutions doing this work contained CO_2, the anthophyllite was acted upon to produce talc and ankerite. The end products of this possible sequence would thus be talc with minor amounts of ankerite. This relation occurs in the most highly altered parts of the talc deposits, although it well may be the result of some other chain of reactions and alterations.

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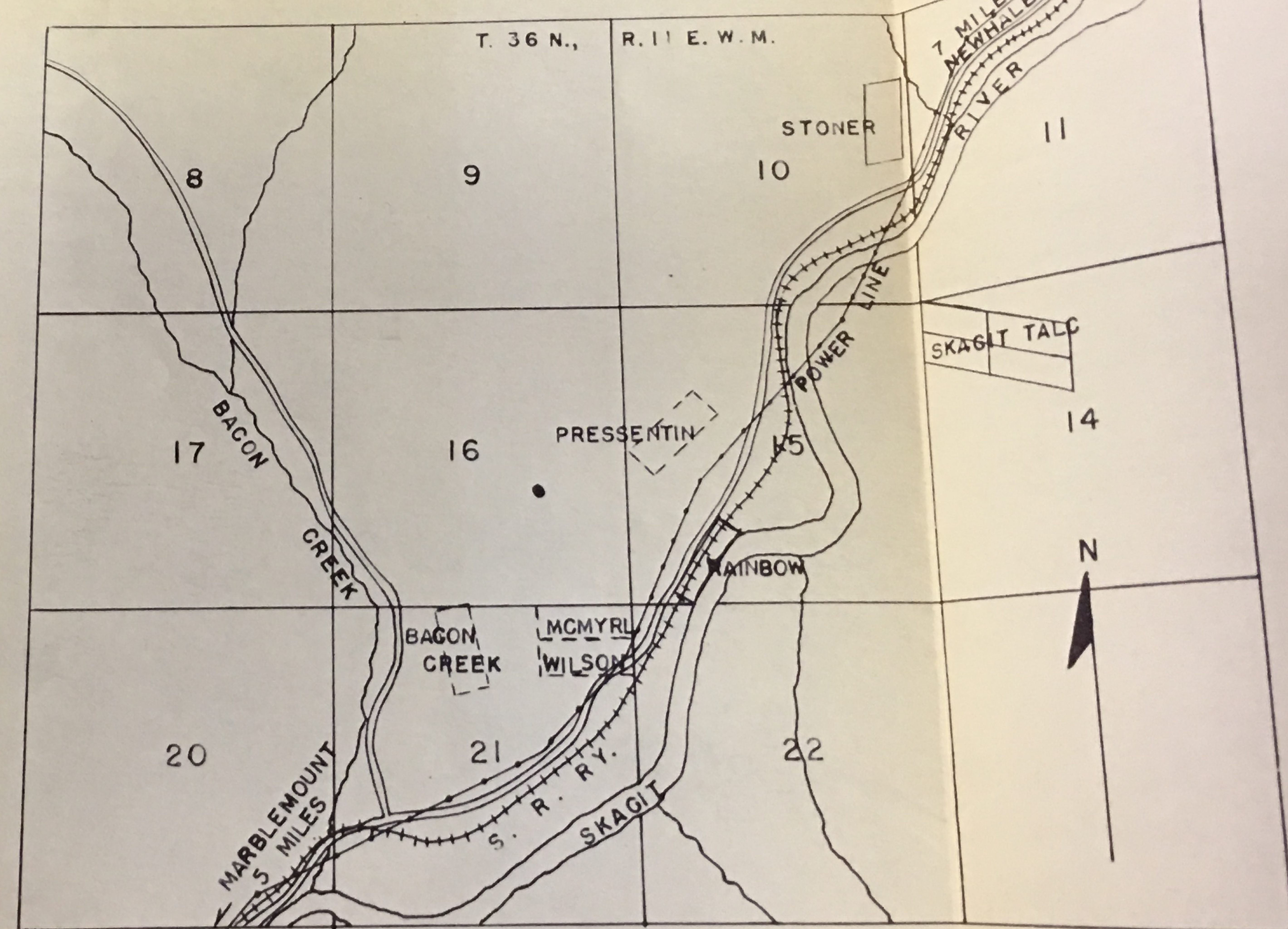
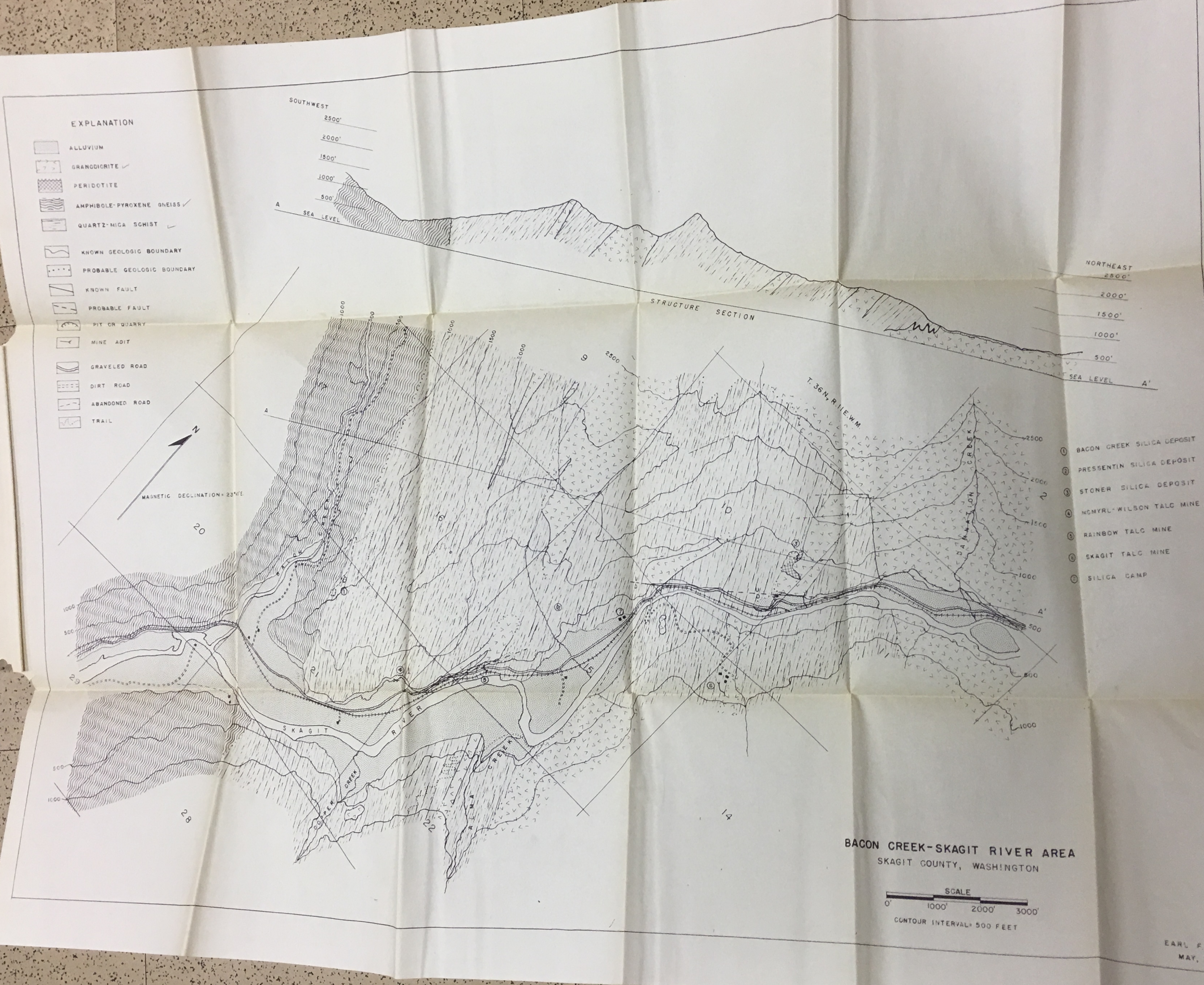
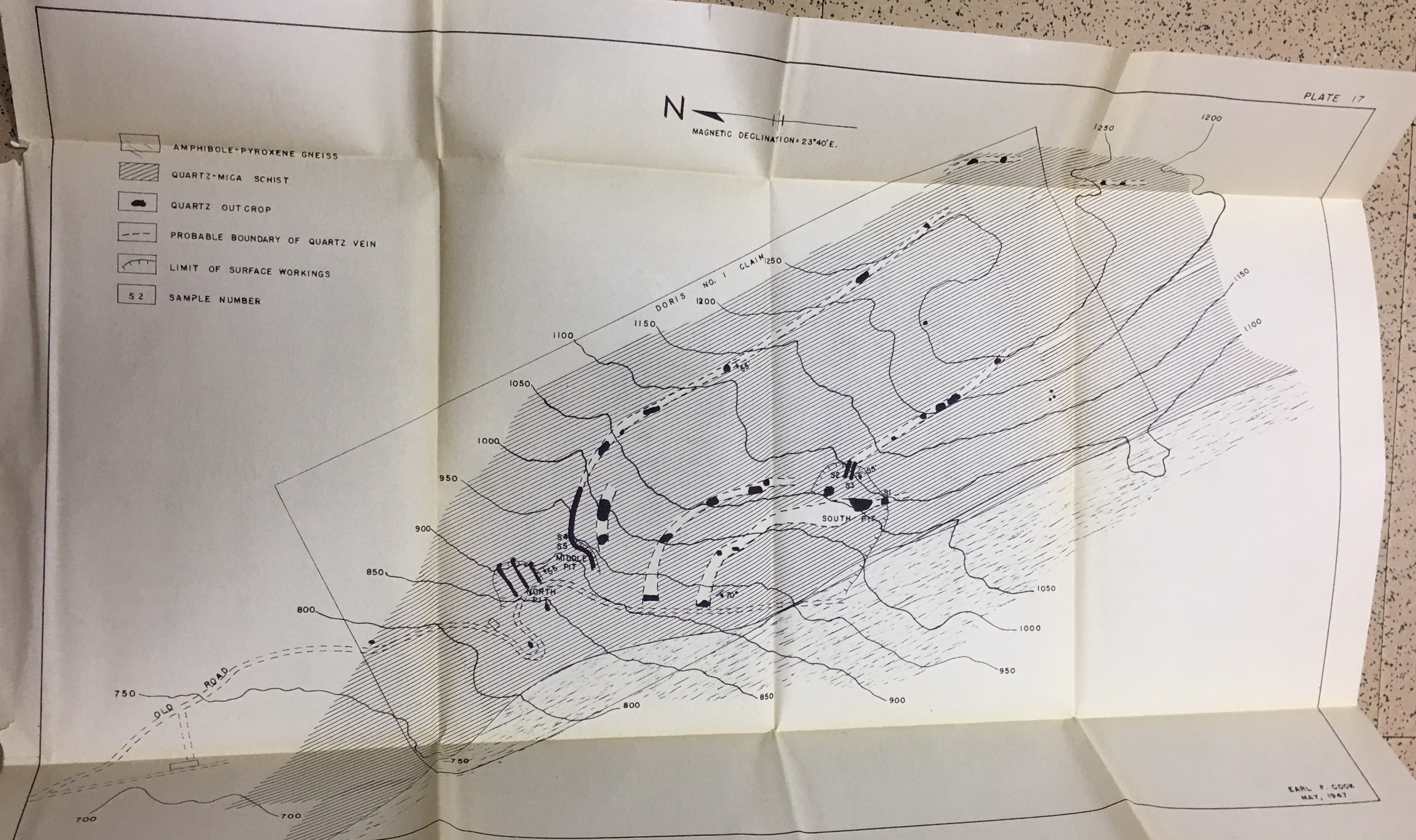
PLATE 7



BACON CREEK-SKAGIT RIVER AREA
DEPOSIT LOCATION MAP
SCALE: 2 IN. = 1 MILE


EXPLANATION
ALLUVIUM
GRANODIORITE
PERIDOTITE
AMPHIBOLE-PYROXENE GNEISS
QUARTZ-MICA SCHIST
KNOWN GEOLOGIC BOUNDARY
PROBABLE GEOLOGIC BOUNDARY
KNOWN FAULT
PROBABLE FAULT
PIT OR QUARRY
MINE ADIT
GRAVELED ROAD
DIRT ROAD
ABANDONED ROAD
TRAIL
MAGNETIC DECLINATION= 23°E
SOUTHWEST
NORTHEAST
SEA LEVEL
STRUCTURE SECTION
T.36N.,R.11E.W.M.
SKAGIT RIVER
① BACON CREEK SILICA DEPOSIT
② PRESSENTIN SILICA DEPOSIT
③ STONER SILICA DEPOSIT
④ MCMYRL-WILSON TALC MINE
⑤ RAINBOW TALC MINE
⑥ SKAGIT TALC MINE
⑦ SILICA CAMP
BACON CREEK-SKAGIT RIVER AREA
SKAGIT COUNTY, WASHINGTON
SCALE
0' 1000' 2000' 3000'
CONTOUR INTERVAL= 500 FEET
EARL F. COOK
MAY, 1947



BACON CREEK SILICA DEPOSIT

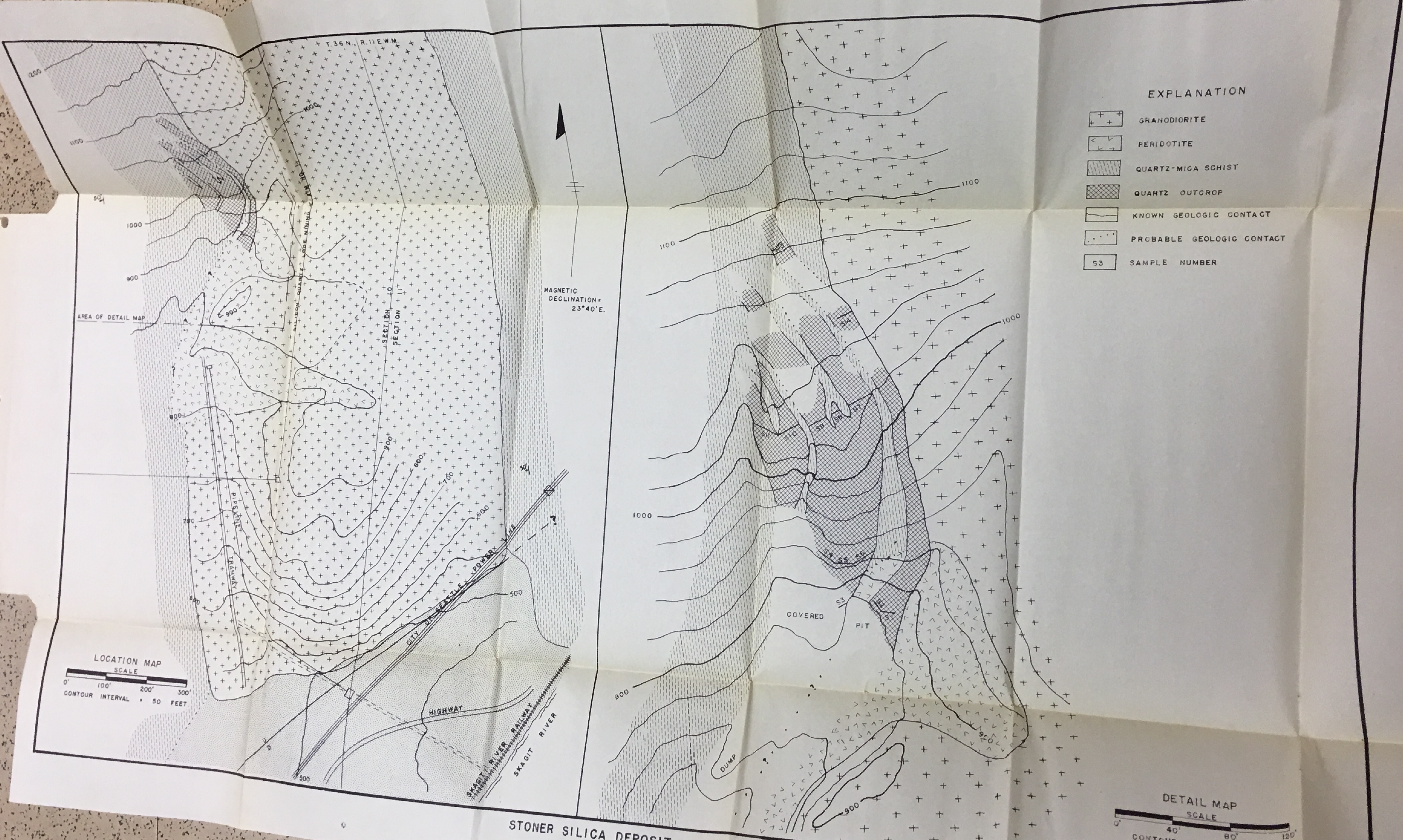
SKAGIT COUNTY, WASHINGTON

SCALE

0' 50' 100' 200' 300'

CONTOUR INTERVAL = 50 FEET

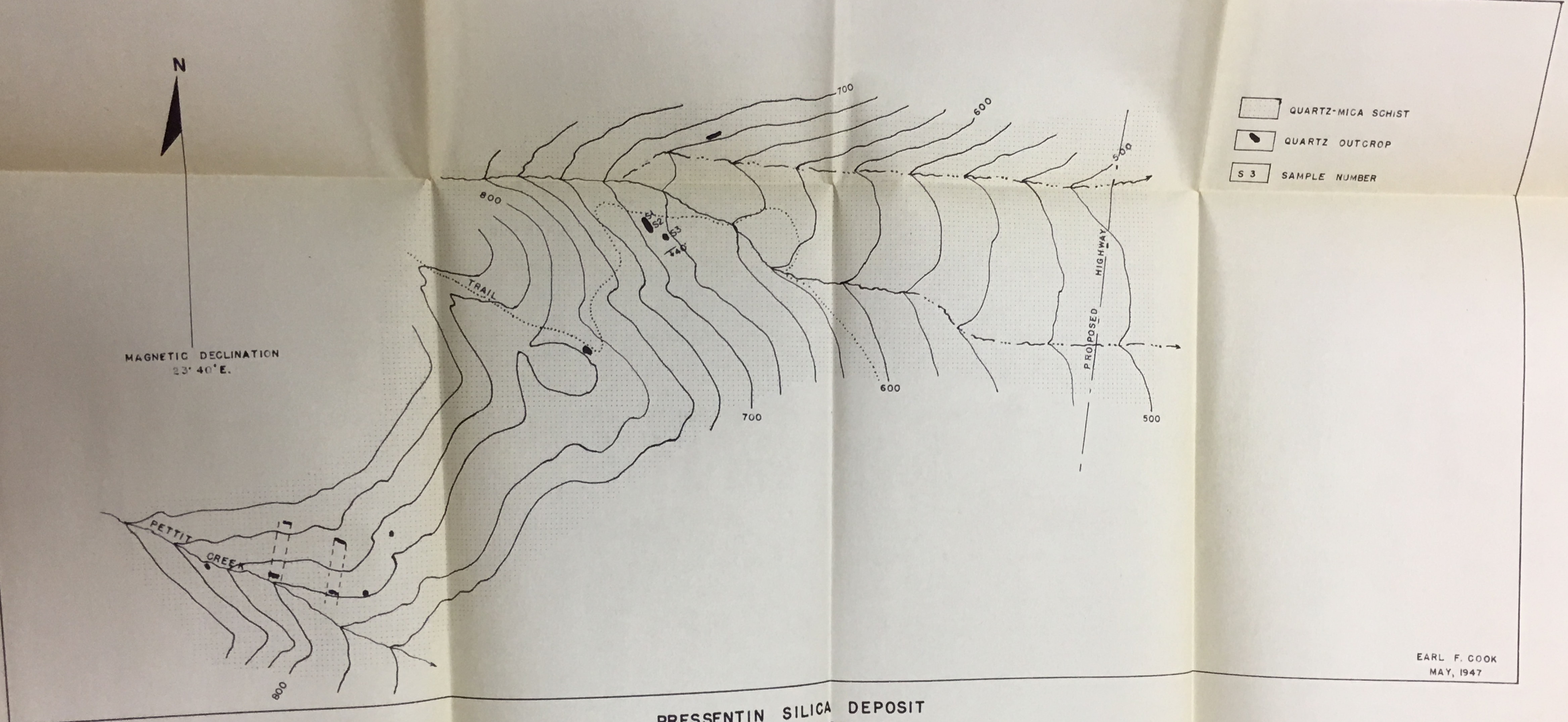
PLATE 19



STONER SILICA DEPOSIT

SKAGIT COUNTY, WASHINGTON

EARL F. COOK
MAY, 1947



PRESSENTIN SILICA DEPOSIT

SKAGIT COUNTY, WASHINGTON

SCALE

0' 100' 200' 300'

CONTOUR INTERVAL: 25 FEET