MAINE PUBLIC DOCUMENTS

1946-48

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VOLUME II.

REPORT

of the

STATE GEOLOGIST

1947 - 1948

Maine Development Commission

Augusta, Maine March, 1949

MAINE GEOLOGICAL SURVEY

Orono, Maine

Joseph M. Trefethen, Ph.D., Director and State Geologist

PERSONNEL

1947

Donaldson Koons	Geologist
Lawrence Wing	Geologist
Henry Allen	Assistant Geologist
J. J. Donohue	Assistant Geologist
Elbert Pratt	Assistant Geologist
Robert Chase	Field Assistant
E. W. Perkins	Field Assistant
L. W Leavitt	Assistant Engineer

1948

L. W. Goldthwait	Geologist
L. W. Wing	Geologist
J. J. Donohue	Assistant Geologist
Edwin Cormier	Field Assistant
E. W. Perkins	Field Assistant and Draughtsman
Raymond Woodman, Jr.	Field Assistant
Earl Fuller	Assistant Engineer

MAINE DEVELOPMENT COMMISSION

Augusta, Maine

REPORT

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STATE GEOLOGIST

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by Joseph M. Trefethen, *State Geologist*
and Professor of Geology,
University of Maine

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ILLUSTRATIONS

ACTIVITY OF THE MAINE GEOLOGICAL SURVEY 1947-1948

By JOSEPH M. TREFETHEN, State Geologist

The Maine Geological Survey, carrying out a part of the Maine Development Commission's program, has a fourfold function:

1) to give **service to landowners and prospectors** through the identification and examination of mineral and rock specimens and prospects;

2) the **exploration and mapping** of areas which appear to have economic prospects for mineral development;

3) **laboratory research** directed towards the discovery of new or improved techniques that may make possible economic advances in the commercial development of our mineral resources; and

4) **the dissemination of information** on the geology and mineral resources of Maine, through publication, correspondence, and talks before various groups. A review, therefore, of the Survey's activity includes a variety of geological work, and is conveniently summarized by following in outline these four functions—service, exploration, laboratory research, and information service.

Service

As in the past few years, many specimens have been received for identification, nearly one a day. Many of these are "fools' gold" to be sure, but anyone who has had the experience of picking up some shining yellow particle from the earth knows the prospector's thrill, but also knows the uncertainty as to the value of the discovery. It is through such curiosity that many new discoveries have been made. Identification of mineral and rock specimens is made without charge at the Orono Laboratory of the survey. Some minerals are easily named; others, especially in this state where the numbers of rare minerals are large, require much patient work to identify correctly.

As in past years, also, requests to examine mineral prospects have come in from nearly all parts of the state. In particular, because of the drought of the past two years, more requests for aid and advice on well locations and development have been received than in previous years. Ground water is, indeed, our most valuable mineral resource, and its value, of course, increases with scarcity.

Exploration and Mapping

In the field seasons of 1947 and 1948, the Geological Survey had parties in the field studying and mapping mineral resources.

In cooperation with the federal geological survey, Professor Vincent Shainin and assistants continued intensive studies of the feldspar-beryl deposits in the vicinity of Rumford. This area is one of the most promising sources of these minerals in New England.

Under the leadership of Professor Lawrence Wing, the study and mapping of asbestos deposits in the northwestern part of the state has been carried out. In the course of this work, asbestos-bearing serpentine rock in the vicinity of Spencer Stream has been investigated, and a large volume of short fiber asbestos rock has been mapped. Although the fiber is short, the deposits are apparently rich enough to work. One large company is running tests on large samples of the material and is considering the development of the area. Other areas of possible asbestos occurrence extend diagonally across Piscataquis and Aroostook Counties. These await further study.

Under the leadership of John J. Donohue, and in cooperation with the State Department of Sea and Shore Fisheries, (1948), a detailed study of the interrelationships of geologic environment and the growth and production of clams has been begun. It is obvious that clams, like any other crop thrive, grow best, and multiply according to the conditions of their surroundings. The complex of biological and physical factors which affect this important coastal industry are little understood. This combined geological-biological study, cooperative between the Development Commission and the Department of Sea and Shore Fisheries is, indeed, a pioneering approach, in which Maine is taking a lead.

The field studies of clay were continued in 1948 by Dr. Koons of Colby College and in 1949 by Professor Lawrence Goldthwait of the University of Maine. Although the inventory is far from complete, information on the types and distribution of our clays is accumulating. An important aspect of this study is the relation of the clays to other types of deposit of glacial origin. Thus, the field studies of the clays are directly related to the occurrence of sand and gravel, our most important geological sources of material for public and private construction; and also related directly to the occurrence of ground water.

In the field season of 1947, Mr. Henry Allen and Mr. Elbert Pratt continued the inventory of Maine limestones by a reconnaissance survey of the limestone resources of Franklin County, and the study of Kennebec County limestone was begun.

Laboratory Research

In the laboratory, a study attempting to treat the common blue clays to eliminate the blue or gray color, and the iron, was continued by Mr. Earl Fuller. If Maine clay could be whitened for use in paper manufacture, or if the iron could be removed so that the red-burning clay would fire white, a new industry could be created based on one of our most abundant resources. A method of iron-removal has been developed. However, the uses of the clay so treated have yet to be explored.

The analysis of the sediments collected by the clam flat survey is also underway in the laboratory by Mr. Donohue.

Information Service

As in previous years, a number of talks before various civic groups have been given. Many requests for information have been answered, some from as far away as California (the California request was about the Desert of Maine). A bulletin on the feldspar-bearing rocks of the Topsham area has been issued. A list of the Maine Geological Survey publications will be found on the inside back cover of this report.

REVIEW OF
THE AROOSTOOK COUNTY MANGANESE DEPOSITS

By Joseph M. Trefethen

The Aroostook County, Maine, manganese deposits have been the subject of much public discussion. The following brief resume of these important reserves of this critical metal is made from Bulletin 4 (1947) of the Maine Geological Survey, Maine Development Commission. The data for that bulletin were gathered by Dr. Ralph Miller of the U. S. Geological Survey, working in cooperation with the Maine Geological Survey.

The Deposits

Manganese-bearing rock occurs in three areas of Aroostook County. These are: 1. Northern Area, in the vicinity of Presque Isle (Mapleton and other townships); 2. Central Area, in Township D, Range 2, and vicinity; and 3. Southern Area, in the vicinity of Houlton.

Northern Area. Over twenty prospects in this Northern Area have been mapped by State and Federal Survey, and have been explored by the M. A. Hanna Company. The best deposits are in the vicinity of the Milton Dudley farm, Castle Hill. In the Dudley prospect roughly twenty million tons of ore have been blocked out. The ore averages about ten to twelve per cent manganese. Although several of the other prospects of this area are large, none appear as promising as the Dudley ore body.

Central Area. The deposits of Maple Mountain and vicinity lie about ten miles from the highway. This area has not been thoroughly explored. The Hanna Co. trenched and took samples of the ore, but did not drill. The State Survey is planning further work in this district. The deposits are probably comparable to these of Castle Hill. The tonnage is probably as great, and the manganese content probably about the same, i. e., some ten per cent.

The Southern District. In the vicinity of Houlton many manganiferous prospects have been examined by federal and state survey, and by various commercial interests including the Hanna Company. No deposit of workable size or favorable structure has been found in the southern area.

Tonnage Estimates

Based on drilling records and detailed field studies, the State and Federal Surveys have estimated about forty million tons of *ore* in the known deposits *within two hundred feet of the surface.* Some of the deposits are known to be deeper than two hundred feet, but that depth is about the limit for open cut mining in that kind of rock for widths of exposed orebody. The ore carries between six and twelve per cent manganese, on the average, which gives a total of some two and a half million tons of *metallic manganese.* This is a conservative estimate based on sound data.

Outlook

Up to the present, no economic process has been found for extraction of the manganese from the ore. However, it is probable that sooner or later a process will be developed to make this resource available to the nation.

Advantages

These deposits have in their favor:

1. The United States depends almost entirely upon imported manganese—an essential to our steel industry.
2. The location with respect to transportation routes is favorable.
3. The ores average about 20-30 per cent iron which should be a substantial by-product of manganese extraction.
4. Power potential of the state, if developed, is more than adequate to serve the operation.
5. The deposits are large, probably second in size, in the United States, only to the manganiferous iron formation of the Cuyuna Range, Minn.

Disadvantages

The deposits have against them:

1. The manganese content of the ore is low—about ten or twelve per cent. High grade ores average between forty and fifty per cent manganese.
2. The manganese is combined with silica, a difficult combination to break down.

Development of the deposits is contingent on discovery of an economic process of manganese extraction from the ore. The research necessary to find a treatment for the ore has been recommended to the Bureau of Mines (federal) by the Maine Geological Survey and by Senator Brewster, and that organization has subsequently indicated that the research will be undertaken. It is also planned to drill the Maple Mountain district.

NOTES ON GROUND WATER CONDITIONS IN MAINE*

By JOSEPH M. TREFETHEN

The exceptionally dry summers of 1947 and 1948 have brought to the attention of many Maine people, especially those of the rural districts, the need for new or better wells. Industry, likewise, has felt the ill effects of the droughts. The Maine Geological Survey assists in the location of water sources, and the increasing requests for this type of service will be met as far as possible.

There are two potential sources of water for industrial and domestic use. The first of these sources is surface water, lakes and streams; the second is sub-surface water. The suitability and development of surface supplies is the responsibility of the chemist and engineer. In the development of sub-surface waters, although the well driller is the chief of operations, the geologist can, at most places, give valuable advice in advance of drilling.

Before any well is started, a number of questions arise. *First*, of course, "Where should the well be located?" *Second*, "How deep will the well have to be?" *Third*, "Through what kind of material will the hole pass?" *Fourth*, "If the hole does not yield water, at what depth shall it be abandoned?" *Fifth*, "How much water will the well yield?" *Sixth*, "What will the water be good for?" The answers to most of these questions depend on local geological conditions. Perhaps at some places, the answers to none of these questions can be given in advance, and seldom can all be answered completely before drilling.

Although the specific answers to these questions depend on the local combination of geologic factors, there are certain general considerations, of universal application which may be briefly reviewed. For anything more than a very temporary supply, the well must be driven below the *water table*, which is the level to which the earth is more or less permanently saturated with water; or into a water-bearing layer in which the water is confined. The first diagram indicates a general case of water table. A part of the water that falls as rain or snow evaporates immediately from the surface; another part finds its way as surface run-off; the remainder becomes part of the sub-surface water.

*The Maine Geological Survey has in preparation a more complete discussion of sub-surface water which will be issued as a bulletin of the survey series in the near future.

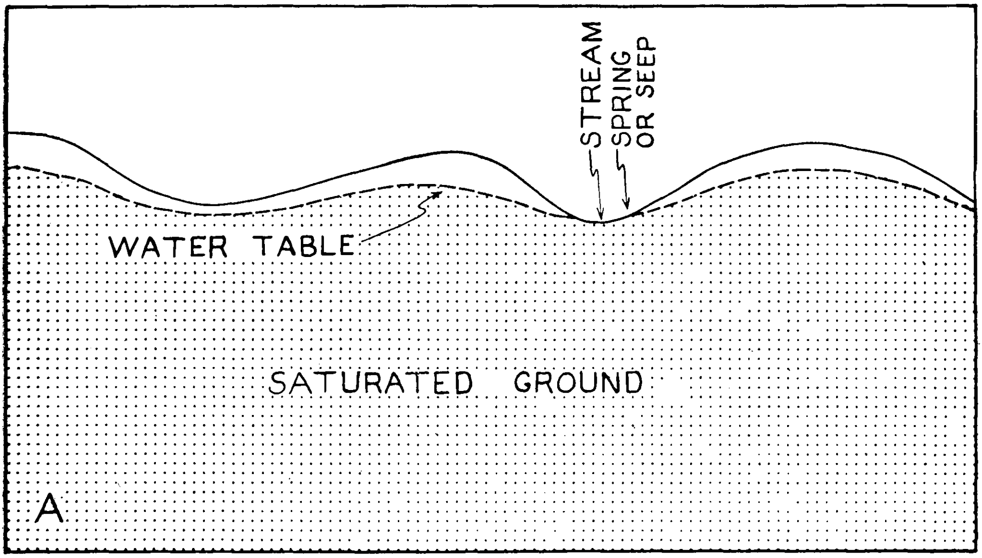


Figure 1A

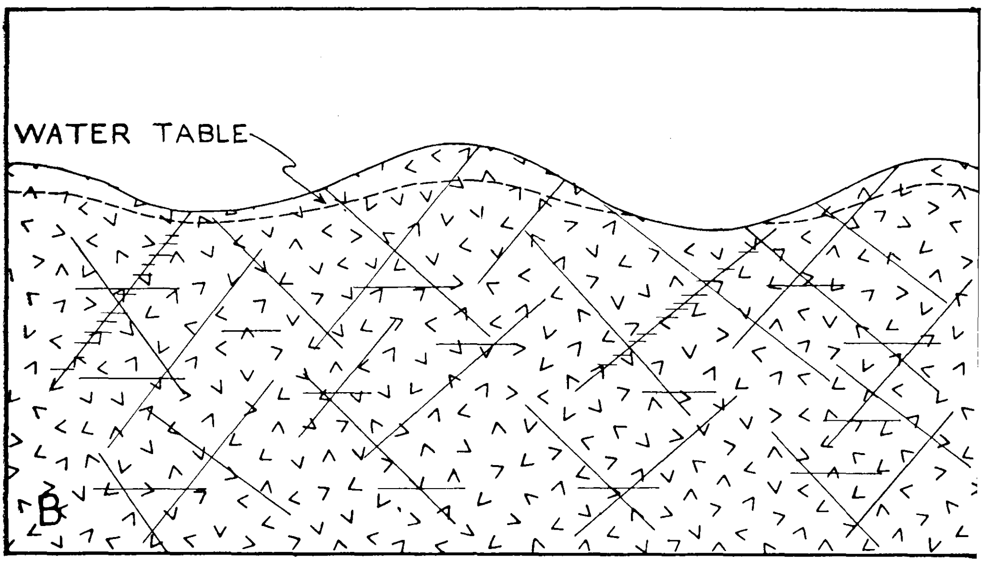


Figure 1B

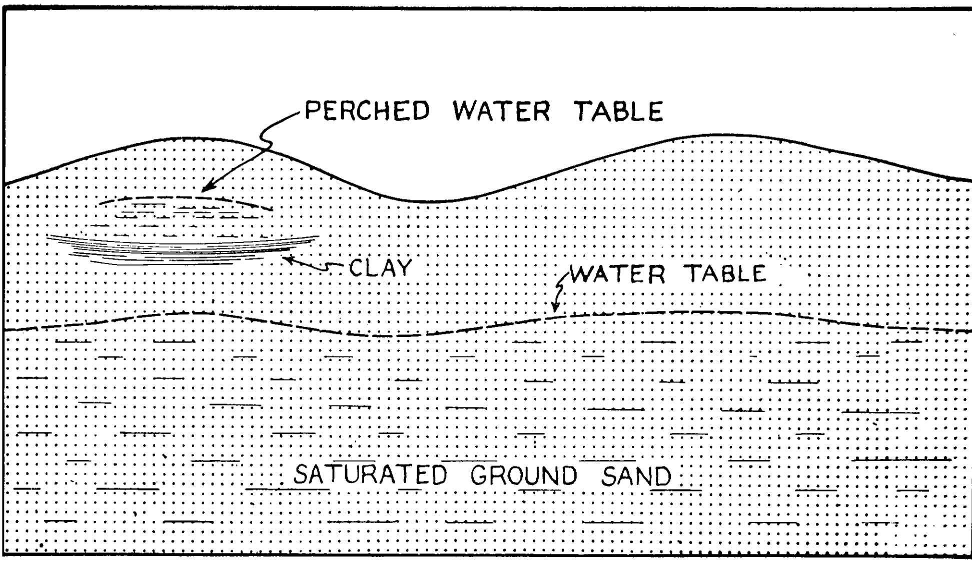


Figure 2

Above the general level of saturation, that is, above the water table, the dominant water movement is downwards. Beneath the surface of the water table, movement may be very slow: its horizontal component of movement is in the direction of the water table slope. Due to the retarding effects of the openings through which the water passes, and because in this climate the supply is more or less constantly replenished, the surface of the water table, in general, parallels the surface configuration. *It is, however, somewhat deeper beneath the hills, and relatively closer to the surface in the valleys.* The relations are shown in Figure 1.

In general, in this region, the permanent streams are those that have cut down to intersect the water table; the temporary or seasonal streams are those that have not yet cut down deep enough to intersect it. Where valleys intersect the water table, springs and seeps may occur, and although this is not the only type of spring, it is a very common one.

In a glaciated region such as New England, it is not uncommon to find a locally perched water table. This is shown in the diagram (Fig. 2), where a layer of clay is interstratified in the sand and gravel drift. In sand and gravel drift, the underlying bed rock is generally less

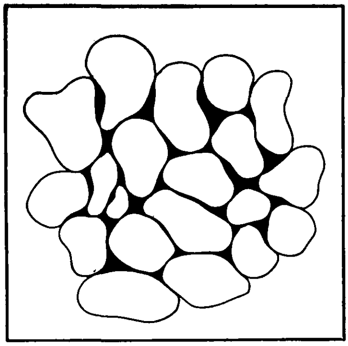


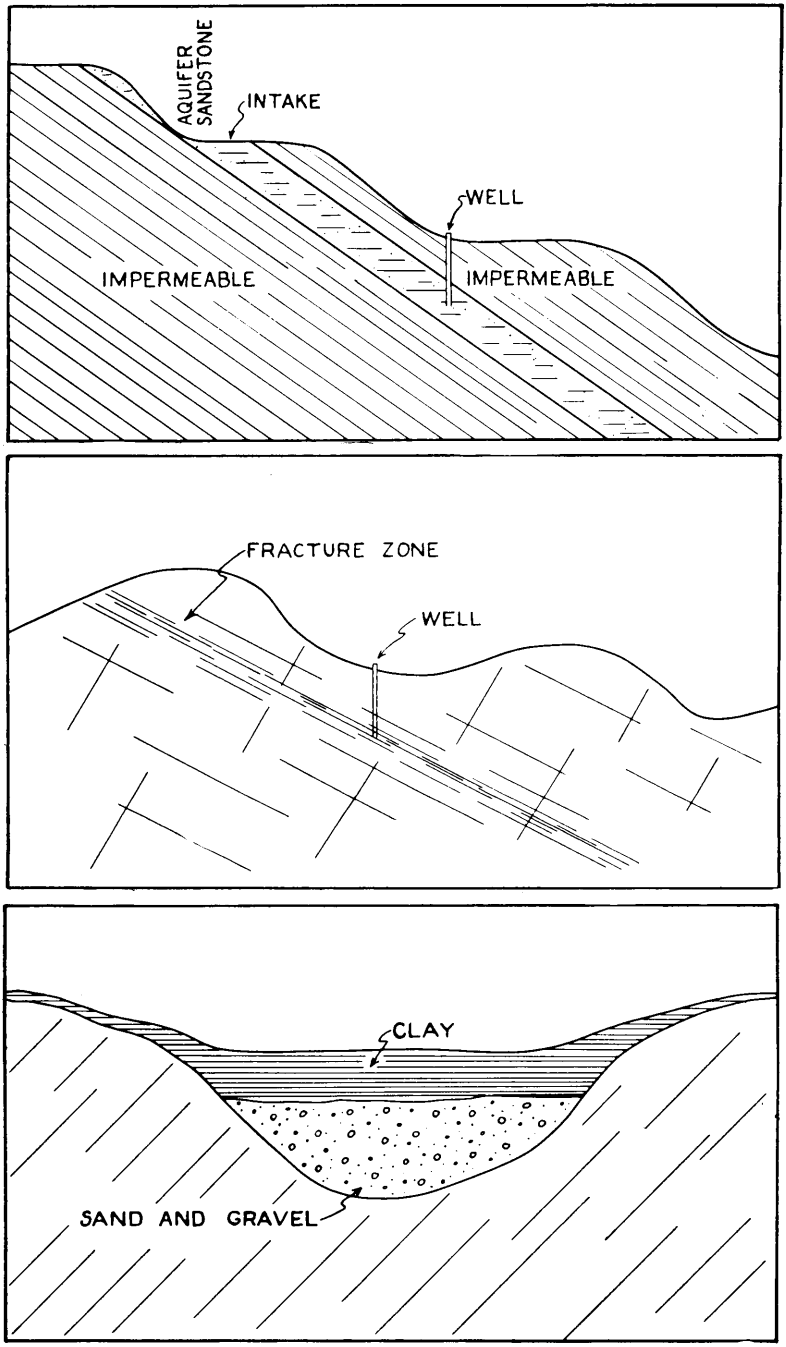
Figure 3

pervious, and with constant additions of water from precipitation, there may be a good source of water at the base of the drift. Another common situation is found in regions where the bed rock is overlain by clays, which in turn, are mantled with sand or gravel. Here the water table is perched on top of the clay. The water in the glacial drift is contained in the interstices of the material (Fig. 3). Gravel, of course, with the larger connecting openings between the pebbles yields the most freely, with sand being also an excellent yielder. Clays, although very porous, are poor yielders because of their low permeability. The glacial drift is composed of two types of material, stratified and unstratified. That is another way of saying, sorted and unsorted. The sorted or stratified glacial deposits are in general composed of sand and gravel, and are potential sources of water supply.

In Maine there are two classes of unstratified drift, the stony, coarse gravelly deposits, and the clayey deposits. The two intergrade. The stony or gravelly *tills*, as they are called, may yield water, the clayey tills are poor sources. The thickness of glacial drift cover varies from nothing at all on many hill tops to depths of over a hundred feet in some of the valleys. The great thickness of glacial drift which was found in the gorge of the Kennebec at Bingham Dam, for example, illustrates this point. Sand and gravel, stratified glacial deposits, have, at some places, been covered with later deposits, as for example by till deposited by glacial ice which overrode the earlier stratified sands and gravels. These buried porous and permeable sands and gravels, some of which mark the courses of glacial or pre-glacial streams, are often fruitful sources of water supply.

Turning to the bed-rock beneath the veneer of glacial deposits we find the water contained in several types of openings. Of most importance, here in this state are divisional openings. Beneath the surface of the water table, these are filled with water, and the intersection of the largest number of such fractures gives the best yield. The fractures may be joints, or cracks, in the rock along which little or no movement has taken place, or they may be shear zones or fault zones, along which the rock masses on either side have been relatively displaced. Since many of these are the results of pressure, they may follow some more or less regular pattern, which makes it possible to locate the well with the best chances of success from a surface study. Frequently, however, the intersection of sufficient number or size of fractures is a matter of chance; this is especially true where the bed rock surface is concealed by a cover of soil or glacial drift. In limestone regions there may be solution openings beneath the surface. The location of these and their penetration by wells is not a problem here in Maine, except possibly very locally, as our limestones are for the most part very impure, and without the development of subsurface drainage characteristic of many parts of the country, as for example, the cave regions of Kentucky and other states. Another type of opening in rock, found in sandstones, is similar to the openings in sand and gravel. This type of water bearer is exceedingly important in many parts of the country, the Great Plains, Mississippi Valley, and other sections. In Maine, our sandstones have so thoroughly recrystallized or have become so firmly cemented together that pore space and permeability have been reduced or practically eliminated. Hence, because of this induration and metamorphism of the sandstones, we are little concerned with such openings, and do not seek out such aquifers by drilling. In Maine, and elsewhere in New England, any deep rock well is called an artesian well. A true artesian well, however, is one in which the water rises above the general level of the water table; some are flowing wells.

At this place it may be well to discuss briefly the conditions for artesian flow. The general condition is shown in the accompanying figure (Fig. 4A). There must be for artesian flow of this type: (1) An aquifer or water bearer, which (2) has an intake, (3) is underlain by some impervious layer to prevent loss of water beneath, and (4) has an impervious layer over it to maintain hydrostatic head. A modification of this primary type is often realized in the glacial drift as shown in the accompanying diagram (Fig. 4B). One of the best ex-


AQUIFER SANDSTONE
INTAKE
WELL
IMPERMEABLE
IMPERMEABLE
FRACTURE ZONE
WELL
CLAY
SAND AND GRAVEL
Figure 4—A, B, C

amples of this type, a classic story in geology classes, is a well known as Jumbo, at Belle Plain, Iowa. There, the water bearing layer was reached at a depth of 193′. The driller attempted to force the flow of the water to ream out a two inch hole to a specified three inch diameter. Since the material was unconsolidated, this was quickly done, but didn't stop there. A three foot diameter hole resulted, with water spouting five feet or more in the air (local press reports gave the height of the fountain as 100′). 500 to 1,000 carloads of sand were discharged. The maximum flow was estimated at between 5,000,000 and 9,000,000 gals. per day. Two weeks later its flow was measured at about 3,000,000 gals. per day. Efforts to case the hold continued over a period of about fourteen months; during this interval 163′ of 18″ pipe, 77′ of 16″ pipe, 60′ of 5″ pipe, and an iron cone 3′ in diameter and 24′ long, and 130 bbls. of cement were consumed.

Most of the flowing or artesian wells in Maine are of another type, however. These tap joints or fracture zones; the water level rises in the well to a level controlled by the hydrostatic head. This situation is shown in the diagram (Fig. 4C). Probably the best known artesian wells in Maine are those in the vicinity of Greenville. The water in these wells rises to a height of 10 to 20 feet above the ground surface. Structural features, as faults and shear zones, often have a surface expression. In many instances their attitude, that is, their inclination and direction may be measured or inferred. To date, not enough geological work has been carried on to permit regional delineation of such structural features.

Throughout most of Maine, the rock is either igneous, as granite, or highly folded sedimentary or metamorphic rock. Ordinarily, the drill does not pass out of the formation in which the hole was started. It may be profitable to discuss briefly, then, the water bearing properties of the chief types of rock encountered in Maine.

Granites. Granites are rocks generally considered to have been squeezed into position as melted masses of rock material. Cooling and solidifying far beneath the surface and only exposed by erosion, granites, and similar intrusive igneous rocks have very little pore space. The average absorption of granites and related rocks is less than one per cent. Hence the water yield of such rocks is dependent on the joint and fracture systems. When a mass of melted rock material cools and solidifies, it shrinks, and certain of the joint systems are due to this volume change on solidification. Near surfaces joints are also developed by weathering. If the rock mass subsequent to solidification has been subjected to overpowering stresses during some convulsion of the earth's crust, systems of fractures are developed. The more homogeneous the granite or other rock mass is, the more regular will be the fracture pattern. With increasing depth, the joints tend to be less numerous, and more tightly closed. If an average yield of a gallon a minute be taken as adequate for domestic wells, the chances of success in drilling granite are about 90 in 100. Few granite wells yield more than ten gallons a minute. Because of the decreasing numbers of joints in depth, and increasing tightness of such deep joints, it is unadvisable to drill to greater depths than 150 to 200 feet. The chances for success are greater if a new hole is started 100 feet or more away. One of the risks in granite wells here in Maine is along the coast, where salt water may invade the well if it goes too deep, or is unfortunately situated with respect to structure.

Slates. Slatey formations are widespread in Maine. Slate is a shale or clay rock that has undergone compression and recrystallization during intense squeezing of the earth's crust. The porosity of slates is very small. In these rocks, as in granite and most other igneous rocks, the water is carried by joints and fractures, but in addition, there are many minute openings along the planes of stratification and schistosity. Some of our Maine slates (and schists) are somewhat calcareous. Enlargement of openings in the calcareous rocks may take place by solution along the water bearing surfaces. With granites and other related igneous rocks the chances for success diminish with depth. There is no such regular rule in the slate areas. The chances for success in drilling wells for domestic supply in slates are about 95 in 100 at depths of less than 200′, but if supply is inadequate at that depth it probably pays to continue another hundred feet, or even deeper.

Gneiss and Schist. Both gneisses and schists are widespread rock types in Maine. These rocks have surficial joints due to weathering, and many have more or less regular fractures due to earth forces which have acted upon them. In addition, there may be some opening up along the foliation planes, especially in the surficial zones, permitting some water seepage. The chances for successful wells in these rocks is about the same as for granites.

Summary

In all rocks, however, due to overlying load, the openings tend to become tighter in depth. In granites the water is often derived from one major fracture or joint. In slates the water does not so commonly come from one principal vein, but is derived from a multitude of smaller openings. In slate and schist wells, less than 100 feet deep, the expected yield is from 1 to 5 gallons per minute, the larger yield is not unusual. In this type of rock, expected yield is increased to between 10 and 50 gallons per minute with depths from 100 to 300 feet. In other words, in slates and schists the yield is ordinarily increased with depth. Where such rocks have been subjected to unusually severe conditions of metamorphism, however, they more nearly resemble the granites and gneisses in their water yielding properties.

Superstitions about ground water are still in the minds of many people. One of the better known of these fanciful delusions is the action of a forked stick in the hands of a "diviner." It is thought by many that some people either are endowed with a special sensitivity or have acquired a certain skill in the use of a divining rod which enables them to locate underground water. The practice of crotched-stick prospecting is variously called *dowsing*, *water-witching*, or *divining.* Many well sites have been located by diviners; consequently many people have implicit faith in the method. The widespread occurrence of ground water accounts for the successes that have been credited to dowsing rather than any special gift or skill on the part of the dowser. In humid regions the chances for a moderately successful well are about nine out of ten wherever the well is put down. With these odds in his favor, a dowser's reputation depends largely on an uninhibited performance with the groaning, wrything, twisting rod. In justice to some, however, it should be said that not all water witches are fakers. Some (self-hypnotized?) undoubtedly believe sincerely in their powers; others craftily practice the art.

THE DESERT OF MAINE, FREEPORT, MAINE

By JOSEPH M. TREFETHEN

Just south of Freeport village and just west of U. S. Route One, lies the widely advertised and much visited "Desert of Maine." In a humid region, where vegetation covers most of the soil, drifting sand is not seen at many places. And where it is seen, giving a desert-like appearance to the landscape, the dunes and drifting sand attract both interest and speculation as to an explanation.

About thirty thousand years ago, Maine was covered by an ice sheet that buried Mount Katahdin, and extended seaward beyond the limits of the present coastline. In the course of its forward advance this ice sheet plowed up the old soil over which it pushed, and ground up millions of tons of rock, producing gravel, sand, silt, and clay sized fragments. The climate finally warmed up enough so that the ice sheet gradually melted away, and as it did so the sea advanced over a part of the land formerly weighted down by the ice. Into this sea, or possibly into a huge ice bound lake within the ice, were washed large amounts of gravel, sand, and silt which were spread as a fairly even cover over the sea or lake bottom. Such a deposit of stratified gravel, and sand washed out of the ice by its melt waters is called an *outwash plain*, or more simply, a *wash plain*. The wash plain of the Topsham-Brunswick-Freeport-Bath area is an extensive one. The famous "Bowdoin Pines" just east of Brunswick grow on this plain, and it takes little imagination when driving over this level surface to picture it water covered as it once was.

Where the deposits of sand are fine enough to be wind drifted, and where the vegetation has been stripped away as it was in the Freeport area perhaps as a result of injudicious land use or overgrazing, wind currents drift the sand.

Such is the origin of the "Desert of Maine." Different layers of the sand have different permeabilities, and the rain water that soaks down through the sand has caused various degrees of oxidation of iron compounds so that strata of sand are variegated—some pink, some red, some brown, with various intermediate shades.

The drifting sand has encroached over land and buildings in its path, and is at present advancing against a wooded area to the east. The advance is marked by trees killed by sand burial. Vegetation is

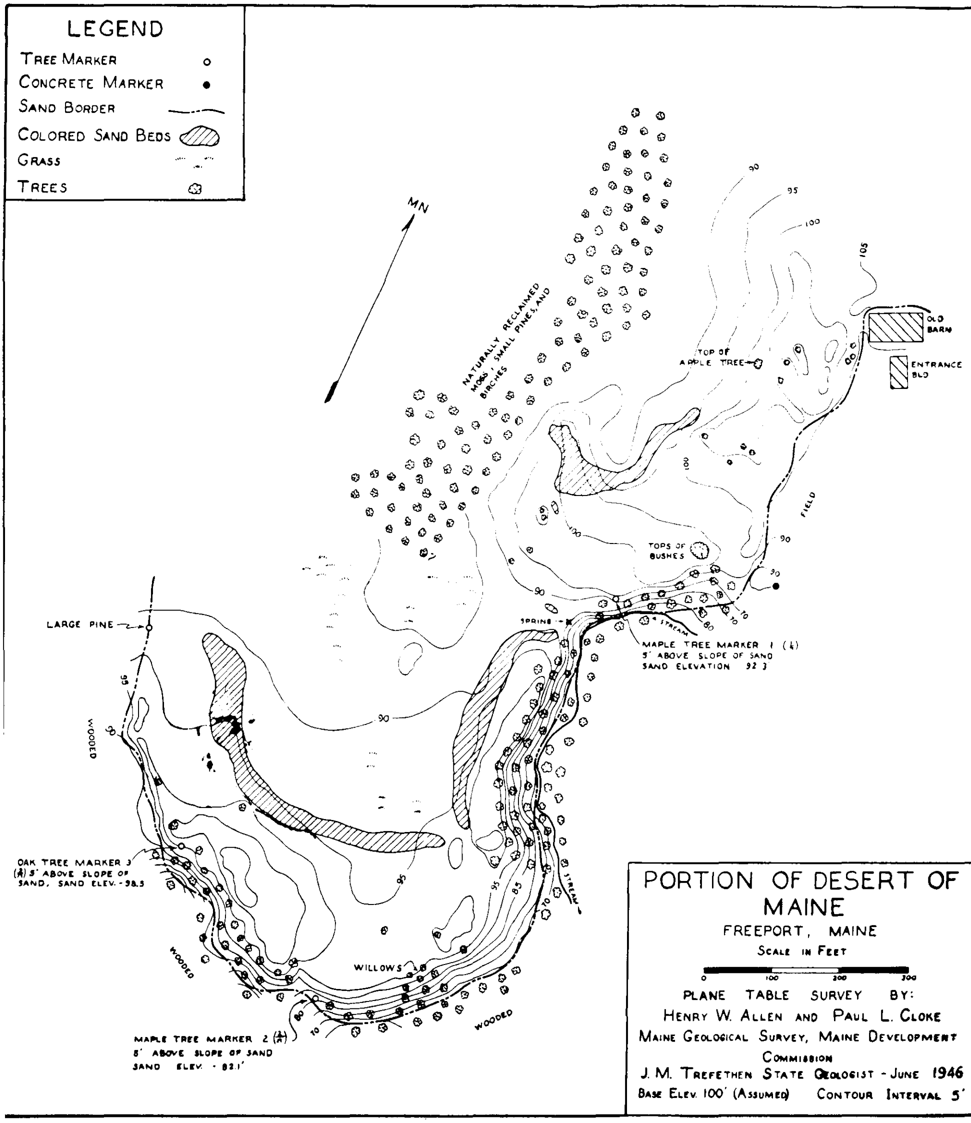

LEGEND
TREE MARKER
CONCRETE MARKER
SAND BORDER
COLORED SAND BEDS
GRASS
TREES
MN
NATURALLY RECLAIMED MOSS, SMALL PINES, AND BIRCHES
TOP OF APPLE TREE
OLD BARN
ENTRANCE BLD
FIELD
TOPS OF BUSHES
SPRING
STREAM
MAPLE TREE MARKER 1 (A) 5' ABOVE SLOPE OF SAND SAND ELEVATION 92.3
LARGE PINE
WOODED
OAK TREE MARKER 3 (A) 5' ABOVE SLOPE OF SAND, SAND ELEV. - 98.5
WILLOWS
MAPLE TREE MARKER 2 (A) 5' ABOVE SLOPE OF SAND SAND ELEV. - 82.1'
PORTION OF DESERT OF MAINE
FREEPORT, MAINE
SCALE IN FEET
0 100 200 300
PLANE TABLE SURVEY BY:
HENRY W. ALLEN AND PAUL L. CLOKE
MAINE GEOLOGICAL SURVEY, MAINE DEVELOPMENT COMMISSION
J. M. TREFETHEN STATE GEOLOGIST - JUNE 1946
BASE ELEV. 100' (ASSUMED) CONTOUR INTERVAL 5'

Figure 1

reestablishing itself, however, so that not only is the "desert" gaining ground, but also it is losing it. It is unlikely that the desert will spread much beyond its present limits.

Because of the interest in this dune area, the Maine Geological Survey has mapped a portion of it (Fig. 1), and will remap the same area at intervals of several years. In this way, over a period of time, a measure of the effectiveness of wind action in this region will be established, and the changes due to wind erosion and wind deposition can be evaluated.

Other somewhat similar "deserts" are found elsewhere in Maine, although less well known. The Leeds "desert", the sand area near the Sandy River in the New Sharon-Farmington Falls region, and the Winslow "desert" are examples.

A RECONNAISSANCE SURVEY OF LIMESTONES* IN FRANKLIN COUNTY, MAINE

E. S. PRATT and H. W. ALLEN

During the summer of 1947 a reconnaissance survey of Franklin County was made for limestone by Elbert Pratt and Henry Allen. This reconnaissance covered nearly the whole county south of Rangeley. There are many localities where limestone can be found, but practically all of it is a low-carbonate lime-silicate gneiss. Locally, in small areas, the calcium carbonate content increases to as much as sixty per cent, a proportion still too low to be of commercial value.

Stratigraphy

The stratigraphic succession proposed as a result of the field work is tentative; much detailed work must be done before a definitive classification can be established. It is the established policy of the Maine Geological Survey to avoid giving formational names to stratigraphic units until enough detailed work has been done to delimit the units closely, and to establish definitely the sequences. The units described in the following section, therefore, are lithologic units, which may or may not subsequently be given formational rank. The oldest rock of the region is the *Rangeley conglomerate.*[1] This is overlain by a staurolite schist of variable composition. In some layers, the staurolite occurs throughout, more or less evenly distributed; it also occurs localized in thin beds which alternate with quartzitic beds in which there is no staurolite. Also, within this unit, are beds of muscovite-biotite schist. Throughout this formation are found beds of lime-silicate gneiss. The most extensive and thickest lime-silicate member lies near the base of the staurolite schist while younger lime-silicate members probably are less extensive.

Overlying the staurolite-lime-silicate beds, there is a dark fine-grained phyllite which in places becomes micaceous quartzite and is heavily iron-stained. There is much iron sulfide in this unit, deposited along the cleavage planes, and also disseminated through the rock.

*This is the second of the county surveys for limestone. The results of the limestone survey of Aroostook County were published in the "Report of the State Geologist, 1946-47."

[1]Smith, E. S. C. "The Rangeley Conglomerate." Amer. Jour. Sci., V. 1933, pp. 147-154.

Overlying the rusty phyllite is more phyllite, unstained, and apparently more lime-silicate gneiss. These beds lie in the flat country north of Farmington in the Kingfield area, where because of heavy drift cover, mapping is difficult.

Staurolite-Bearing Unit

The first unit considered is predominantly staurolite schist with some muscovite, biotite schist and lime-silicate gneiss members.

Staurolite Member

The Staurolite schists are light to dark gray in color with beds from one inch to one foot thick; the majority are from two to four inches thick.

That part of the schist containing the staurolite commonly has much biotite mica; locally it also has garnet and muscovite. The staurolite crystals themselves vary from very small to one and a half inches in length.

More massive beds, with staurolite distributed more or less evenly throughout, represent the original silty, fine-grained sediments.

Locally within this unit, there are also staurolite beds interbedded with quartzitic, granular beds.

Lime Silicate Gneiss

The lime silicate gneiss beds which are interstratified with the staurolite schists are light to dark greenish in color, bedded one to three inches thick, and are fine to medium textured. They are composed of a light matrix of quartzitic material through which are dispersed green lime silicates, diopside and hornblende.

Iron Sulfide-Bearing Unit

Pyrite-bearing phyllite overlies the staurolite schist. This unit is brownish red on weathered surface and hence is easily distinguished from the schist. The phyllite itself is dark gray to black in color, fine textured, with well developed cleavage. Along the cleavage planes are flat plates of sulfide which range in size from fine flakes to veins as thick as a finger that extend many feet in length. Just north of Madrid this unit is well exposed along the roadside. Here the rock is a phyllitic micaceous quartzite with pyrite disseminated through the rock, as well as along the cleavages. There is a question as to whether the sulfide is of primary or secondary origin in the rock. Over widely separated areas in the phyllite, the sulfide varies in amount; at some places there is much, elsewhere there is very little. Also the regional study of the county indicates that there may be places where this phyllite grades into an entirely different appearing type of rock. This is a necessary assumption if the pyritiferrous phyllite of the Rumford, Byron, Madrid region is to be connected with that in the Strong, Farmington area. These similar formations, however, may represent two different periods of deposition.

One approach to this problem of correlation is through an understanding of the deposition of the sediment and of the origin of the pyrite. The rock is fine-grained, dark, and shaly, a deposit of quiet waters. If the pyrite is syngenetic, stagnant water is suggested with possible accumulation of hydrogen sulfide-forming bacteria. These deposits with a change of facies, could be continuous with formations deposited under conditions not favorable to the formation of hydrogen sulfide.

In New Sharon and Temple, there is found a fine-textured, shaly formation which is pitted with little rust spots, which may be continuous with the pyrrhotite shale. Also, between Rumford and Dixfield there is a much weathered iron-stained, rather crumbly, muscovite biotite schist which extends northward toward Phillips. It is a thick formation and may be the equivalent of the sulfide bearing shale and connect with the Byron and Madrid pyrite-bearing phyllites and micaceous quartzites with the sulfide-bearing beds of Strong and Farmington.

Upper Staurolite Formation

Overlying the pyritiferrous phyllites, as seen at Phillips, there is a repetition of the staurolite schist lime-silicate gneiss series found beneath the shale. Here, however, there seem to be more of the lime silicate members and fewer of the staurolite members.

Structure

The structure is complex, and the interpretation offered here is admittedly oversimplified and tentative, based on regional distribution of the lithologic units (see Map I). Formational boundaries have been only approximately established. Furthermore, certain of the smaller lithologic have been grouped with the larger ones, though they are distinctive. Detailed areal mapping was beyond the scope of this survey.

The axes of folding strike northeast and plunge in the same direction. The structure, beginning at the west with the Rangeley Conglomerate, appears to be the west limb of a fold whose axis passes in a northeasterly direction through Phillips. This fold seems to be best demonstrated by the topography of the region and also by the fact that a lime-silicate gneiss passing southwestward across Route 4 between Phillips and Madrid appears to follow the contours around the axis and proceed in a northeasterly direction just north of Pope Mountain.

East of Phillips there appears an anticlinal axis in the region of Strong and a synclinal axis just northwest of Farmington. This fold can be traced in the pyrite bearing beds in the Strong-Farmington area and is reflected further to the south in Wilton and Jay.

East of Farmington there is another anticlinal axis in the Chesterville area quite well defined by the lime-silicate gneisses there.

Correlations over large portions of this area are sketchy, but the fundamental structure as outlined seems to be consistent with the information at hand.

Limestone Localities in Franklin County

The limestones of Franklin County found on this survey are all in the form of lime-silicate gneisses. Some have no calcite but most of them carry varying amounts of that mineral. However, it is apparent that all are of low lime-carbonate content; that is, none discovered contain more than 60% calcium-carbonate.

I. The first location is in the Swift River Valley near the town of Houghton. On a stream, Mountain Brook, there is seen a lime-silicate gneiss formation 400 to 500 feet thick. The lime-carbonate content is low. This location is not of economic interest.

II. A second location, which may correlate stratigraphically with the Mountain Brook lime-silicate gneiss is the Livermore Falls lime-silicate. Here, in the Androscoggin River, can be seen a continuous section of lime-silicate gneiss about 1,000 feet thick.

In the Livermore Falls area a measured section shows an eastern lime-silicate gneiss bed about 1,500 feet thick. This is followed by a granite-intruded schist series about 450 feet thick, followed in turn by 250 feet of lime-silicate gneiss, then 400 feet of schist, followed by 1,350 feet of lime-silicate gneiss, next, possibly 100 feet of schist, 450 feet of lime-silicate gneiss, 200 feet of schist, and 400 feet of lime-silicate gneiss. This gives a total thickness of about 3,950 feet of lime-silicate gneiss interspersed with some schists. It is difficult to establish repetition by folding in this section, but some indication is given by the convergence of contact lines in places.

This lime-silicate bearing unit, as a whole, extends well up into Chesterville, probably as far north as North Chesterville before swinging around the nose of the anticline to the east.

The lime content of these rocks where seen is low, less than 50% lime-carbonate, and at no place was found to be of economic grade.

III. Traveling northwesterly across the strike into the town of Jay, several lime-silicate beds are crossed. They are seen only in isolated outcrops and were not broad enough or marked enough to be traced any great distance. They are generally quite massive. Exposures are found on the road one mile north of Macomber Hill school, North Jay, and also one and a half miles southeast of Macomber Hill school toward Stones Corner and Route 133.

Also in the town of Wilton at McCrillis Corner, incorrectly labeled McQuillis Corner on the quadrangle map, on Route 133, can be found more lime-silicate of the same quality. None of these beds are of economic grade.

At Wilton village, a very crumbly, deeply weathered lime-silicate gneiss is found at the northwest end of Wilson Lake, apparently striking into the lake, so that the shape and position of the lake basin may have a lithologic control.

IV. In the town of Dixfield, southwest of Wilton, several lime-silicate gneiss beds were discovered. The first outcrop lies one mile east of East Dixfield on Route 17 to North Jay. It is so deeply weathered and crumbled that it appears in the road cut as a sand bank.

Two miles west of East Dixfield is a lime-silicate gneiss which may be seen on Bob Gould Hill and can be traced southwesterly through Dixfield Center to the Androscoggin River.

The last lime-silicate gneiss located in the Dixfield area is on the southern tip of Bald Mountain and appears to run northward to Hildreth's Mills, Perkins Plantation, on the road between Wilton and Weld.

To the west of this mountain is a great valley with practically no outcrops which extends northward from Dixfield through Carthage, Weld, and Phillips to Mount Abram, and beyond into Kingfield.

V. In the Farmington area is a very impure lime-silicate gneiss, showing little green color, but having some calcite veins which occurs in a roadcut one mile south of West Farmington on Route 4.

VI. All the lime-silicate gneisses so far discussed are considered to lie in what has been termed the staurolite schist unit and to be interbedded with it. Thus they are lower in the stratigraphic column than the rusty pyritic phyllites. These sulfide bearing phyllites may be seen at West Farmington on the road to Temple and on Route 4 between Farmington and Strong. Extensions of these phyllites somewhat more schistose, as discussed previously, may be seen in Temple village and on the back road between New Sharon and Industry to the north, and in Anson, northeast of Farmington. To the west are the typical exposures seen west of Madrid.

The lime-silicate gneisses and limy shales that follow, found in Farmington and Phillips, are considered to be higher in the stratigraphic column than the sulfide bearing phyllite. In the Farmington area, gray limy shales and phyllites are found at Fairbanks and Temple. These are near the Sandy River bridge, east side at Fairbanks and at the Farmington-Temple town line on the road between Farmington and Temple.

VII. In Strong and Phillips are other lime-silicate beds of significance. A small outcrop of lime-silicate gneiss is found two miles northwest of Strong on the Phillips road following the north shore of Sandy River. This outcrop may be important in that it may lie under the pyritic phyllite and thus may be a northern extension of the Bald Mountain, Hildreth's Mills lime-silicate found in Carthage and Perkins Plantation. This is topographically possible since the mountain range between these points is continuous.

At Phillips the most important lime-silicate gneiss is found on Whitney Hill, just north of the village. In some places this rock is a marble, white and blue banded and very massive. Jackson determined that formation to be about 60% calcium carbonate. The bed is 40 feet thick with a second bed 20 feet thick just to the south of it. Although this rock does not meet current government standards, a low grade agricultural lime could be produced from it.

Extensive, though very low grade, lime-silicates are found on Route 4 between Phillips and Madrid and in the Sandy River to the north of this road. They are characterized by a massive appearance, some greenish color and may or may not carry calcite.

A study of the topographic map of the Phillips Quadrangle shows a very definite synclinal structure northeast and southwest of Phillips village. The one to the northeast is composed of Whitney Hill and Tory Hill. The one to the southwest can be seen between Winship School and Blueberry Mountain. The lime-silicate gneiss found on Route 4 between Madrid and Phillips may swing down around this syncline at Blueberry Hill and proceed northeast just north of Pope Mountain. Lime-silicate gneiss formation was discovered on the farm of Guy Stevens one mile east of Winship School on county road.

Summary

To summarize this work, four lithologic units are recognized: the Rangeley Conglomerate; a lower staurolite formation containing lime-silicate gneiss; a sulfide-bearing unit, phyllite and micaceous quartzite; and an upper staurolite formation also containing lime-silicate gneiss.

The pyrite-bearing unit may be composed of several facies depending upon varied environments of deposition.

The lime-silicate gneisses are extensive and locally have considerable thickness, but all appear to be so impure as to make them worthless commercially.

PRELIMINARY REPORT ON ASBESTOS AND ASSOCIATED ROCKS OF NORTHWESTERN MAINE

By LAWRENCE A. WING and ARTHUR S. DAWSON

Introduction

Occurrences of asbestos have been reported in the past from several sections of the state. As a result of these reports, the Maine Geological Survey has maintained a field party in the counties of Oxford, Franklin, and Somerset for the summers of 1947 and 1948.

The field parties were under the direction of Dr. Joseph M. Trefethen, state geologist, and consisted of Lawrence A. Wing of the Maine Geological Survey and Arthur S. Dawson, geologist for the Canadian Pacific Railway Company. Robert M. Chase acted as field assistant for the season of 1947 and Raymond Woodman, Jr. for the season of 1948. Final drafting of the maps was done by Carton P. Wing.

The purpose of the investigations was to check the earlier reports and to evaluate the occurrences of asbestos. For the areas investigated this purpose was accomplished by pace and compass mapping of a reconnaissance nature. Detailed maps were made in the more promising localities.

Location

The region lies generally in the western part of the State of Maine and close to the international boundary. Work was carried out in three separate areas in the northern parts of Oxford and Franklin Counties and in the central part of Somerset County. These areas are shown on the key map in Figure 1.

The three areas have been named after the most prominent topographic feature or regional name and are hereafter referred to as the *Parmachenee Area*, *Jim Pond Area*, and *Spencer Area*. In as much as the areas have been mapped separately, they are discussed as individual units in the same order as given above.

THE PARMACHENEE AREA

A small area on the Maine-Quebec boundary was mapped in July, 1947. The field party consisted of the authors assisted by Robert M. Chase.

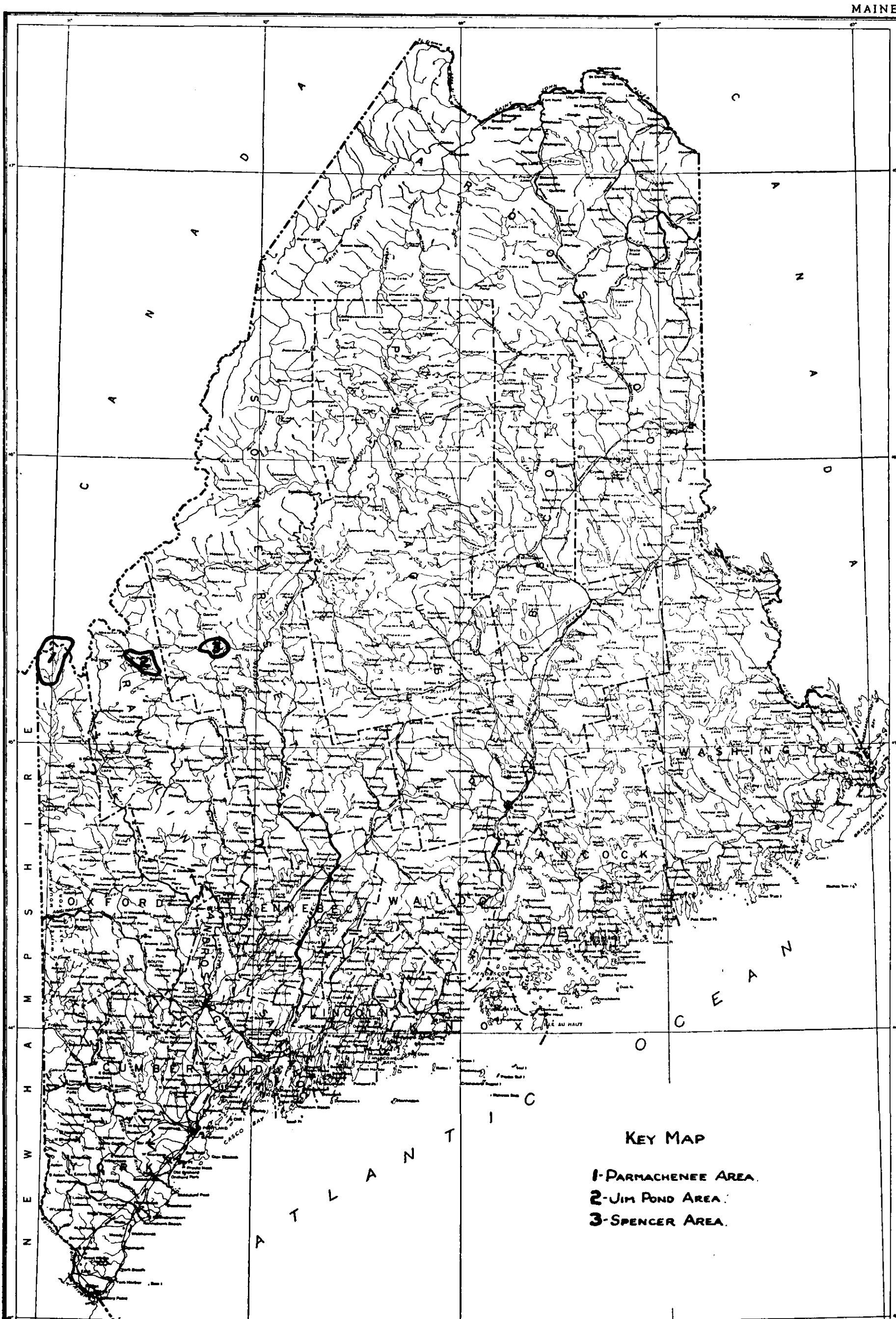

MAINE
CANADA
NEW HAMPSHIRE
OXFORD
KENNEBEC
WALDO
LINCOLN
CUMBERLAND
YORK
WASHINGTON
ATLANTIC OCEAN
KEY MAP
1-PARMACHENEE AREA
2-JIM POND AREA
3-SPENCER AREA

Figure 1

The main purpose of the mapping was to examine a belt of volcanic rock for its economic possibilities, particularly because of the suspected presence of ultra-basic rocks favorable to the occurrence of asbestos. The mapping was by pace and compass and of a reconnaissance nature. (See Map II.)

Location and Access

The area lies to the east of the extreme northern part of the Maine-New Hampshire boundary and extends northward into Quebec for about three miles. It includes all of the township of Bowman and the northern part of Parmachenee, both in Oxford County, Maine, and parts of Chesham and Woburn Townships, Frontenac County, Quebec.

The area, in Quebec, is served in part by secondary roads. On the Maine side, travel must be on foot or by pack mule or saddle horse. A long established but now little used road, known as the Magalloway Road, traverses the map area from south to north. It starts near Parmachenee Lake and connects with a secondary road in Quebec about thirteen miles to the north. The northern part of the road and its several branches to the east have been brushed out in recent years for use in logging operations from the Quebec side of the boundary.

General Character of the Area

The area is generally mountainous, becoming hilly to rolling in the Quebec section. The mountains form a part of the Appalachian Piedmont and are known in Maine as the Boundary Mountains. The highest peaks along the boundary itself are the adjacent Saddle Hill (elev. 3192) and Marble Mountain (over 3000). A cliff on the southern flank of the latter is the most conspicuous topographic feature of the area; it rises more than 700 feet and is over one-half mile in length. Highest of all is Rump Mountain (elev. 3647) at the southwestern corner of the mapped area. Nine miles to the northeast of Rump Mountain is steep-faced Twin Peaks (elev. 3010).

Because the International Boundary here follows the height-of-land separating the St. Lawrence drainage basin from the region draining directly to the Atlantic, there are no large streams, although small ones are numerous. The southern section is drained by a tributary of the Androscoggin, the Magalloway River, which is fed by three principal branches rising close to the boundary. In Quebec, the principal streams are branches of Salmon River on the west and of Arnold River on the east, tributaries to the St. Francis River and Chaudière River respectively. None of the streams within the area are navigable for any appreciable distance by canoe. There are few lakes and these are all less than one-half mile in length.

The area is well wooded except for sections in Quebec which have been cleared for farming by a small and scattered population. Timber is the valuable resource and lumbering the principal occupation. That part of the area lying in Maine has no permanent population but is the scene of seasonal woodcutting and occasional visits by fishermen and hunters.

Previous Work

The belt of volcanic rock was indicated by Arthur Keith[1] in his Preliminary Geologic Map of Maine published in 1933.

In Quebec, the earliest work, and the only previous work east of longitude 71 degrees, was by R. W. Ells[2] in 1886. The section west of longitude 71 formed a part of the Mount Megantic Area mapped by H. W. McGerrigle[3] in 1934. The Megantic Sheet (West Half), mapped by C. S. Lord[4] in 1935, lies eight miles to the north of the area covered by this report. Harvie[5] has reported on the Quebec side of the boundary in a publication by the Canadian Department of Mines.

The closest work in detail on the United States side of the boundary is that of Billings[6] and associates about forty miles to the southeast in New Hampshire.

General Geology

The sedimentary and volcanic rocks that underlie nearly all of the area were assigned to the Precambrian by Ells[1]. Keith[1] has shown the sediments to the west of the volcanic belt as Ordovician and Cambrian and the volcanics and sediments to the east as mainly Silurian.

[1]Published by the Maine Geological Survey, Orono, Maine.

[2]Ells, R. W.: "Report on the Geology of a Portion of the Eastern Townships of Quebec"; Geol. Sur. Can., Ann. Report, 1886, Vol. 2, Part J, with map.

[3]McGerrigle, H. W.: "Mount Megantic Area, Southeastern Quebec"; Quebec Bur. of Mines, Ann. Report, 1934, Part D, with map.

[4]Map 379A, Megantic Sheet (West Half); Can. Dept. of Mines and Resources, Bur. of Geol. and Top., issued 1938 (Ottawa).

[5]Harvie, R.: "Asbestos Deposits of the Province of Quebec," Guidebook Number 2, Excursion A9, Can. Dept. of Mines.

[6]Billings, M. P.: "Structure and Metamorphism in the Mount Washington Area, New Hampshire"; Bull. of the Geol. Soc. of Amer., Vol. 52, pp. 863-936.
Williams, C. P. and Billings, M. P.: "Petrology and Structure of the Franconia Quadrangle, New Hampshire"; Bull. of the Geol. Soc. of Amer., Vol. 49, pp. 1011-1044, 1938.

McGerrigle[1] groups the bulk of both sediments and volcanics with the Frontenac Volcanics of early or Pre-Ordovician age, including however down-folded remnants of the Compton Sediments of Ordovician age. Identical rocks a few miles to the north form a part of Lord's[1] Frontenac Series (Ordovician or Cambrian) which includes both sedimentary and volcanic types. Billings[1] Ammonoosuc Volcanics (Ordovician?) differ lithologically from the volcanics of the Parmachenee Area but may be correlatives. Lithologically and structurally the interpretation by Lord[1] ties in best with the recent mapping and is adopted for this report with the reservation that a Precambrian age for at least some of these rocks has not been disproved.

The classification of lithological units adopted as a result of this study is shown in Table I.

TABLE I

Table of Formations in the Parmachenee Area

Cenozoic	Recent		Alluvial deposits: gravel, silt, sand, clay.
	Pleistocene		Glacial deposits: boulders, gravel, sand, silt, clay.
Great Unconformity			
Paleozoic	Late or Post Devonian		Alkaline intrusives: Granite, Diorite.
	Intrusive Contact		
	Ordovician or Earlier	Frontenac Series	Sediments: Mica schist and gneiss, staurolite schist, slate, quartzite, cherty and tuffaceous sediments.
			Volcanics: greenstone, Chlorite schist.

Description of Formations

The sediments and volcanics are believed to be of the same general age as shown by the interbedding along the borders or geological boundaries; both have been mapped and described on a basis of rock type. As the work was done principally on an economic basis, further separation of the sediments is neither justified or necessary at the present time.

[1] Op. cit.

Volcanics

One large belt of volcanic rocks was encountered, which trends in a general northeasterly direction across the area. Its greatest width is at the New Hampshire boundary where the belt is over five miles wide; it tapers to a little over a mile in width at the northern limit of the area mapped. The northwestern contact passes through Marble Mountain.

The predominant rock type is that commonly referred to as greenstone; a fine-textured, often massive, dark green rock in which well defined pillows and banded flow structure can be seen at a few places. Small, irregular masses or knots of epidote occur in many places. Flow tops can be seen at some exposures and they are commonly characterized by irregular bands of light to dark green or brown cherty rock. Along zones of movement, the rock is locally sheared to a highly fissile chlorite schist.

Microscopic examination shows the rock to be highly altered. Zoisite, epidote, and carbonate are abundant constituents. The principal ferromagnesian minerals are hornblende, chlorite, and pyroxene. Some sections show serpentine. Quartz, biotite, olivine, magnetite, ilmenite, and titanite are common accessory minerals. A thin section of the rock from the international boundary, close to the southeast border of the belt, shows zeolite amygdules of microscopic size.

The volcanic rocks seem to have ranged originally from andesite to olivine-basalt in composition.

Sediments

The greater part of the area is underlain by sedimentary rocks which lie on both sides of the volcanic belt. Slates and quartzites are the predominant rock types, but there are minor amounts of cherty and tuffaceous sediments. The slates and quartzites are interbedded and were not mapped separately; in general, quartzite is more widespread in the northwestern than in the southeastern part of the map, whereas slate is abundant in both sections. Some of the slates of the southeastern section are distinctly limy.

Typical slates are light to dark grey with very well developed cleavage. Those examined are too soft to be of industrial use. In a few places along the Magalloway River, the cleavage is strongly crenulated, indicating subsequent deformation.

Microscopic examination shows a typical slate composition of quartz and micaceous minerals in an extremely fine-grained banded aggregate. One-half mile east of the junction of the McKie Fork and the Second East Branch of the Magalloway River, a limy slate is encountered which contains bands rich in calcite.

Along the West Branch of the Magalloway River, about one-half mile northwest of an outcrop of crenulated slate, the slate is altered to phyllite, a green, chloritic rock with a greasy feel and a schistose rather than a slaty structure. This rock, in thin section, is seen to consist of a very fine-grained, banded mixture of quartz, calcite, kaolin, chlorite, and other micas.

Typical quartzite, such as that seen at the north end of the Magolloway Road, is a dark grey, thick-bedded rock that weathers to light grey. In places it is thinly interbedded with slate. Fracture planes sparkle with tiny flakes of mica. Micropsopic examination shows the rock to be ninety to ninety-five per cent fine grained quartz. Biotite is the other principal constituent, with small amounts of magnetite, carbonate, apatite, and zircon present.

An outcrop near Gold Brook is brownish-grey, weathering light-grey to pinkish, arkose. This rock is a mixture of quartz, orthoclase, plaigioclase, and hornblende, with other minerals present in small amounts.

Chert was encountered near the west end of a small pond about one-half mile southwest of the cliff on Marble Mountain. It is faintly banded material of various shades of green. Mica is developed along fracture planes and the rock is cut by tiny veinlets of calcite. Light grey, schistose, tuffaceous material is interbedded with it.

Highly Metamorphic Types

Strongly metamorphosed rocks, of probable sedimentary origin, were encountered near the eastern margin of the map-sheet at its northern and southern extremities. They represent either a distinct series, possibly Precambrian, or a metamorphic phase of the Frontenac Series. The latter interpretation is favored by the writers, believing the rock to be a contact aureole about a large granite mass lying a short distance to the east of the region mapped. The degree of metamorphism diminishes westward from the contact. The following rock types were noted in going westward from the granite: mica schist and gneiss, slaty staurolite schist, micaceous slate or phyllite, normal slate of the Frontenac Series.

The mica gneisses are dark weathering rocks whose gneissic structure is due to parallel-oriented, and usually coarse, flakes of mica in a groundmass consisting largely of quartz with appreciable amounts of feldspar. The strongly foliated mica schists contain a much larger percentage of mica. The staurolite schist is a dark grey rock with a distinct slaty structure. The staurolite crystals are up to one-quarter inch in length and for the most part lie parallel to cleavage planes.

Intrusive Rocks

The largest single mass of intrusive rock lies a little over two miles south of Notre Dame des Bois, Quebec. Here outcrops are numerous in an area more than two miles long (east to west) and over one mile wide (north to south). The shape and attitude of the intrusive mass were not determined, and its contacts are mapped as approximate.

The rock commonly weathers brown. It is green on the fresh surface, showing pyroxene crystals about one-sixteenth inch in size in a lighter green groundmass. Microscopic examination shows the pyroxene to be aegirine and diopside, both partly altered to chlorite. The aegirine is in masses of parallel needles. The other essential minerals are orthoclase and nepheline, and in minor amount, labradorite and quartz. Accessory minerals are: serpentine, calcite, titanite, ilmenite, pyrrhotite, and zircon. The rock is alkaline, similar in type to those of the Monteregian suite classified as tinguaite. Pleochroic halos about tiny zircon crystals enclosed in pyroxene are immature, similar to those of the Monteregian rocks described by McGerrigle[1] as evidence of the post-Devonian or possibly post-Paleozoic age of these rocks.

The cliff on Marble Mountain is cut by a complex of dikes of granitic to dioritic composition. Similar dikes are exposed along the boundary to the south of this point. These rocks are probably related to the widespread granite of Devonian age.

Outcrops of basic rock were encountered along the Magalloway Road approximately one mile northwest of the crossing of the Magalloway River. This is a dark green serpentinous material in which lath-shaped plagioclase crystals up to one-eighth inch long glisten. The rock consists of diopside, serpentine, orthoclase, calcic plagioclase, magnetite to the amount of five per cent, and pyrite. The first formed magnetites have been greatly resorbed.

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[1] Op. cit.

The rock has a granitoid, ophitic texture and is much fresher than the volcanic rocks studied. It is probably intrusive, but no conclusive evidence of its origin was seen in the field.

Pleistocene and Recent Deposits

The whole area, including the highest ridges, has been glaciated. Glacial till mantles most of the area to the extent that bedrock outcrops are in large part confined to the ridgelines, steep faces, and occasionally in brook beds. A few small kames were noted.

Recent alluvial deposits are minor in amount and are confined to sections, away from the height of land, where the gradient of the valleys is gentle. For a few miles above Rump Pond, the Magalloway River meanders through a narrow, silty flood plain.

Structural Geology

Bedding is usually difficult to distinguish in the closely folded and altered sedimentary and volcanic rocks. Observed strikes vary from north twenty-five to forty-five degrees east. Dips are mostly steep and at places the beds are overturned. Strikes of cleavage and schistosity also lie in the northeast quadrant, with variable but usually steep dips.

The only clear indications of the local structure were found in the southeast margin of the volcanics and still further to the southeast in the slates.

Flow tops were distinguished at two places between Rump Mountain and Ledge Ridge. One example shows the flow top marked with an eight inch band of chert, often occurring as pods at the junction of two pillow tops. The top apparently faces the southeast and the beds are overturned.

At the southeast part of the area, bedding could be distinguished in the slates. Its northeasterly strike is close to that of the cleavage and its dip somewhat steeper (bedding strikes twenty-five degrees east of north and dips eighty degrees west, cleavage strikes thirty-five degrees east of north and dips sixty-five degrees west.) This relationship indicates that the beds lie on the southeast limb of an anticlinal fold that it overturned.

A logical interpretation of these observations is that the principal structure of the area is a northeasterly trending anticline whose axial region is occupied by the volcanic rocks. Judging by the pattern of the volcanic belt, the anticline probably plunges at a low angle. This is borne out by a computation of the cleavage and bedding relationship which would indicate a plunge of about 28 degrees and the strike of the axis about 20 degrees east of north.

This anticline has been previously mentioned by Harvie[1] although in his text there is no description of the structure or the evidence upon which it is based.

This structural interpretation would place the volcanics as older than the sediments, but because there is some interbedding on the contacts, volcanics and sediments are considered to be a single series.

Zones of intense shearing indicate the probability of faulting in the area. The absence of markers and the scarcity of outcrops make it difficult to determine the direction and extent of movements.

Economic Geology

Placer Gold

Placer gold is known to occur near the northwestern part of the mapped area and has been reported in the southern part. Time did not permit a thorough investigation of placer possibilities. It is believed that any deposits that might occur would be too lean for small scale operations and too small and scattered for large scale operations.

Lode Gold

Quartz veins are not common in the area, although small ones were seen at scattered localities, mostly in the volcanic rocks. Those that showed any promise were sampled but none of the samples showed more than a trace of gold on assay.

Asbestos

A small occurrence of asbestos has been reported by McGerrigle[2] in the basic rock a short distance west of the area. No asbestos was encountered in the mapping of the present area, nor was any body of ultra-basic rock that would warrant prospecting for the mineral. Basic rock from along the Magalloway Road was tested for chromite with negative results.

[1] Op. cit.
[2] Op. cit.

Conclusion

The results of the field work in this area give little hope for economic discoveries. The area does not appear to hold promise for the occurrence of metallic or industrial minerals. The attention of prospectors would be better directed to more favorable areas in both Maine and Quebec.

THE JIM POND AREA

The Jim Pond Area, straddling State Highway Number 4 and lying between the town of Eustis and the International Boundary, was mapped during the month of August, 1947. The field party consisted of L. A. Wing, and R. M. Chase, of the Maine Geological Survey. A. S. Dawson, geologist for the Canadian Pacific Railway Company, was present for the first week of the work.

The main purpose of the mapping was to examine the area for the possible occurrence of asbestos which has been previously reported from several locations within the area. (See Map III.)

Location and Access

The area lies in the northern part of Franklin County and close to the Maine-Quebec boundary. It includes nearly all of Jim Pond Township and parts of the Townships of Chain of Ponds, Kibby, Alder Stream, and Eustis.

Route 4 running northwest-southeast, traverses nearly through the center of the area. Access roads to private camps and lumbering regions are fairly numerous throughout the area, they are generally passable during the summer months but are extremely rough in places.

The town of Eustis lies on the extreme south of the mapped area and the town of Coburn Gore, on the International Boundary, lies about twelve miles to the northwest of the upper limits of the map. Both towns are small and depend primarily on the lumbering operations for a livelihood. The region supports several sporting camps and numerous private camps and is well known for its hunting and fishing.

General Character of the Region

The area mapped is generally mountainous with elevations ranging between 1190 and 2810. Distinctive landmarks or topographic features are not common within the area but are very common a few miles distant in nearly any direction. Distinctive features slightly outside the area were used extensively for location by resection during mapping; some of those used are: Bigelow Mountain (elev. 4150) about 15 miles to the southeast, Crocker Mountain (elev. 4168) and Sugarloaf Mountain (elev. 4237) both about 20 miles to the south, Boil Mountain (nearly 3600) about 10 miles west, and Snow Mountain (elev. 3948) about 8 miles northwest.

The region is drained by a branch of the Kennebec, the North Branch of Dead River, and its tributaries. The river flows to the southeast nearly through the center of the region mapped and parallel to Route 4. The river and short sections of its tributaries are navigable by canoe, but with difficulty during dry seasons. The largest body of water is Jim Pond about one and one-half miles long and one-half mile wide. There are several smaller ponds but all are less than three-fourths of a mile in length.

The region is heavily wooded throughout, although for the most part, past lumbering operations have left little in the way of commercial timber. The river and several of its tributaries are the scene of annual log drives but for the most part the wood comes from regions outside that covered by the present mapping.

Previous Work

The region has been shown on the Preliminary Geologic Map of Maine by Keith.[1] No other published report of the immediate region is known to the authors. The references previously listed describe areas nearest to the region.

The region has been visited from time to time by various prospectors and available information is in the form of hearsay from local residents. In no case was actual proof of asbestos in place furnished although several samples were seen which were said to have come from the region.

General Geology

The sedimentary and volcanic rocks that underlie nearly all of the area have been mapped as Silurian by Keith.[1] He has assigned the mica gneiss and schist, seen on the northern part of the present mapping, to the Precambrian.

The present mapping has turned up no additional evidence bearing on the age of the sediments and volcanics. It is believed that the mica

[1] Op. cit.

gneiss and schist to the north is of the same age as the sediments—the metamorphosed equivalent. This conclusion is similar to that held for the Parmachenee Area where the gneisses and schists of (Ordovican ?) age show a clear gradation in the degree of metamorphism going westward from the granite contact. The same granite lies to the west of the metamorphics in the present mapping. While the gneiss and schist of the present mapping have been called Silurian, a Precambrian age of at least some of these rocks has not been disproved.

The classification of lithological units adopted as a result of this study is shown on Table II.

TABLE II

Table of Formations in the Jim Pond Area

Cenozoic	Recent	Alluvial deposits: gravel, sand, silt, clay.
	Pleistocene	Glacial deposits: Boulders, gravel, sand, silt, clay.
Great Unconformity		
Paleozoic	Late or Post Devonian	Alkaline intrusives: granite, diorite. Extrusives: rhyolite.
	Unconformity	
	Silurian (?)	Sediments: mica schist and gneiss, slates, quartzites, conglomerate, sandstone, impure limestones.
		Volcanics: greenstone, chlorite schist.

Description of Formations

Thin section study on the rocks of this region had not been completed at the time of writing (January, 1949) and the rock descriptions are from megascopic study only. Changes may be desirable after microscopic examinations have been completed. It is improbable, however, that the economic possibilities will be affected by thin section study.

Volcanics

One large belt of volcanic rocks was found in the area. It trends about thirty degrees north of east and is broken by thin strips of slate running through the volcanics. The width of the belt is from two to four miles including the thin strips of sediments.

The predominant rock type is greenstone occurring as a fine textured, generally massive, dark- to light-green rock which at many places shows well defined flow banding and occasional poorly formed pillows. The rock shows variations from a very dark green chloritic schist to a light green, fine-textured rock which shows very little structure. The latter often contains knots of epidote and small veins of epidote intergrown with calcite and chrysotile asbestos. Veins which carry asbestos are rare, although epidote and calcite veins are common. The rock seems to be less deformed and metamorphosed than that of similar type seen in the Parmachenee Area.

Rhyolite occurs as strips within the greenstone and is believed to be of roughly the same age. The best exposures of this rock are found along the southern slopes of Shallow Pond Mountain and Chase Pond Mountain. The western terminus of the body is about one-quarter mile east of the North Branch of Dead River. The eastern extent of the body is unknown but may be cut off by a fault a short distance to the northwest of Jim Pond.

The rhyolite is a very dense almost glassy textured rock which shows small phenocrysts of quartz and less commonly of feldspar. It ranges in color from a dark to light grey.

Sediments

The greater part of the area to the south and east is underlain by sedimentary rocks. One thin strip cuts nearly through the center of the map area and another very small occurrence is found on the southeast slope of Barnard Mountain. Slate and sandstone are the most abundant rock types. Quartzites are common as thin beds within the slate. Thin lens-like bodies of limestone are also found in the slates but are not common except in the area immediately northeast of Jim Pond.

Typical slates are light to dark grey in color and show a well developed slaty cleavage. In a few places reddish colored slates are found interbedded with the light grey, as for example in the bed of Tim Brook about two miles upstrean from Route 4. At this point the brook has cut a deep gorge in the slates so that here are excellent exposures.

The slates which outcrop as thin exposures within the greenstone area often are altered to phyllite and in some places, nearly to schist. They commonly show finely divided biotite and chlorite on the cleavage planes but generally retain the slaty structure.

Quartzites occur as thin beds within the slate and for the purpose of mapping were included as the same formation. They are commonly grey and often show traces of bedding and in some places, well developed fracture cleavage is present.

The sandstone is one of the most distinctive rock types of the region and has been mapped separately in the hope that it might prove to be a definite marker upon which to work out the regional structure. The sandstone is a well cemented rock with coarse grains of quartz up to one-quarter inch in diameter, some of the larger pebbles are a dark quartzite. Most of the quartz grains appear to be of the smoky variety. There apparently has been little deformation of the individual grains.

The trend of the bed is nearly east with a strong bend to the north near the eastern end. The bed tapers out near the foot of Jim Pond to the east but its limit is unknown. Outcrops are numerous on the eastern end and also in the central portion, about one-half mile north of Little Barnard Pond. Intervening contacts are mapped as approximate and are largely controlled by outcrops of greenstone to the north and slates to the south. The bed shows a very consistent width of about one-half mile over its known length.

Small patches of conglomerate are present in the sandstone but are usually only a coarser section of the sandstone itself. Tuffaceous sediments may be present but they have not been identified as such by megascopic examination.

Impure limestones occur in the area adjacent to and northeast of Jim Pond; some of the best exposures are on the shoreline. The limestones range from dark grey coral limestone to grey-white rock with scattered green stains probably due to slight mineralization by sulphides. The limestone occurs as thin beds which are difficult to trace for any appreciable distance. They are probably lens-like in shape.

Highly Metamorphic Types

Strongly metamorphosed rocks, of probable sedimentary origin, are found on the northern part of the mapped area. They have been mapped as a separate rock type but are interpreted here as a metamorphic equivalent of the Silurian sediments to the south, although the Precambrian age assigned to them by Keith[1] has not been disproved.

[1] Op. cit.

The metamorphic rocks consist of mica gneiss and schist. They weather to a very consistent dark grey and show a strong foliation due to parallel orientation of the mica flakes. Quartz is the other most abundant mineral and some feldspar is present.

Quartz veins are common in the gneiss and range from a fraction of an inch up to several feet in width. The veins commonly show some mineralization. An assay on one of the more promising samples however yielded only a trace of gold.

Since mapping, other large veins of quartz have been exposed by recent road cuts. They were visited very briefly in September 1948 and appear to be about the same as those seen at the time of mapping. Disappointing assays have been reported.

Intrusive Rocks

The largest body of intrusive rock lies in the northeastern part of the area mapped and is a fine grained muscovite-biotite granite. Only a small portion of the body lies within the mapped region and its shape and attitude beyond this region is not known.

The large granite mass which lies a short distance west of the gneiss is a coarse biotite granite but is not shown on the accompanying map.

A long thin body of diorite lies on the southern contact of the gneiss. The body is a little less than one-half mile in width and has been mapped for about five miles of its length. Its western terminus was not seen. Outcrops are numerous over its entire length except in the vicinity of Little Alder Stream where it is covered with glacial till.

The rock ranges from a dark, coarse diorite on its northern border to a light, feldspathic rock along its southern side. Great variations are seen in texture from a coarse, blocky appearance due to large crystals of hornblende and feldspar, to a fine-textured rock in which individual minerals are not recognizable. This variation in grain size apparently has no definite pattern and may take place in any part of the body and in a very short distance. Composition also exhibits a wide range. It seems to be a gradation from the dark, more basic rock on the northern side to the lighter, less basic rock of the southern side. If, as probable, the body is in the form of a sill and follows the regional dip, the dark minerals appear to be concentrated at the base of the sill.

In places the rock shows considerable sulfide mineralization and it is this body which is supposed to have been the location of the reported asbestos. Some light smears of slip fiber can be seen in shear zones but no cross fiber was found.

One small outcrop of what appears to be serpentinized basic rock was seen on the lower border of the greenstone about one-quarter mile south of Tea Pond. The rock may be a separate body or a part of the greenstone, outcrops are scarce and a definite relationship could not be established. Some very fine cross fiber is visible in the rock which is primarily serpentine.

Several very small occurrences of granite and diorite were seen in the region and are presumed to be related to the large granite mass to the west and north.

Pleistocene and Recent Deposits

Like the Parmachenee Area, the whole area has been glaciated. Bouldery glacial till mantles most of the area although bedrock outcrops are quite numerous. Several outwash deposits are present but are generally small.

Recent alluvial deposits are minor in amount and are confined to the region immediately adjacent to the river and mostly in the section close to Eustis where the river meanders slightly to form a narrow flood plain.

Occurrence of Asbestos

Asbestos has been reported from the area several times in the past and excellent samples of cross fiber have been seen by the authors. These samples are reported to have come from the body of intrusive rock bordering on the southern side of the gneiss and have been described in the preceding section of this report. Extensive field work in that area failed to uncover any of the asbestos in place and the rock itself is not altered to an extent such that it would seem a good prospect. Serpentine if present at all, is in very small amounts and past experience has shown serpentine has always been present with large occurrences of asbestos.

One small outcrop of serpentinized rock contains tiny veins of cross fiber with lengths of about one-thirty-second of an inch. The amount of fiber is not encouraging and the body appears to be small.

Asbestos has been noted in the greenstone, intergrown with calcite and epidote in small veins. Occurrences of this type are the exception rather than the rule and volume alone seems to rule this type of occurrence out as an economic possibility. The best exposures of this type of fiber are found on the north side of Barnard Mountain near the top, and a short distance to the east of the eastern end of Tea Pond. Single veins may be seen at numerous places in the greenstone.

The region does not appear to hold much promise of asbestos in economic quantities. The small occurrence to the south side of Tea Pond would indicate the possibility that other bodies might exist in the vicinity and prospecting would seem best directed in the areas to the west of the region mapped and around the headwaters of Tim Brook.

Structural Geology

Bedding is usually difficult to distinguish in the closely folded and altered sediments. General strikes of beddings are a little to the north of east and dips are steep in both north and south directions. Clear readings on beddings are generally confined to the thin layers of quartzite within the slate.

Banded flow structure is common in the greenstones and pillow structure can be seen at several locations. The pillows are so deformed that they have not been used for interpretation of structure. Observed folds on Eustis Ridge and the bedding and cleavage relationship in the quartzite show steep pitches to the south and southwest. Interpretation of folding from the pattern of outcrops would indicate an anticlinal fold pitching steeply to the southwest.

According to this interpretation of structure, the greenstone lies directly under the sandstone. Slates and quartzite lie over the sandstone and a thin bed of slate is included in the greenstone. As the dips of bedding are generally steep, the various rock types are shown in nearly their true thicknesses.

Intense shearing may be seen in several outcrops throughout the area and beds appear to be displaced in the vicinity of Jim Pond. Faults have not been inferred on the present map pending further field work to the northwest and east.

Economic Geology

Placer Gold

Placer gold is known to occur in Gold Brook in the northern part of the map and also in Kibby and Spencer Streams a few miles to the northeast. It has also been reported from some of the other streams within the area. Panning was tried in some of the more promising localities with poor results. Nearly all of the streams show considerable magnetite or "black sand" in the concentrates. A pan from Tim Brook near Eustis showed one small grain of gold. It is believed that any placer deposits are too small and lean for successful exploitation.

Lode Gold

Quartz veins are common in the gneiss to the north of the mapped area, and a few are found in the greenstone. The most promising sample seen by the field party was assayed but only a trace of gold was reported.

Asbestos

From the evidence seen in the field, it does not appear that there is much hope for economic recovery of asbestos from this area. All the fiber seen was short and in such small concentrations that present mining methods would not make any operation feasible.

Conclusions

The results of field work give little hope for economic discoveries within the mapped area. Future prospecting for asbestos within the area would be best directed to the west and south of the current mapping. Prospects of placer deposits of gold are not promising but cannot be discounted in the country to the northeast where some small scale operations by panning have been reported to yield day wages.

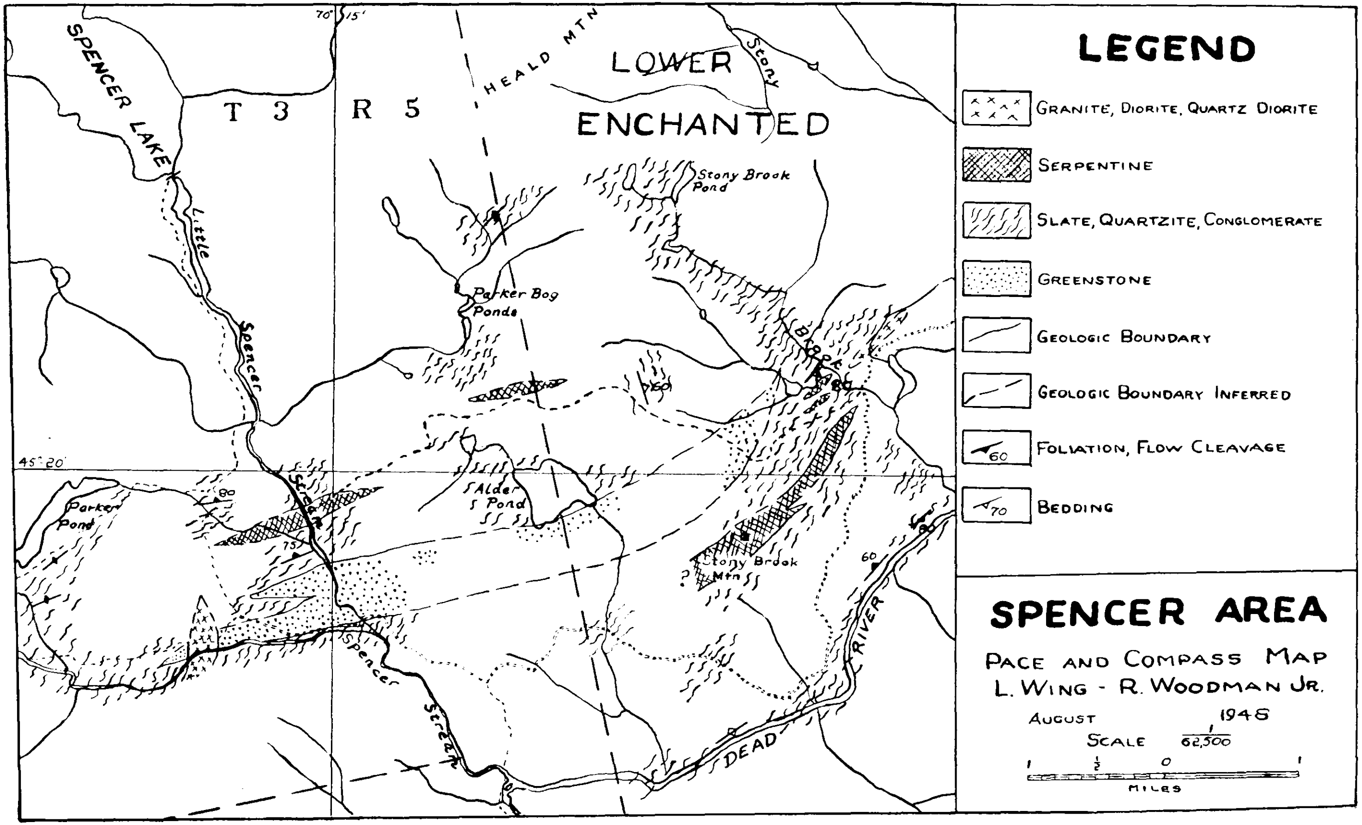
THE SPENCER AREA

This small area located on the eastern side of Little Spencer Stream was mapped during July and August 1948. The field party consisted of the authors, assisted by Raymond Woodman Jr.

The main purpose of the mapping was to make a detailed inspection of a serpentine body on the Little Spencer Stream that was known to carry asbestos. Mapping was also carried out in the surrounding region with the hope of discovering other bodies of serpentine. Mapping was done on a reconnaissance basis for the entire area on the scale of one inch to the mile (see Fig. 2) and detailed maps on the scale of one inch to two hundred feet were made in two of the more promising areas. All mapping was done by pace and compass.

Location and Access

The area lies nearly in the center of Somerset County and straddles the Little Spencer Stream at about three miles below the outlet of Spencer Lake. Mapping covers the eastern part of T3 R5 and the western part of the Township of Lower Enchanted. The map is bor-


LEGEND
Granite, Diorite, Quartz Diorite
Serpentine
Slate, Quartzite, Conglomerate
Greenstone
Geologic Boundary
Geologic Boundary Inferred
Foliation, Flow Cleavage
Bedding
SPENCER AREA
Pace and Compass Map
L. Wing - R. Woodman Jr.
August 1948
Scale 1/62,500
Miles
Spencer Lake
T 3 R 5
Heald Mtn
Lower Enchanted
Stony
Stony Brook Pond
Little Spencer Stream
Parker Bog Ponds
Alder Pond
Parker Pond
Stony Brook Mtn
Spencer Stream
Dead River
70° 15'
45° 20'

dered on the south by the Dead River and on the east by Stony Brook. Parker Pond lies at the western end of the area and Heald Mountain makes up the northern side.

The area is quite remote and served only by trails and tote roeds passable to horses and tractors. The Little Spencer Stream and Daad River are both rapid but can be travelled by canoe. Spencer Lake to the north and Parker Pond to the west have been used for landing of small planes equipped with floats or skis. A good foot trail exists from the foot of Spencer Lake to the largest or best known serpentine occurrence on the stream.

General Character of the Area

This section of the state is generally mountainous but the small area included in the map is comparatively flat with elevations between 900 and 1400 feet. The hills within the map are gentle and many of the flat regions are boggy. The highest mountains are Grannys Cap (elev. 2740) and Heald Mountain (elev. 2421); both lie a few miles to the north of the area mapped.

The area is drained by Little Spencer Stream, Spencer Stream, and the Dead River along with the various tributaries of each. The three streams are all rapid but navigable by canoe. The tributaries are generally small and often partially filled in with undergrowth and bogs. Spencer Lake, about six miles long, is the largest body of water nearby and lies about three miles north of the mapped area. Parker Pond on the western side is about one mile in length. Small ponds are numerous throughout the area but are generally less than one-half mile in length.

The area is completely wooded, chiefly with white birch and poplar. Timber for pulpwood and long lumber has been the only economic product of the region to date with the exception of the furs taken out by trappers. The Spencer Stream and Dead River have been the scenes of annual log drives since the early 1800's and are still used for that purpose.

Previous Work

The belt of greenstone and surrounding sediments is shown on the Preliminary Geological Map of Maine by Keith.[1] An area about forty miles to the northeast, of somewhat similar geology, has been described by Perkins.[1]

The area has been recently prospected by asbestos companies, but information as to the results has not been published to date.

[1] Op. cit.

General Geology

Both the sedimentary rocks and the greenstone that underlie the greater part of the area have been mapped as Silurian by Keith.[2] Perkins[2] has also tentatively placed corresponding sediments to the south of the Moose River Sandstone in the Silurian.

The most widespread is a thick, steeply dipping series of sediments consisting chiefly of interbedded slates, quartzite, conglomerate, and sandstone. Bedding strikes generally slightly north of east with variable but usually steep dips. A few small quartz veins are present but there is little indication of mineralization.

Of equivalent age to the sediments, is a belt of greenstone about one-half mile wide. The trend of the greenstone is parallel to that of the sediments and there is some interbedding with the sediments along the margins.

Numerous dikes and sills of granite and diorite occur throughout the area and they are believed to be related to the nearby granite masses both to the north and south of the mapped area and of probable Devonian age.

Several sill-like bodies of serpentines are found in the area. The locations of the serpentine bodies and the related asbestos are described in a following section of this report.

The classification of lithologic units adopted for this report is shown in Table III.

TABLE III

Table of Formations in the Spencer Area

Cenozoic	Recent	Alluvial deposits: gravel, sand, silt and clay.
	Pleistocene	Glacial deposits: Boulders, gravel, sand, silt, clay.
Great Unconformity		
Paleozoic	Late or Post Devonian	Intrusives: Granite, diorite. Serpentine (age of serpentine doubtful)
	Early Devonian (Oriskany)	Moose River Sandstone
	Unconformity	
	Silurian (?)	Sediments: slate, quartzite, sandstone, conglomerate.
		Volcanics: Greenstone, chlorite schist.

[2] Op. cit.

Description of Formations

The different rock types as described below are identified from megascopic inspection only, thin section study not being complete at the time of this report. For this reason the descriptions will necessarily be brief and of general nature.

Volcanics

One belt of volcanic rocks was encountered in the mapping of this area. This belt shows a width of about one-half mile and a length of about five miles. The trend of the greenstone is about seventy degrees east of north. The lower, or southern edge, of the belt passes through the junction of the Spencer Streams and the greater part of the mass lies to the east of this confluence. Outcrops are numerous on the western end of the belt, but are rather scarce on the eastern end.

The rock is generally fine-textured and dark green with well defined, banded flow structure. It closely resembles the greenstone of the Jim Pond Area and is classified as of the same age. The rock generally shows a very even texture, but in some places, notably at the southern tip of Alder Pond, amydaloidal fillings, up to one-eighth inch in diameter, of pink and white calcite are found.

On the south side of the greenstone body and slightly east of Little Spencer Stream, small veins occur which carry epidote, calcite, and chrysotile asbestos. The minerals are intergrown and lie normal to the walls of the veins. The veins are not abundant and were not seen at any other location. The occurrence of these veins is similar to that noted in the greenstone of the Jim Pond Area.

Sediments

The greater part of the area is underlain by sedimentary rocks which are found on all sides of the volcanic belt. The sediments are considered to be of Silurian age with the possible exception that some of those shown in the very northern part of the map may be Devonian. The contact between the Silurian and Devonian rocks lies slightly north of Stony Brook Pond and some of the sediments shown to the west of this point may well belong to the Devonian. No attempt has been made to map this contact.

The predominant rock types are the slates and quartzites, with slate being the more abundant of the two. Conglomerate and coarse sandstone also occur in scattered localities.

The slates range from a light green to a dark grey color. At a few places the slates are of a deep reddish color, as for example on the northern slope of Stony Brook Mountain. All of the slates show a well developed cleavage. In places the slates tend to be somewhat limey, although they never approach a true limestone.

The quartzites are generally thin bedded and of medium grey color. Locally they show a well developed cleavage and bedding relationship.

Conglomerate is present in lens-like beds which seldom have any considerable width or length. The conglomerate is generally found within the slates and shows numerous small pebbles of quartzite and a few larger pebbles of jasper.

Sandstone is locally exposed as a well-cemented, coarse-textured rock similar to the sandstone of the Jim Pond Area. Outcrops are few and no attempt has been made to map it separately as was done in the Jim Pond Area.

Intrusive Rocks

The only rock of the region that is certainly intrusive is a granite which locally has quartz diorite and diorite facies. One large dike is shown on the Spencer Stream. The contacts as mapped are approximate. Many smaller dikes and sills occur throughout the region, more numerous in the south than in the north. Some of these smaller bodies are included in the detailed map of Stony Brook Mountain (Map V) where they cut through the serpentine. The diorites and granites are believed to be of Devonian age and probably related to one or both of the large granite areas lying both to the north and south of the area, they are the youngest rocks included on the present map.

The Occurrence of Serpentine and Asbestos

The occurrence of serpentine and asbestos have been treated as a separate group for two reasons; first, the original rock from which the serpentine was derived is not definitely established and it may be either igneous or sedimentary; secondly, the occurrence of serpentine and asbestos is discussed primarily from an economic aspect.

The serpentine occurs in at least five separate localities which are described separately. Because much of the area is covered with glacial drift, there is a good possibility that other bodies remain as yet undiscovered in the area.

Fresh surfaces of the serpentine present a dark green color and are slightly greasy to the touch. The rock is soft but difficult to break unless fractures are present. From a megascopic examination, the bodies seem to be almost completely serpentinized and uniform in composition. Thin section study will be necessary before detailed description can be given. The serpentine contains good percentages, reported up to eight per cent, of asbestos. Pyrite is present in many specimens.

Zones of intense fracturing are commonly present, many of which are accompanied by high percentages of fiber.

The fiber of the Spencer Area occurs as two different types. The least common occurrence is as cross fiber in which the asbestos fiber is found as a vein filling at high angles to the walls of the vein. This occurrence is found in many places in several different bodies, but the fiber is not long enough to have any great commercial value. The more common occurrence, and the one that merits consideration from an economic viewpoint, is that referred to in the asbestos industry as shear fiber. In the Spencer Area this is believed to have been formed by shearing of the original veins of cross fiber. Hand samples give the appearance of a smear or coating on the fracture or planes of movement. The shear fiber generally is of uniform length and quality.

Slip fiber, the more brittle variety formed along planes of movement, is not abundant in the Spencer Area.

Following is a detailed description of the individual bodies of serpentine that were seen by the field party.

Spencer Serpentine

The most important body of serpentine known to date is located on the Little Spencer Stream about one mile north from its junction with the Spencer Stream. (See Fig. 2).

Mapping of Serpentine Body—An outcrop map of the serpentine body was made on a scale of one inch to two hundred feet. Because of the scarcity of outcrops, a Gurley dip needle was used to trace extensions of the structure. This seemed to give excellent results. Observed or closely determined faults gave distinctly high anomaly readings, and this was used in tracing them. The north contact of the body, at the only place it was observed, is a fault. The dip needle readings along extensions of this line served well in tracing the north contact. The observed south contact consistently resulted in low anomaly readings, and its extensions were thus also traceable. The typical dip needle reading in the sediments away from the serpentine was about thirty degrees. The high readings along the north contact and on faults were as high as forty-six degrees, and the low readings along the south contact went down to twenty-five degrees. No attempt was made to contour the dip needle readings, rather they were plotted as profiles and variations in the pattern were studied. Dip needle readings were not considered where the pattern flattened out.

The results of the survey by dip needle are open to several interpretations, but the one chosen seems to fit best with the data as observed from the outcrops.

Description of the Serpentine Body—The survey indicates a body of quite uniform width (between 800 and 900 feet) striking slightly north of east and conformable in dip with the sediments which enclose it. It is traced over a length of about 3100 feet. To the east, under heavy overburden, it seems to be cut off by a northeasterly striking fault or fault system as assumed from the dip needle readings. There is no indication of pinching and it is possible that the eastward extension can be picked up by future work. To the west the body passes under a large area of overburden and the dip needle pattern fails to aid inference in extending the body. The body may pinch out in this direction, or it may be cut off by one of the many faults which transect the area.

In addition to the assumed faults at the east end of the body, two other northeasterly trending faults can be reasonably inferred from the surface outcrops and dip needle readings. These divide the known length of serpentine into three blocks. The more westerly fault has the effect of offsetting the west side roughly 200 feet to the north, and the more easterly has the effect of offsetting the central block 300 feet to the south.

Just to the east of the stream, the north contact of the serpentine can be closely followed for 300 feet, and a fault is visible at the eastern end of the exposure. This is a gouge filled zone about one foot wide and with slickensided walls. The gouge is a soft clay-like mixture of rock flour and asbestos-like material. The straitions on the walls strike eighty degrees east of north and pitch at thirty-one degrees to the east. The fault itself strikes east and dips eighty-three degrees south. Hackles on the walls show the sediments to be on the upthrown side. The fault appears to be curved at this point and the strike as given probably does not hold true for any great distance.

Typical serpentine of this body is dense, dark green to blue material with a greasy luster. It is intersected by closely spaced fracture planes in nearly every conceivable direction. Many of these fracture planes show evidence of movement. In the fiber bearing zones, these fractures contain shear fiber. Away from the fiber bearing zone, many small veinlets of cross fiber are seen.

Toward the south contact, and usually close to it, there is a distinct change in the rock. This change is due to the presence of a large proportion of what appears to be a carbonate mineral. The significance of this material and its exact composition cannot be stated until thin section studies have been made. Shortly to the south of the most western exposure, there is a zone several feet wide of light green, fine grained serpentine containing a little disseminated magnetite and pyrite. Analyzed samples of this material contained 0.11 and 0.10 per cent nickel; one was tested for chromium and contained 0.48 per cent.

The serpentine body is sill-like in structure. It stands nearly vertical and seems to follow consistently the dip of the sediments. It is possibly a highly altered sill of ultrabasic intrusive rock, or an originally thick dolomite formation almost completely altered, or replaced by, serpentine. It is hoped that its origin may be determined as thin section studies are completed.

Description of Fiber-Bearing Zones—The two occurrences of the fiber bearing zone are located on either side of the stream and are approximately 2200 feet apart in a general east-west direction. The intervening area is entirely drift covered.

The east occurrence, 800 feet east of the stream, consists of two outcrops which represent a width of 150 feet in the north-south direction and are separated by about 55 feet of drift. The fiber-bearing zone passes into massive serpentine on the northernmost of the outcrops and the zone probably ends here. The southern boundary lies in a drift covered zone of about 80 feet which separates the southernmost fiber bearing crop from a barren outcrop to the south.

The western outcrop is on the side of a high ridge to the south of Parker Pond Brook and roughly 1400 feet west of Little Spencer Stream. The exposure shows both fiber-bearing serpentine and barren or nearly barren serpentine. It is believed to be cut by a northeasterly trending fault with a horizontal offset of about 200 feet. Although the outcrop is not more than 100 feet wide, north to south, both boundaries of the fiber bearing zone seem to be exposed because of the faulting. If the horizontal offset of 200 feet is correct, calculation would indicate that the zone at this point is about 260 feet wide. The vertical component of movement is unknown and the above calculation only indicates a possibility. The total length of the fiber bearing zone at this point is about 250 feet, it passes into overburden at each end.

The reasons for localization of the fiber bearing zones are not known. They may be structural, compositional, or both. That most of the fiber seems to be concentrated in fractures indicates the possibility of structural control. The entire serpentine body is greatly fractured but it is possible that shattering is more intense in the areas where fiber is concentrated.

Milling tests on samples taken from the eastern fiber bearing zone are reliably reported to have contained a fiber content up to eight per cent, all of short lengths, but of good quality. No long fiber has been encountered to date. It is not known if the percentages reported from the milled samples are consistent throughout the fiber bearing zones. Field examination of both east and west outcrops lead to the belief that percentages would run about the same for both and that they are uniform.

Diamond Drilling—Results of the diamond drilling carried on by the Johnson Asbestos Company of Thetford Mines, Quebec, are not known at the time of writing, beyond the general statement that they were unsatisfactory. The drilling was confined to that part of the body lying to the east of the stream. The total footage is not known to the Survey at the time of writing, although the locations of 16 holes have been plotted on the map. (Map V)

The location and observed bearings of the drill holes, as seen in the field, would seem to indicate that the likelihood of delimiting the fiber bearing zone or finding other zones by the drilling was remote. The exposed zone was not cross-sectioned from north to south by any of the holes. The area to the west of the exposed fiber-bearing rock was practically untouched by any of the drill holes; this is the region which would seem most likely to contain fiber as an extension of the eastern exposure and possibly a continuous zone between the east and west exposures.

Conclusions—As the existence of the western outcrop was not known at the time of drilling and the drilling was done without the benefits of a geological map or dip needle survey, it is the opinion of the writers that further drilling to test the possibility of a fiber bearing zone existing between the two outcrops is warranted. If the zone is continuous, the tonnage would be great enough to develop. Other considerations of course would have to be taken into account.

Stony Brook Mountain Serpentine

The occurrence at Stony Brook Mountain is the largest seen in the Spencer Area. Small concentrations of shear fiber and also of tiny veinlets of cross fiber are present. Inasmuch as the body had not been previously reported and showed good fiber in places, it was mapped in detail on the scale of one inch to two hundred feet (See Map VI).

Mapping was carried out in much the same manner as on the Spencer body although a characteristic pattern could not be worked up with the dip needle. The topographic map of the United States Geological Survey is rather poor in this region. It is believed that the top of Stony Brook Mountain is correctly located on the Pierce Pond quadrangle, and this has been used as a reference point.

The serpentine body shows a width varying from about 1000 feet on the eastern end to nearly 2000 feet at the western part of the map. Lack of outcrops on the western slope of the mountain made it impossible to complete the map in that direction. The length, as mapped, is about two miles.

The serpentine body is cut in many places by dikes of diorite. Many small offshoots of serpentine penetrate the sediments on either side. The diorite dikes appear to be definitely later than the serpentine and many more of them pinch out in the serpentine. The strike of the serpentine body is roughly northeast, and many of the diorite dikes which cut the serpentine strike about thirty degrees east of north and dip steeply to the south. Most of the diorite dikes are parallel and appear to be controlled by structure.

The serpentine has much the same appearance as that noted on the Little Spencer Stream about four miles to the west and is very likely of the same age and origin. Samples taken from the peak of the mountain are apparently made up completely, or nearly so, of serpentine; however, the texture suggests that the serpentine has replaced what originally was a basic intrusive type of rock; outlines or ghosts of what may have been pyroxene are present. Thin section study may possibly give the answer to this question of origin.

Zones of shattering are present; but the fracturing is not nearly as intense as that noted at the Spencer Stream occurrence. In the regions which have been fractured but slightly, asbestos has not been seen.

Occurrence of Fiber—Small veins of cross fiber can be seen at many places throughout the body, but high percentages of either cross or shear fiber have been located at only two places. These are shown on the detailed map. The group of outcrops near the foot of the eastern slope of the mountain consist primarily of shear fiber of the same type and about the same percentages as that seen on the Little Spencer stream. This occurrence differs from the Spencer body in that the distribution of the fiber is not uniform; it occurs rather as individual concentrations only a few feet across separated by barren regions of a few feet. The reason for this spotty type of occurrence is unknown. From visual inspection there is no difference in composition, or in the degree of fracturing to account for the localization. A few tiny veins of cross fiber occur mixed in with the shear fiber.

Another concentration of fiber is seen close to the top of the eastern slope of the mountain. Here the fiber is mostly of the cross variety with rare occurrences of shear fiber. The tiny veinlets are usually parallel and closely spaced. One vein one-half inch wide was seen but the fiber was somewhat distorted and broken by a medial parting containing flecks of serpentine and magnetite. The fact that the veins are mostly parallel would indicate the probability of structural control, but no fracture system could be worked out and many of the veins seem to occur in undisturbed serpentine. The fiber is generally too short to be of commercial quality under present milling methods.

Conclusions—It appears that at the Stony Brook Mountain Area the volume of ore present is not large enough to warrant mining under present methods. There is some possibility of fiber occurring in the unknown western end of the body.

Eagle Pond Serpentine

A serpentine body of moderate size is found a little less than one-half mile north of Eagle Pond, and about three-quarters of a mile north along the town line from Alder Pond. The serpentine occurs in a swampy area and only one group of outcrops was found. The contacts are mapped as approximate, but represent a minimum width.

In the outcrop present, all the fiber seen was of the cross variety and of very short length. The veins appear as very fine ribbons and are closely spaced. The parallel arrangement as noted at Stony Brook Mountain is also present in this body.

The economic possibilities seem poor from the exposures seen but again much of the body must remain unknown to surface mapping and may contain good fiber. Drift rock of much the same type is common for at least one-half mile east of the limits of the body as shown and this may indicate an extension beyond that shown on the present map.

Stony Brook Serpentine

Several small outcrops of serpentine are found slightly to the west of Stony Brook and close to the eastern end of the Stony Brook Mountain serpentine. No fiber was seen and the bodies are small. They may represent isolated bodies or may be offshoots from the body at Stony Brook Mountain. In any case, they are not large enough to be considered from an economic standpoint.

Lower Enchanted Pond Serpentine

Outcrops of serpentine are found at the waters edge on the south-eastern side of Lower Enchanged Pond. Very little cross fiber was noted. No detailed study was made of this body, and extensive swamps to the north and east would make information from surface mapping very incomplete.

Pleistocene and Recent Deposits

Like the other areas reported upon, the Spencer Region was completely covered by the last glaciation. Glacial till containing large and numerous boulders covers a high percentage of the area.

One well defined esker was noted along the Little Spencer Stream and follows it closely from near the foot of Spencer Lake down as far as the serpentine occurrence on the stream. Other wash deposits are present but were not mapped in the current work.

Bogs are common in the flat areas and are mostly made up of peat. Silt is found in patches in some of the bogs where drainage is still rapid during flood time.

The major streams of the area are all rapid and with comparatively straight courses. There has been very little development of alluvial deposits other than those in the stream beds.

Structural Geology

Bedding is difficult to distinguish in the slates, but can be seen at many places where thin beds of quartzite are present. The strike of bedding is slightly north of east and dips are steep in both directions. Readings on slaty cleavage closely parallel those from bedding.

A well developed fold was found in Spencer Stream a short distance below Spencer Gut. The fold axis strikes sixty-five degrees east of north and pitches at about forty-five degrees to the northeast. This reading is confirmed by a solution of the bedding and cleavage relationship, as found in the quartzite at the mouth of Little Spencer Stream. Here bedding strikes east and dips seventy-seven degrees north and cleavage strikes forty degrees east of north and dips seventy-five degrees south. A solution of this intersection shows the axis to be striking sixty-five degrees east of north and pitching about sixty degrees to the northeast.

This interpretation of structure shows most of the area mapped to be on the northern limb of an anticline pitching to the northeast. If this is true the formation will show in nearly their true thickness as the dips are consistently near the vertical.

Several small faults are shown on the detailed map of the Spencer Body and it is highly possible that others not mapped are present in the area. However, surface outcrops do not indicate a major fault.

Economic Geology

Gold

Placer gold has been reported from sections of the Spencer Stream several miles to the west of the area mapped. Current mapping has not given any evidence leading toward a belief that either placer or lode gold is present.

Chromite and Nickel

Assays were run on two of the more promising samples to determine their chromium and nickel content. Nickel was present in amounts of 0.11 and 0.10 per cent and a chromium test on one sample showed 0.48 per cent. The percentages are low and the areas from which the samples were taken are small. Unless new prospects are turned up, the economic occurrence of these metals does not seem likely.

Asbestos

The only body discovered to date that seems to merit consideration from an economic viewpoint is that seen on the Little Spencer Stream. Here the fiber seems to be of good quality and in relatively high percentages. Exploratory work must be done by diamond drilling before any estimate is made of tonnage. The possibility of a large volume of fiber bearing rock is present.

Conclusions

Asbestos is the only mineral of the Spencer Region that has shown promise of an economic occurrence. Further work on existing serpentine bodies by diamond drilling is necessary. Prospecting for new bodies would be best directed to the east and west of the region covered in the present mapping. Granite masses to both north and south, and rock of a different age to the north would make the occurrence of serpentine in those directions seem unlikely.

Future exploration might well find geophysical methods of exploration to be of considerable assistance.

CLAY SURVEY--1948

By Lawrence Goldthwait

Introduction

This report summarizes the fieldwork on clay deposits in Maine done by L. Goldthwait and E. Cormier in 1948. Previous fieldwork has been carried out by Savage and Miller in 1946 and by Koons and Donohue in 1947. Miller and Savage worked mostly in the Androscoggin, Kennebec and Penobscot river valleys; Koons and Donohue covered the eastern and northeastern portions of the state.

During July, 1948, the clay survey was extended to the southwest portion of the State in the Freeport-Kittery-Shapleigh-Sebago region. In addition an attempt was made to locate more closely the northern limit of clays from the Sebago region eastward. The outline of the clays may be seen on the field maps. Because of limited time only a reconnaissance survey could be made. Fieldwork consisted of as complete inspection of the area as time allowed, and study of all gravel pits and exposures available. A careful determination of clay boundaries was made in critical places, and forty-four samples of clay were taken. Also, twenty-five testholes were put down to determine the depth, structure, and thickness of clay. The areas covered by the clays, gravel, and till were roughly mapped. Since such large areas had to be covered in a short time, these maps represent only approximately the distribution of the clays. Much more detailed fieldwork in small selected areas should be carried out in an attempt to solve some of the many problems related to the origin and distribution of the clays.

Discussion of Clays

In the following paragraphs a brief discussion of some of the problems related to the clays is presented. These problems include the distribution of the clay, the relations of the brown and blue clays, relations of the clays to other glacial deposits, time of deposition, topography of the clays, and related shoreline problems.

Distribution

The overall distribution of marine clays in Maine is approximately as follows. The clay occurs at low elevations (in many areas less than ten feet) along the present shore. Inland from the shore the clays are found in the valleys at increasing elevations to the north or northwest, with the highest elevations above four hundred feet at distances of eighty miles, more or less, from the present strandline. The highest elevations at which marine clay was found was approximately four hundred and forty feet, in the Farmington district. The clays do not cover the entire coastal area, but tend to be restricted to the valleys with perhaps a more generally wide distribution in the southwest corner of the State than elsewhere. The deeper the valleys the more limited the clays in areal distribution.

Clay limits.

An attempt was made to locate more exactly than had been done before the northern limit of clay in Maine. This proved to be very difficult since in the central and eastern portions of the State much of the clay is covered with gravel and sand deposits. However the northern limit was pushed farther inland particularly in the vicinity of Lincoln and Bingham. If the problems of how and when the clay was formed were solved, a much better estimate of the actual extent of the clays and thus the volume of clay available could be made.

From the most detailed maps of clay now available (of the Portland district) an attempt has been made to draw profiles to illustrate the extent of post-glacial upwarping, as shown by the increasing elevations of the clays inland, but these proved to be inconclusive, either because the mapping was not detailed sufficiently or because the clay limits do not follow a definite pattern of increase in elevation inland (which is contrary to the accepted theory of postglacial upwarping).

Depth of water.

One of the interesting problems related to the origin of the clays is the depth of water in which the clays were deposited. It is generally agreed that they were deposited in the ocean. Marine fossils are found locally in the clay, and the clay lacks the true varying characteristics of fresh water clays. It is a problem however as to how deep the sea was in which the clays were laid down. Perkins mentions[1] that "in the Waterville region the marine clays mantle the hillside to an elevation of about 200 feet, while the highest delta records an elevation of about 350 feet." This implies that the clays were deposited in deep water, and that the water level reached about 150 feet higher than is indicated by the clays themselves.

Fieldwork has suggested the possibility that the clays were actually laid down in relatively shallow water, the upper limit of clay repre-

[1]Perkins, E. H. (1935) "*Glacial Geology of Maine,*" Maine Tech. Exper. Sta., Bull. 30, vol. 2, p. 199.

Fig. 1. Preliminary map showing extent of marine clays in Maine

senting the approximate sealevel—in much the same manner that marsh deposits and mudflats are being formed at the present time. If the water had been much deeper, as suggested by Perkins, it is difficult to account for a well defined upper limit to the clays in a given area, and for the fact that the whole floor beneath the sealevel did not receive some clay rather than just the lower portions of the valleys. Detailed fieldwork consisting of careful mapping of the upper clay limits in selected areas and the study of the deltas might solve this basic problem regarding the origin of the clays.

Two clays.

There are problems related to the color of the clay, which is yet unsatisfactorily explained. There is also difference of opinion as to the reason for the two colors in the clay, the upper brown and the lower blue.

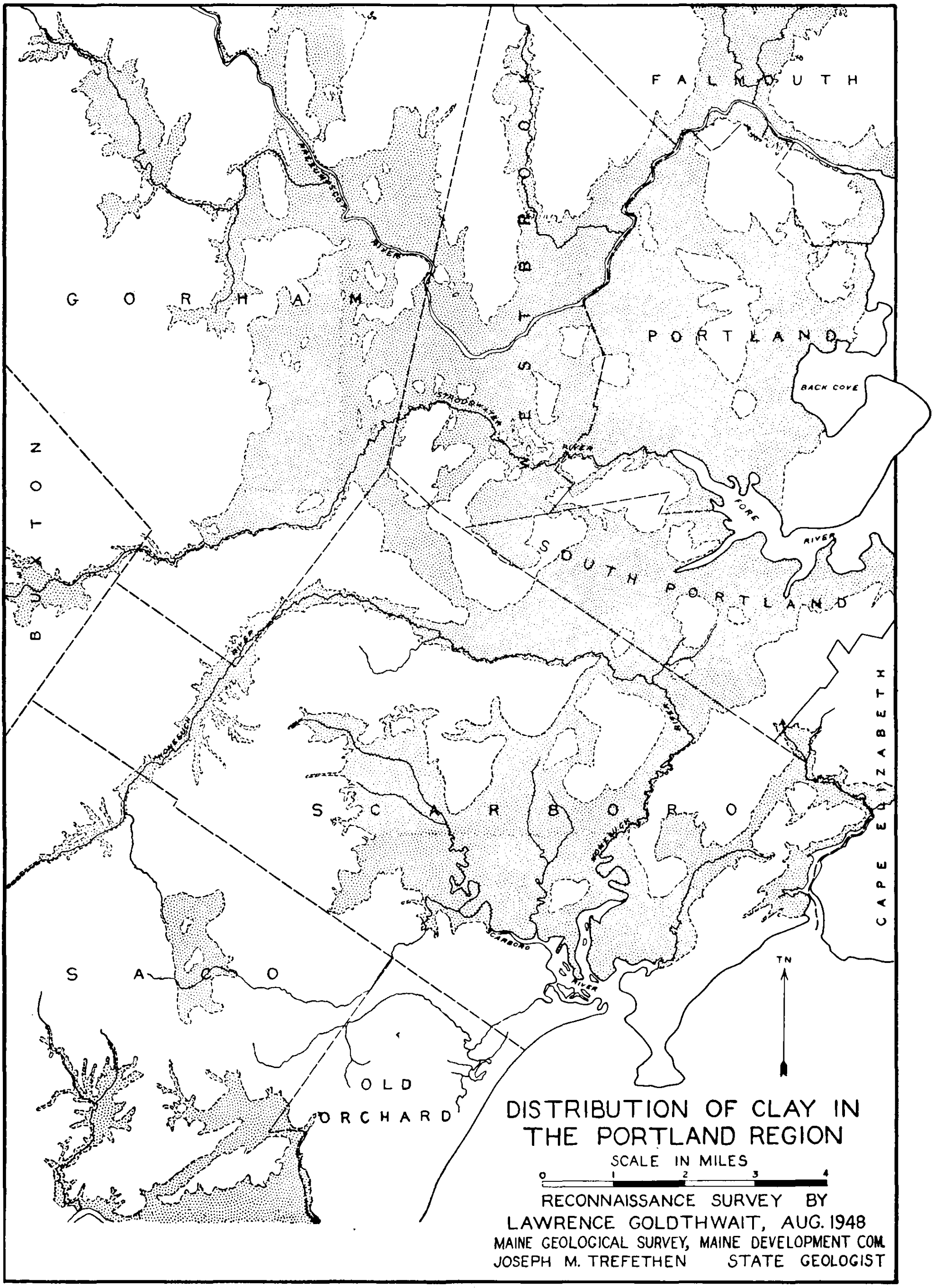
Miller and Savage[2] expressed the belief that locally the two clays were deposited at different times, and are separated by an unconformity. Where mixing of the two has been found there might have been: 1, a reworking of the lower blue at the time of deposition of the upper brown and thus a mixing; or 2, that the lower blue was intruded into the upper brown, after deposition, by the weight of the overlying brown clay.

Koons however was of the opinion that the two clays were approximately the same age, deposition having been continuous for all of the clay. Oxidation has since altered the upper portions of the clay to the characteristic brown, the lower portions remaining unchanged and blue.

Few good exposures of the contact between the brown and blue were seen in the summer of 1948. However the sections that were observed tended to substantiate Koons view that the difference of color was due to oxidation of a once continuance blue deposit.

It would be interesting to make a study of present deposition in marine estuaries for comparison with the clays under study. The possibility should be considered that both the upper brown and the lower blue clay represent a continuous shallow water deposit, the upper brown having formed within the range of tides, while the lower blue settled at approximately the same time below the level of low tide. Incidentally several localities in the southwest portion of the State lend good opportunities for such a study where the modern sediments are being formed next to the earlier clays.

[2]Trefethen, J. M., "*Report of the State Geologist,*" 1945-1946, p. 13.


FALMOUTH
GORHAM
PORTLAND
BACK COVE
BUXTON
SOUTH PORTLAND
FORE RIVER
STROUDWATER RIVER
PRESUMPSCOT RIVER
WEST BROOK
SCARBORO
CAPE ELIZABETH
SACO
OLD ORCHARD
SCARBORO RIVER
TN
DISTRIBUTION OF CLAY IN THE PORTLAND REGION
SCALE IN MILES
0 1 2 3 4
RECONNAISSANCE SURVEY BY
LAWRENCE GOLDTHWAIT, AUG. 1948
MAINE GEOLOGICAL SURVEY, MAINE DEVELOPMENT COM.
JOSEPH M. TREFETHEN STATE GEOLOGIST

Relation of clays to outwash.

The age relationship between the clay and the glacio-fluvial deposits has never been satisfactorily worked out. It is a question whether the ocean encroached onto the present land surface directly against the ice while the ice melted down and back, or whether there was a lapse of time after the ice melted off and before the marine invasion. It is also a question how long the marine invasion lasted.

The Sebago Lake area might shed light on these problems. Marine clays may be traced up to elevations such that the ocean here should have flooded the Sebago Lake Basin unless the Basin was filled with ice. Clays are traced to the edge of Sebago Lake Basin just west of North Windham. No clays have been found in the Lake itself or in the immediate vicinity except at the northern end at Songo Lock, and it is questionable whether these particular clays are of marine or fresh water origin. If fresh, it implies that the ice filled the basin at the time of, and for the duration of, the marine invasion.

A somewhat similar occurrence is found at the entrance of Cold Stream Pond where the marine clays extend nearly up to the level of the Pond, but not into the basin itself.

The relationship of the clays to the various outwash deposits (kames, eskers, outwash plains, moraine banks, etc.) is important and deserves more attention than it has been given. Generally the clay covers the various deposits in the southwest portion of the State, whereas the clays are likely to be veneered by gravel and sand in the central and eastern portions. There are many exceptions to this general statement however.

North of Westbrook there is an interesting occurrence of a large area of blue and brown clay overlain by many feet of fine sand and silt. Coarser gravels overlie clays at Bingham. The occurrence of clay on and under eskers, and the extension of clays into the "moraine embankments" still needs further study. Such features are important in determining the time of the deposition of the clay, and therefore the origin.

Topography of the clay.

The topography of the marine clay surface presents still another basic problem in relation to the origin of the clay. Locally the surface of the clay appears to have been controlled by the underlying gravel and sand deposits. At other places the clay topography appears to have been formed by subaerial erosion. In still other places the clay topography is strikingly like that of glacio-fluvial deposits (kames, pitted outwash plains, etc.) even in deposits known to be clay throughout. Was the clay laid down in open water, or might it have been laid down against ice, or possibly under floating ice?

Shore problems.

The lack of clay, and particularly the low elevation of clay near the present sea, presents problems also. In some areas there is no clay to be found at the shoreline—possibly the clay is buried under more recent deposits, or possibly the clay in such areas has been retained only in isolated pockets. It may be that locally the upper limit of clay at the present shoreline is below present sealevel. How far offshore the clay extends is unknown.

Very few remnants of former shorelines, produced at the time of the sea invasion and clay deposition, have been identified, and even these are questionable. Old beaches, wave-cut benches, spits, etc., are surprisingly lacking. In many places there has been evident washing of the lower surfaces along coastal areas by the sea or by outwash streams. But there are no well-defined strandlines.

Summary of the 1948 Fieldwork

More detailed mapping was carried out in the areas of clay occurrence in the southwest portion of Maine. These studies brought into focus many basic problems of interest to glacial geology as well as of interest in determining the origin and distribution of the clay. The northern limit of clays was pushed farther north, but the northern limit is still unsatisfactorily known, partly because much of the clay is covered with other deposits. To understand the clay and its origin, more careful and detailed work is needed on certain selected areas—such as the Sebago Lake region, the Portland-Westbrook region, and certain spots in the York area.

The accompanying reconnaissance map (Fig. 2 Portland quadrangle) shows roughly the distribution of marine clay in the Portland area, and the small scale map of the State (Fig. 1) indicates roughly the northerly limits of marine clays.

IMPROVING THE QUALITY OF MAINE CLAYS

By Earl W. Fuller

Clay is a mixture of finely divided compounds formed from the weathering of the earth's crust. Many clays are very plastic in the moist state. Most retain shape when dry and become very hard if heated to redness. Many of the small grains making up clays are essentially colloidal in nature; and this, together with the surface reactions of the grains, accounts for most of the physical properties of clay. The following minerals are present in the clay used in this investigation: hydromica, quartz, albite, tourmaline, zircon, hornblende, limonite, biotite, and chlorite. The clays which contain fluxing impurities, the oxides of iron, potassium, calcium, sodium and magnesium, will have lower melting points. Thus the Maine clays fuse or melt at temperatures below 2300°F, and are not suited to refractory uses. The impurities, therefore, may be the most important constituents in clay. Iron is one fluxing agent that is especially undesirable, since even a small amount will color the clay when fired and greatly limit its uses.

Clay particles can be produced and left where the rock is weathered, or can be transported and deposited elsewhere. Maine clays are considered to be a "rock flour" and not clay in the sense of being composed of clay minerals. This is because the action forming them was not chemical weathering, but was that of grinding by the overriding ice sheet. The powdered rocks were then washed out of the glacial debris and deposited in the valleys and basins. However, since the word *clay* refers to a physical condition, and Maine clays possess physical characteristics comparable to other clays, they can be considered true clays.

Clays of Maine are at present used mainly in the manufacture of common brick. When fired they burn to various shades of color from pink to red, which is not usually harmful to the sale of the product. It would be very advantageous, however, to produce a clay which would burn white, thus suitable to whiteware production. The undesirable impurities in Maine clays are about four per cent iron oxides and some carbonaceous material which gives the clay a grey-blue color.

Since the paper industry in the state uses approximately 50,000 tons of imported southern clay a year as filler and coater, it would be most desirable to use a local clay if removing the impurities were economically possible. Other industries which use clay for such products as linoleum, rubber goods and ceramics ware would also profit. The object of this investigation, therefore, was to develop a process which would allow the economical removal of the iron and organic coloring from Maine clays.

In previous work on the same problem,[1] sulfur dichloride was used to remove the coloring impurities. This gave a white product but had the disadvantage of dehydrating the clay, rendering it useless to the paper and ceramic industries. Therefore, it was decided to investigate low temperature treatment of the clay in order to preserve necessary physical properties. Flotation of the iron bearing minerals was tried at American Cyanamid's Mineral Dressing Laboratory, but with discouraging results.

Upon survey of the literature, it was found that several processes are in use involving leaching methods. Chiefly, they involved solubilizing the iron with acid reducing agents such as hydrosulfurous acid and zinc dust; or use of a reducing gas such as hydrogen or sulfur dioxide. These methods, however, are more applicable to a clay of the kaolinite type. It was decided to use sulfuric acid leaching and reduction with hydrogen for iron removal, followed by various bleaching methods for the removal of carbonaceous material. These methods involved treatment at temperatures of 100°C. or less. The problem, therefore, seemed to be divided into two distinct parts—(1) removal of iron bearing constituents which color the clay when fired, and (2) removal of carbonaceous material coloring the clay as found in the bog.

Procedure[2]

An outline of the laboratory procedures followed in the course of these experiments is next presented, to be followed by a summation of results.

Removal of Iron Bearing Constituents

The clay for this investigation was obtained from the Old Pond area near Howland, Maine. Since the clay from the bog contains up to twenty per cent moisture, it was decided to use the samples in this form to give better dispersion. At first no particular attention was paid to acid concentrations or temperatures of treatment.

About ten pounds of clay were mixed to a slurry in a five gallon crock with three liters of water. One liter of concentrated sulfuric acid

[1]Report of the State Geologist, 1945-46, Me. Geol. Survey.

[2]See Appendix A

was added and live steam admitted to the mixture for heat and agitation. The batch was also stirred by hand to keep the clay in suspension for better reaction. Acid concentration varied from about twenty-five to ten per cent due to dilution by the steam condensate. The slurry was then washed with hot water and steam to dissolve the iron, and allowed to settle overnight.

The liquid was then decanted from the clay and tested for iron with potassium thiocyanste. Leaching was continued with more acid and steam. On standing overnight, the clay had swelled considerably due to adsorption of water by the colloidal clay micella. This swelled portion was saved for later tests.

A total of six leaches were given this batch of clay until the iron in the wash water decreased and further reaction showed no evidence of iron removal. The soluble iron was completely washed from the clay and the slurry was saved for later treatment.

It was thought that the acid leach would remove the easily soluble iron and that further treatment by reduction with zinc dust and hydrochloric acid would be necessary to remove the more complex forms of iron. A small amount of zinc dust was added to the crock, with enough hydrochloric acid to acidify with the generation of hydrogen. This was continued for two hours and the clay washed with steam again. Very little iron was found in the wash water. With smaller batches, it was also observed that reduction with hydrogen removed very little iron. Later it was confirmed (see Results and Discussion) that this method is less efficient than the sulfuric acid leach in the removal of iron. Since in the preceding experiments little attention was paid to the concentrations of acid used, it was decided to observe the effect of change in concentration on the leach. Samples were taken to check the amount of iron removed for different intervals of leach.

Eight pounds of clay were mixed with a volume of 1:1 water to acid, giving an acid of sixty per cent strength by weight. Steam was admitted to the crock and the mixture stirred by hand. As the volume increased, more acid was added to keep the concentration nearly constant. This batch was leached five hours with samples taken at various times and saved for later analysis. After settling overnight, the acid was decanted from the clay and the clay washed with wet steam to remove the solubilized iron. The slurry was then reacted with more acid until the wash water gave no test for iron. The mixture was washed free of iron, dried and pulverized for future use. Another run was similarly made with a ratio of water to acid of 3:1. Samples were taken and saved for analysis. Both runs required an average of ten hours leaching before the clay would burn white.

On analysis, it was learned that over eighty per cent of the iron could be removed in the first hour while several more hours of leaching were necessary to remove the balance. This is too time consuming and uneconomical, and led to the use of a high speed agitator in an attempt to reduce the leaching time, and possibly the acid concentration.

Two runs were made using twenty per cent clay solids and twenty-five per cent acid concentration. One run was made at 85°C. and the other at 50°C. to ascertain the effect of temperature on the leach. Concentration was kept constant by using indirect steam instead of live steam. Samples were taken every hour and saved for iron analysis. With this increased agitation, considerable frothing of carbonaceous material was observed. Much of this was skimmed off and dried for examination. Very little frothing was observed at the lower temperature of 50°C.

Results of the Iron Removal Experiments

In the preceding runs, results which would give the limiting concentration of acid needed for best iron removal were not obtained. This led to leaching of small samples in Erlonmeyer flasks at acid strengths of ten, twenty, thirty, forty, and sixty per cent, both at boiling temperature and room temperature. The length of leach was one hour since most of the iron could be removed in that time. A small laboratory agitator was also used. Better control could be exercised, and consequently results were obtained that could be correlated better. The experimental procedures have just been outlined. It remains to present the results of the work.

Removal of Iron

The results of the various leaching methods are given in Tables I-IV and the trend of iron removal is shown by graphs, Figures 1-5.

Steam Agitation. The majority of the iron is removed during the first hour of the leach—eighty per cent or above. The curve slopes off after three hours with less than ten per cent being removed after that time. It is shown by Figure 1 that acid concentration does affect iron removal, the effect being less after the first two hours of leaching. The color of the ignited product was fairly white after four hours of leaching. The analysis of those runs gave somewhat scattered results, due probably to uneven contact with the acid because of agglomeration of the clay particles. The main problem with this method is the dilution of the acid by steam condensate, which necessitates longer reaction time and increased cost of evaporation in industrial application.

TABLE I

Results of Sulfuric Acid Leach with Steam Agitation

Run No.	Acid concentration % by weight	Temperature °C.	Per Cent Fe Removed, Hours: 1	3	4	5	6	7	9	11
3	60	70–80	—	89	90	93	91	95	—	93
4	37	70–80	77	84	84	—	89	—	91	—

TABLE II

Results of Sulfuric Acid Leach with Mechanical Agitation

Run No.	Acid concentration % by weight	Temperature °C.	Per Cent Fe Removed, Hours: 1/2	1	2	3	4	5
6	25	85	77	84	87	90	94	—
7	25	50	41	78	83	90	90	92
9	10	50–60	52	70	85	—	91	—

TABLE III

Results of Sulfuric Acid Leach on Small Samples with Agitation

Run No.	Acid concentration % by weight	Temperature °C.	Per Cent Fe Removed in one hour
10	10	100	86.5
11	20	100	88
12	30	100	92
13	40	100	92
14	60	100	92
15	10	25	29.5
16	20	25	51.5
17	30	25	60.2
18	40	25	70.9

TABLE IV

Results of Reduction and Leach Plus Bleach in Iron Removal

Run No.	Leaching Conditions	Temperature °C.	Per Cent Iron Removal, Hours: 1/2	1	2	2-1/2	3
19	Reduction with H_2 ($HCl + Zn$)	100	—	62	66	68	—
20	Leach + Bleach (20% H_2SO_4)	100	80	85	86	—	86

Mechanical Agitation with Lightning Agitator. From the analysis of runs 6 and 7, better correlating results were obtained than from runs 3 and 4, indicating that more uniform reaction took place throughout the mixture. This is why there are deviations of about two per cent in iron concentrations in Table I which are due to difficulty in obtaining a representative sample. Data from Table II show that temperature has a much greater effect upon the removal of iron during the first hour than later, with the results being nearly equal after three hours leach.

A comparison of steam agitation with high speed agitation, Figures 1 and 2, shows that acid of much lower strength gives better results when mechanically agitated. Lower temperatures also give better iron removal by this method. Mechanical agitation reduces the leaching time at least three hours.

After the slurry was agitated at high speed, it was noticed that when agitation ceased the clay would set to a gel, which would become fluid again upon further agitation. This phenomenon is known as thixotropy and is common in bentonite clays.

Reduction with Hydrogen. Reduction with hydrogen, although used satisfactorily to remove iron from various other earths, does not show very good results with this clay, as evidenced by Figure 3. This method, industrially, would give rise to the problem of removing zinc reaction products and unreacted zinc.

Leaching of Small Samples. The results from the leaching of small samples show more clearly the effect of time and temperature on iron removal. For best results, i. e., the largest amount of iron removed in the shortest time, it is necessary to use fairly high acid concentration—about twenty-five to thirty per cent, and temperatures of 85° to 90°C. This is shown by Figure 4. As the acid concentration rises above this figure, no appreciable gain is noticed. The amount of iron in the clay must be reduced to approximately 0.3 per cent to give a product burning fairly white. In small samples this was done in one hour, while in crocks three hours' treatment was needed. The leaching of the iron from the clay depends upon two main variables—time and temperature—with lesser dependence upon acid strength and degree of agitation.

Economic Considerations. The cost of 60% sulfuric acid at the current market (May 1948) is $15.00 per ton. The acid consumed in removing the iron to 0.3 per cent from 3.65 per cent is estimated to cost

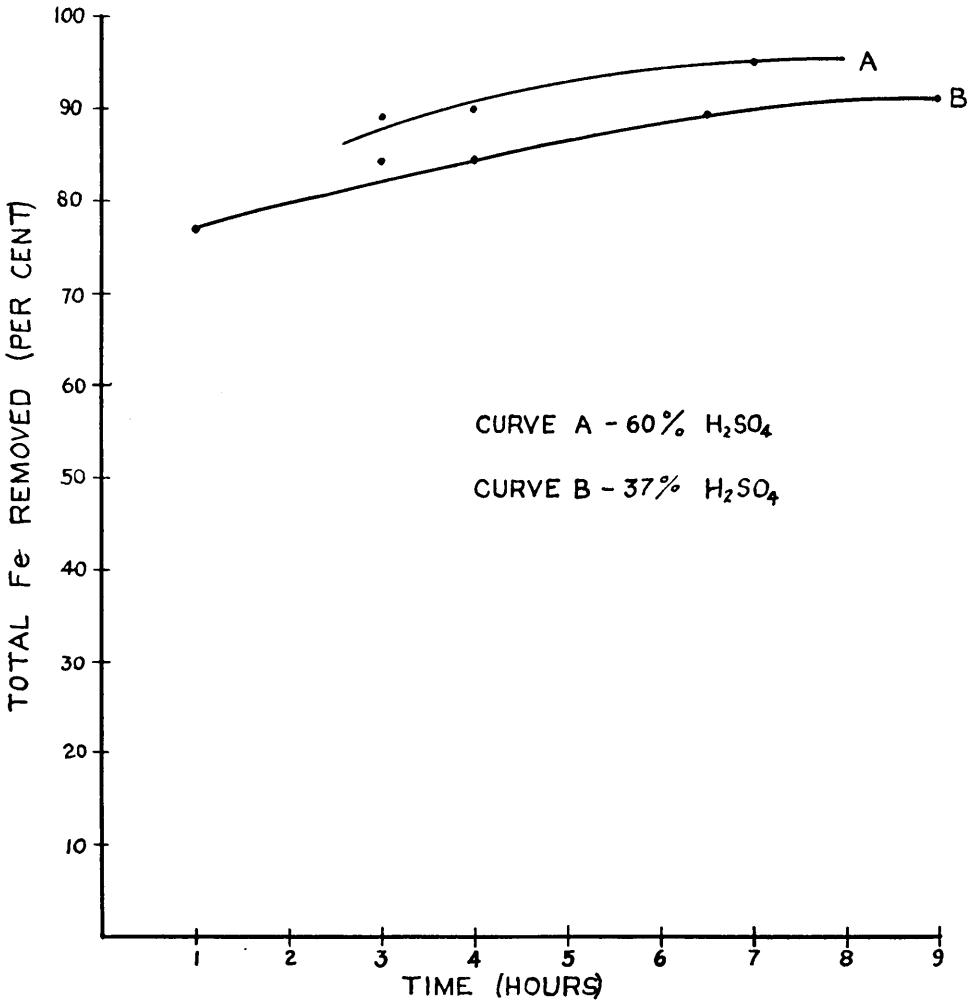


Fig. 1. Leaching with sulfuric acid solution and steam agitation

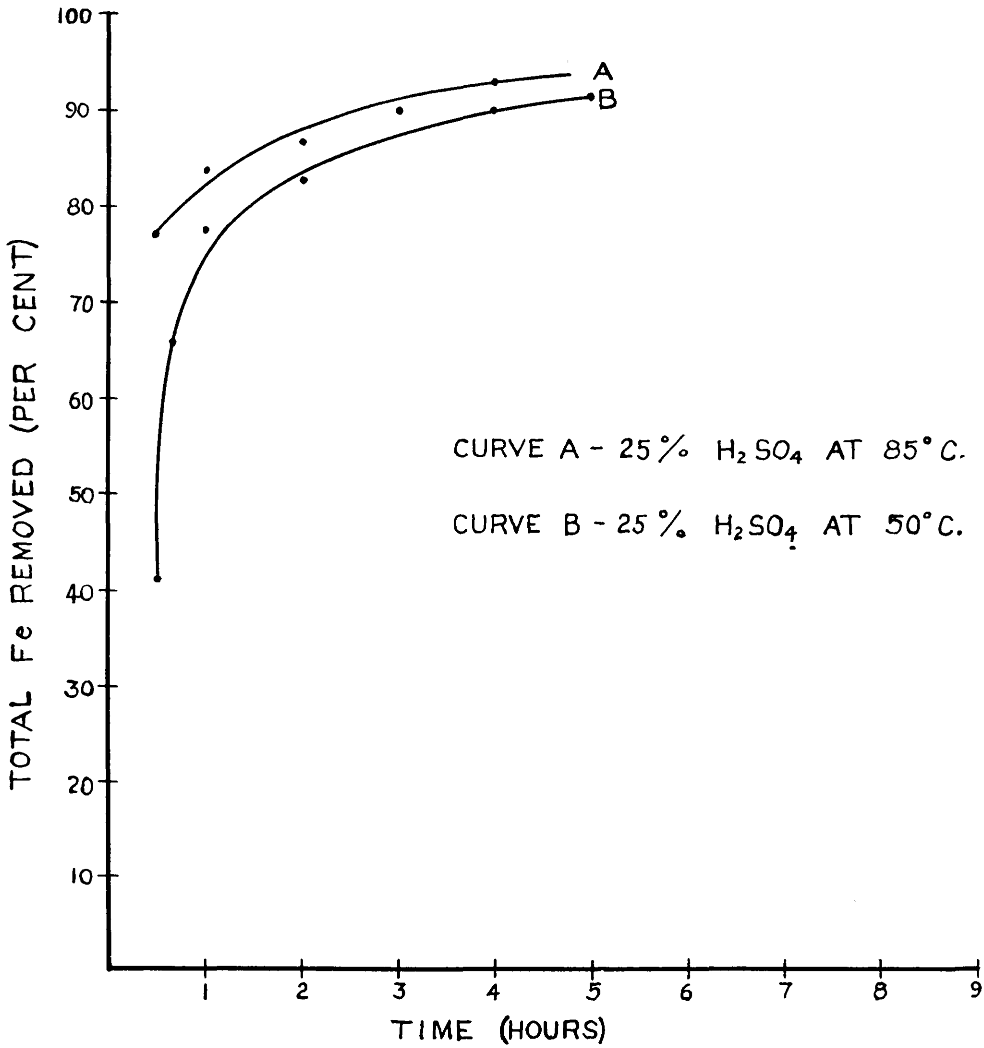


Fig. 2. Leaching with sulfuric acid solution, using high speed agitation

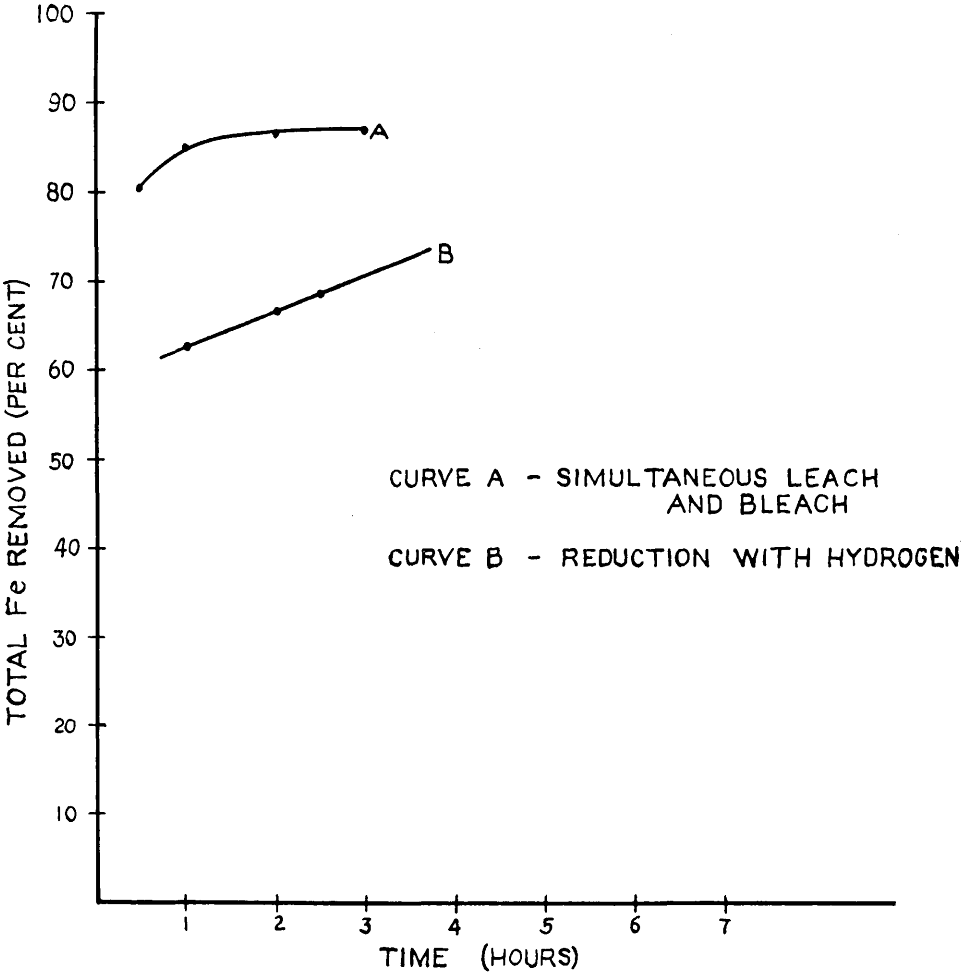


Fig. 3. Variation in iron removal with time of leach and bleach and reduction with hydrogen

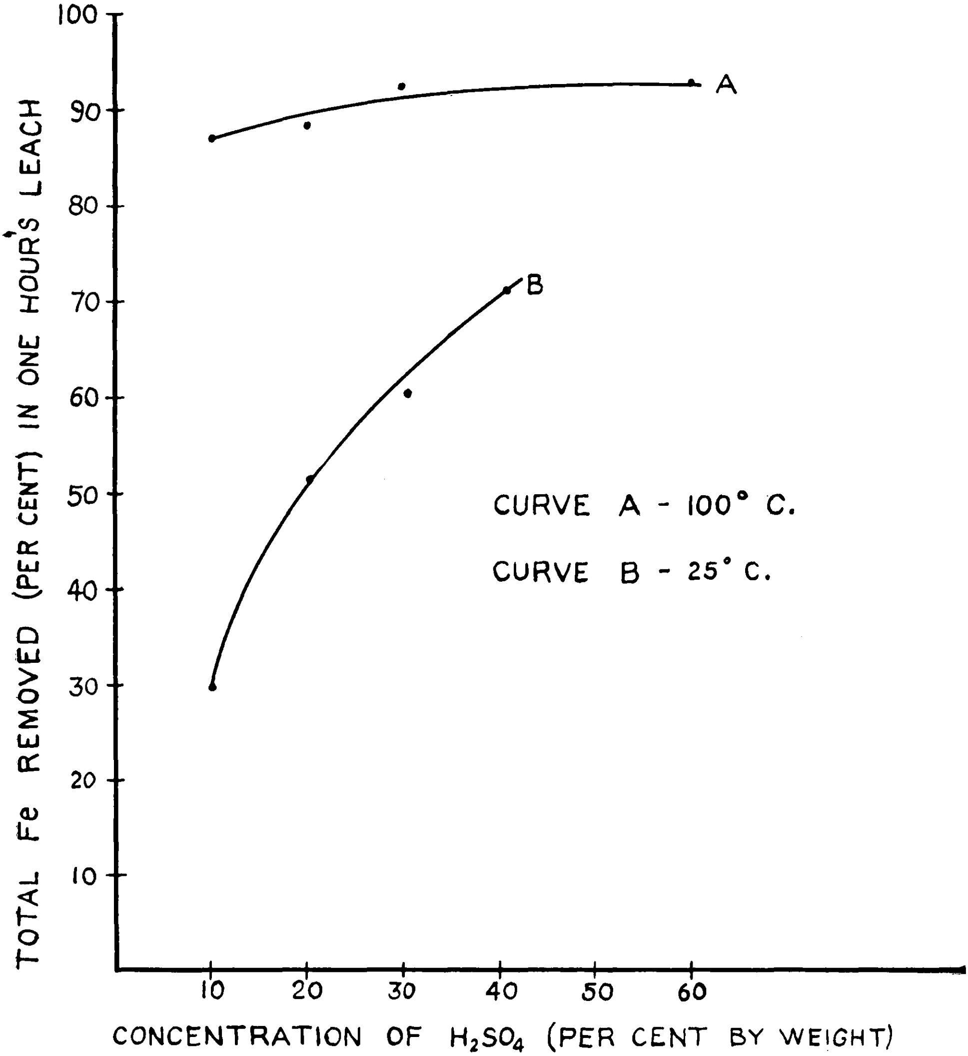


Fig. 4. Leaching with sulfuric acid solution, small samples

$0.85 per ton of clay treated (See Appendix B). The cost of reconcentrating the acid from fifteen to twenty-five per cent would be $1.00 per ton of clay, as shown under *Sample Calculations* in Appendix C. By experimental investigation, it was observed that about twenty per cent of the acid used would be lost in the washings or retained by the clay. This loss seems unnecessarily large and probably could be greatly reduced with large scale equipment. The acid lost would cost about $3.00 per ton of clay using twenty-five per cent acid strength as a leach, bringing the total to $4.85 per ton of clay treated. Other items, such as labor, equipment and depreciation, could not safely be predicted until development of an operating cycle on a pilot plant scale.

Removal of Carbonaceous Material[3]

Clay, used as a filler and coater in the paper industry, or as an extender in the rubber industry, needs only whiteness and certain physical properties to make it commercially valuable. Maine clays possess the desired physical characteristics but are grey-blue in color. Several methods were tried to remove this color: (1) bleaching, (2) flotation, and (3) solvent extraction.

Bleaching Methods. Samples for bleaching were taken from clay that had the iron leached out of it. A basic bleach was first tried by mixing the clay slurry with a small amount of lime in a flask and introducing chlorine from a cylinder. Reaction of chlorine with the milk of lime furnished the OCl^- ion necessary for the bleaching action. Considerable change of color was observed in thirty minutes bleach with no further change after one hour. The product was quite white, a little short of the desired whiteness however, because of a faint grey cast.

Varying amounts of lime were then used in the bleach, and it was noticed that as the bleach became more and more acid, the product became greyer until a bleach with no lime gave little or no color change. A combination of acid plus alkaline bleach was then used but the product was no whiter than from the straight alkali bleach. Readings were taken during some of the runs to follow the pH of the bleach liquor.

On visual examination, the samples were slightly under the whiteness desired, so it was decided to try titanium dioxide as a base exchange medium in the bleach. At first the results were good, but the

[3]Report of The State Geologist 1945-46, Me. Geol. Survey.

proportion of titanium to clay was high and would result in considerable added expense. Titanium dioxide in amounts as small as two per cent does aid the bleach, but the desired whiteness is not achieved.

Flotation. As previously stated, a scum of black particles formed on the surface during the leach. To a certain extent, the scum could be skimmed off. On examination the scum appears to be amorphous carbon. The investigation of the possibility of floating off the carbonaceous material from the clay seemed to be the next logical step.

Various collectors for carbonaceous material were tried on small samples of clay slurry in a beaker. Air was blown through to give the necessary bubble formation. Of the collectors used, Armac T. D. Cocoa fat, cresylic acid, and pine oil, pine oil was the only one that was effective. With pine oil a black scum forms in the oil on the surface of the slurry. Attempts were made using bleached and unbleached clay both in an acid and alkaline medium. A sample was run in a laboratory size flotation cell with pine oil as collector to observe any difference in color between product and tailings.

Solvent Extraction. It was suggested by Dr. A. N. Winchell that extraction be tried using a long chain alcohol. This suggestion was followed, using isopropyl ether instead of the alcohol. Several attempts were made using both pure water and 7.5 normal hydrochloric acid as a dispersion medium for the clay. The clay and ether were put in a Woulff bottle and agitated several hours with a laboratory size agitator. The ether and clay layers were separated and extraction continued with fresh ether. A total of six hours were consumed in extraction with both mediums.

Results of Carbon Removing Experiments

The procedures of experiments to remove the carbonaceous material have been presented. The results of these experiments follow.

Bleaching Methods. The clay bleached with two per cent titanium dioxide in an alkaline medium, shows the best degree of whiteness that the author was able to obtain. Whether the effect of the titanium dioxide was chemical or physical is unknown. However, in a visual comparison with Georgia kaolin, this sample is a little under the desired whiteness.

Various shades of off-white resulted from a straight alkaline chlorine bleach, depending upon the amount of lime used. Clay bleached with a four per cent milk of lime showed very good whiteness, but as the lime strength decreased, the product became greyer until, with only a chlorine bleach, there was no color change. Figure 5 shows the pH variation during the bleach. With an acid chlorine bleach, there was evidence of some iron removed in the wash water, while an alkaline bleach did not show this.

During these alkaline bleaches, the greatest color change was noted in the first half hour, with little or no change after one hour. There was also evidence of better clay settling when dispersed in an alkaline medium.

Flotation Methods. Flotation as a means of decolorizing the clay gave very poor results. Pine oil was the only agent that gave any visual evidence of collecting the carbonaceous matter. The oil would collect the material in a scum on the surface but various attempts with oleic acid and other frothing agents would not froth it over when air was bubbled through.

However, it was possible to skim some of this black substance off. This was done several times with a small sample, followed by a chlorine bleach. There was no apparent change in whiteness with this method.

When a sample of clay was run in the flotation cell in a soda ash circuit, there was good bubble formation, and some carbonaceous material seemed to be collected in the bubbles. However, when the product and tailings were dried, there was no color distinction between the two.

Solvent Extraction. The result of solvent extraction in removing coloring material from the clay was unsatisfactory. The greatest color change was noticed when the raw clay was extracted. When bleached clay was extracted with ether, there was only a slight color differential. More research must be undertaken using solvents, but results of this preliminary work are disappointing.

Conclusions

From the previous results and discussion these conclusions are drawn:

1. It is possible to remove above ninety per cent of the iron from the clay; the clay will then burn to a white color.

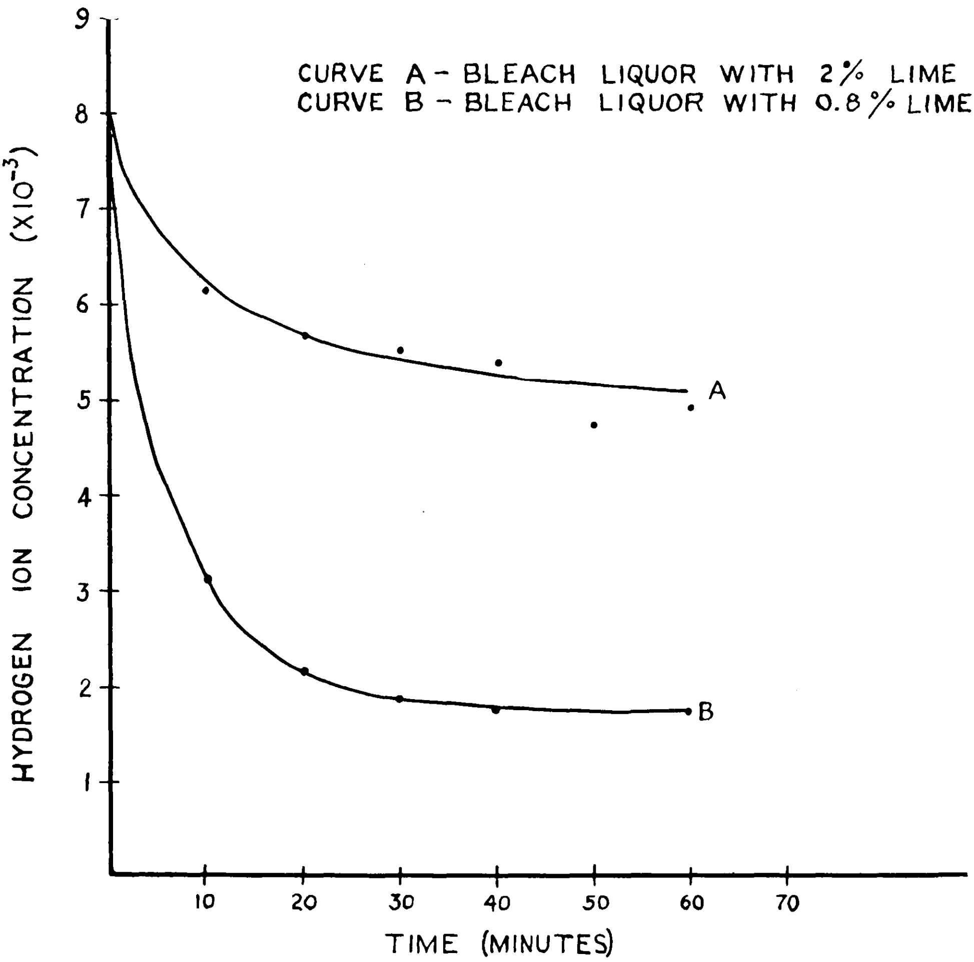


Fig. 5. Variation of hydrogen ion concentration during bleach

2. More than seventy per cent of the iron can be removed during the first thirty minutes' leach. A commercial process which would remove the iron content to the necessary 0.3 per cent would take from one to three hours.

3. The most economical process for removing the iron would be a high temperature, high concentration (25 to 30%) sulfuric acid leach with agitation.

4. It is possible to bleach the clay fairly white with an alkaline bleach. Two per cent titanium dioxide can be added for slightly better results. The clay thus whitened could be used in the paper or rubber industry, in special cases where a high brightness is not necessary.

Recommendations

It is recommended:

1. That in industrial application of the sulfuric acid leach to remove iron, a counter current cycle be used as shown in Figure 6.

2. That a means of settling the clay be found so that much time can be saved in washing out the solubilized iron.

3. That pilot plant studies be made on iron removal to obtain a more accurate cost and operating cycle.

4. That the thixotropy of the clay be investigated for possible industrial use.

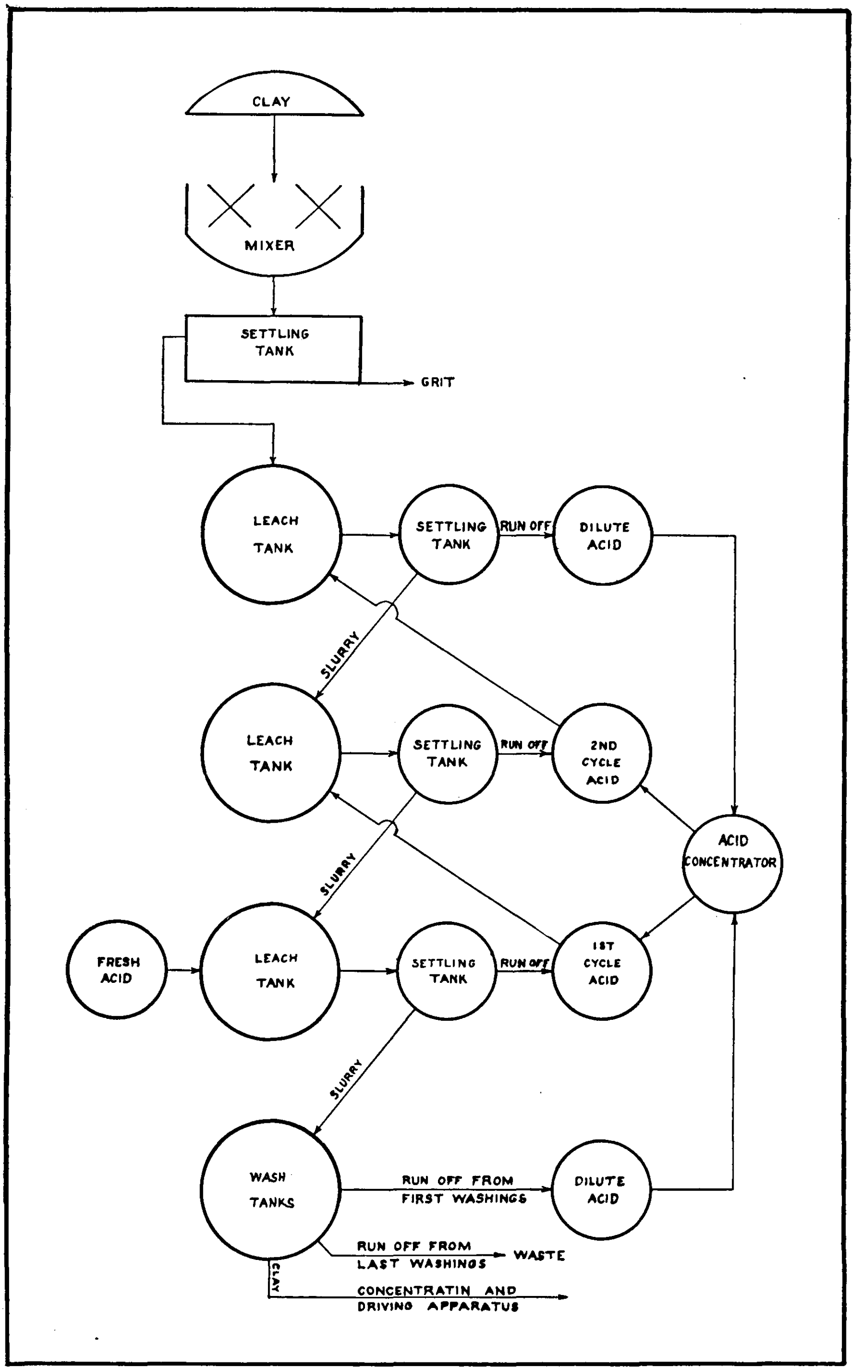


Fig. 6. Schematic flow sheet for clay bleaching plant

APPENDIX A

Details of Procedure

1. *Steam Agitation.*

In the runs using steam agitation, the details are similar to Run 3 which is described. Eight pounds of clay, as found, were mixed to a thin paste with a half-liter of water in a five gallon crock. To this was added one liter of water and one liter of concentrated sulfuric acid. Live steam of 40 p.s.i.g. was admitted to the crock at a rate sufficient to keep the temperature between seventy and eighty degrees Centigrade. The volume content was measured with a meter stick and more acid added as the volume increased to keep the concentration of acid constant.

Samples of the slurry taken at various time intervals were washed with hot water until there was no further positive test for iron, and saved for later analysis.

After leaching for five hours, the clay was allowed to settle and the acid decanted. The clay was then washed seven times to completely remove the soluble iron. On ignition to a low red heat, the clay turned a light pink color showing iron still to be present.

More acid and steam were added to the mixture and the reaction continued for six more hours. At the end of this time, the clay on burning was white showing that the iron had been almost, if not completely, removed.

A total of eight liters of acid were used in leaching and ten washes were necessary in removing the solubilized iron. Since the clay is colloidal in nature, the process of washing and settling was very time consuming.

2. *Mechanical Agitation.*

The agitator used was a high speed Lightning agitator rotating at 1750 r.p.m. Before leaching, the crock was fitted with a lead coil to permit indirect steam heat. Ten pounds of clay were mixed to a twenty-five per cent solids with forty pounds of twenty per cent sulfuric acid. The steam was admitted to the coil until the temperature of the mixture reached 85°C. in one run and 50°C. in the other. Agitation was continuous. Samples were taken every hour and saved for later iron analysis. The mixture was leached for a total of five hours, washed free of iron, dried and ground for submitting to various companies for experimental purposes.

During the run at 85°C., a large amount of carbonaceous material was observed frothing to the top. This was collected and dried for later examination. Also, when agitation ceased the mixture would set to a gel structure which broke down again under agitation.

3. *Operation of Flotation Cell.*

The machine used was a 1000 gram Denver "Sub-A" Flotation Cell. The cell was filled three-fourths full of water and a small amount of clay slurry was added. Agitation was started and the valve opened to admit air to the bottom of the cell. Ten per cent soda ash solution was added as a conditioner and the slurry was agitated several minutes. Then a few drops of sodium silicate were added as a depressant for the clay minerals, together with some pine oil as a collector for the carbonaceous material. A froth was immediately formed on top of the mixture—the bubbles seeming to contain some of the carbonaceous material. The froth was floated off by increasing the speed of agitation, and subsequently dried. The tailings or residue from the cell was also dried and a comparison made between the residue and froth.

4. *Method of Solvent Extraction.*

Twenty-five grams of leached clay, one-half liter of water and 250 ml. of isopropyl ether were put into a Woulff bottle to which was attached a reflux condenser to condense any ether volatilized. A small laboratory mixer was used for agitation. After three hours' agitation, the ether and water layers were separated and extraction continued with 250 ml. of fresh ether.

Three of these extractions were made for a total of ten hours contact between the clay slurry and the ether. The water layer with its clay content was dried and compared with the original.

Another extraction was made using 7.5 normal hydrochloric acid instead of pure water as a dispersing medium for the clay. Since a similar method has been used to extract iron from solution, it was thought that this might give some advantageous results.

5. *Analytical Procedure for Iron Determination.*

The clay sample, washed free of soluble iron, was dried from five hours to twelve hours at 110°C. and pulverized very fine in a mortar and pestle. Approximately one gram of the clay was fused with five grams of sodium carbonate in a platinum crucible for twenty minutes. The melt was dissolved in dilute hydrochloric acid until only undissolved silica remained. The silica was filtered from the solution containing the iron. The iron in solution was reduced from the ferric to ferrous state by slow addition of stannous chloride solution (60 gr. $SnCl_2$ in 600 ml. HCl and 400 ml. H_2O) until the yellow color of ferric iron disappeared. The excess of stannous chloride was neutralized with a saturated solution of mercuric chloride.

Fifteen ml. of sulfuric-phosphoric mixture (150 ml. conc. sulfuric acid plus 150 ml. conc. phosphoric acid diluted to 1 liter) and three drops of diphenylamine indicator were added to the solution. The solution was then titrated with 0.1 N potassium dichromate solution until there was a color change from deep green to violet blue.
1 ml. 0.1 N $K_2Cr_2O_7$ = 0.0056 gr. Fe.

6. *Determination of pH of Bleach.*

The hydrogen ion concentration of the clay slurry during the bleach was determined by the use of Cambridge Electron-ray pH meter—industrial model. Ten ml. samples of the bleach were taken every ten minutes for this determination. This instrument was designed to measure directly either in pH units or in E.M.F. units.

APPENDIX B

Sample Calculations

1. *Iron Content of Leached Clay—Run* 6.

A. Thirty minutes leach

Weight of sample = 1.0146 grams
1.5 ml. of 0.1 N $K_2Cr_2O_7$ used in titrating iron solution
1 ml. of 0.1 N $K_2Cr_2O_7$ = 0.0056 gr. Fe

$$\text{Per cent Fe in sample} = \frac{1.5 \times .0056}{1.0146} \times 100 = 0.82\%$$

Per cent Fe in original clay = 3.65%

$$\text{Per cent Fe removed} = \frac{3.65 - 0.82}{3.65} \times 100 = 77\%$$

B. The same procedure as above was used in the calculation of the per cent iron removed in all runs.

2. *Cost Data on Iron Removal.*

Amount of Fe removed to give a white product =
3.65 − 0.30 = 3.25%
Lbs. of iron removed/ton of clay = 0.0325 × 2000 = 65 lbs. Fe

The primary reaction was assumed to be:

$$Fe^{++} + H_2SO_4 = FeSO_4 + 2H^+$$

Then acid consumed per ton of clay is:

$$55.8:98 = 65:\text{lbs. } H_2SO_4$$

Lbs. of H_2SO_4 = 114

$$\text{Cost of acid consumed} = \frac{114}{2000} \times \$15.00/\text{ton} = \$0.85/\text{ton of clay}$$

By using a 20% clay slurry or one ton of clay to four tons of 25% H_2SO_4, one ton of conc. H_2SO_4 will be used per ton of clay reacted.

By interpolation from the curves of Burke and Mantius (5), approximately 2500 pounds of steam per ton of concentrated H_2SO_4 would be needed to concentrate the 15% acid (after washing) to 25% strength for reaction.

Cost of concentrating acid = 2500 × \$0.40/1000 lbs.
= \$1.00 per ton, conc. acid

\$1.00 × one ton of conc. acid = \$1.00 per ton of clay

Assuming, from experimental evidence, that 20% of the acid used will be lost in wash water and retained by the clay, the cost of waste acid is:

$$2000 \text{ lbs.} \times .20 \times \frac{\$15.00}{2000 \text{ lbs.}} = \$3.00 \text{ per ton of clay}$$

The cost of iron removal per ton of clay, relative to acid treatment only, is as indicated:

Cost of acid consumed	= \$0.85
Cost of concentrating acid	= \$3.00
Cost of waste acid	= \$1.00
Total	= \$4.85 per ton of clay.

PRELIMINARY REPORT OF THE PEGMATITES ON RED HILL, RUMFORD, MAINE*

By VINCENT E. SHAININ

Abstract

Five major beryl-bearing pegmatites have been mapped and studied on Red Hill, Rumford, Maine. The pegmatites are discordant, tabular or lens-shaped bodies. In general, they strike within a few degrees of north and dip approximately 60° E.

The pegmatites possess a zonal structure, consisting, in general, of border zone, wall zone, intermediate zone, core-margin zone and core. The estimated composition of each zone is given, including percentage of beryl, based on beryl-counts on surface exposures.

Beryl reserves have been estimated for each zone to a depth of 50 feet down dip. The total inferred reserves are about 520 tons.

Introduction

The Newry-Rumford area, Oxford County, in western Maine (Fig. 1) contains economically important and geologically significant pegmatites. A long-term study of the geology of the region was begun in 1946, as a cooperative project of the Maine Geological Survey and the United States Geological Survey. The project is a continuation of earlier cooperative studies of the pegmatites of Topsham, Maine.[1]

Twenty-five weeks were spent in detailed and areal mapping in the summer months of 1946, 1947 and 1948. Five major pegmatites (Map VI) on Red Hill, Rumford, have been mapped and studied in detail; most of Newry Hill, Newry, has been mapped and studies of the pegmatites there are continuing; and mapping of pegmatites in the Plumbago-Puzzle Mountain region is in progress.

Method of Field Work and Acknowledgments

The pegmatites on Red Hill were mapped at a scale of 60 feet per inch with a five-foot contour interval, by alidade and plane-table (Map VI).

The cooperative studies of pegmatites in Maine have been carried out under the direction of the writer assisted by Kurt E. Biehl and William H. Condon in 1946, Paul L. Cloke, Wallace J. Cropper, John J. Donohue, William A. Linton, Charles A. Sandberg, Harlan P. Beach and K. K. Menon in 1947, and Paul L. Cloke, Edward W. Perkins and Hans H. Adler in 1948.

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*Published by permission of the Director, U. S. Geological Survey.

[1]Shainin, Vincent E., *Economic Geology of Some Pegmatites in Topsham, Maine:* Maine Geological Survey Bull. 5, 1948.

Location and Access

The Red Hill pegmatites are in the town of Rumford, Oxford County, Maine, 4.5 miles due west of the city of Rumford. To reach the deposits from the city, proceed 6.1 miles westward on U. S. Route 2 to Rumford Center, then northwestward on a town road 2.0 miles to an intersection with a dirt road. Drive northward on this road, turning right at the first fork and passing the Red Hill Schoolhouse. At the second fork, turn right 0.4 mile to the house of J. Albert Blaine and follow the road that leads approximately 2,000 feet southward to Red Hill.

History

The pegmatites on Red Hill were first prospected in the summer of 1946 by the Whitehall Company, Keene, N. H., for feldspar. At this

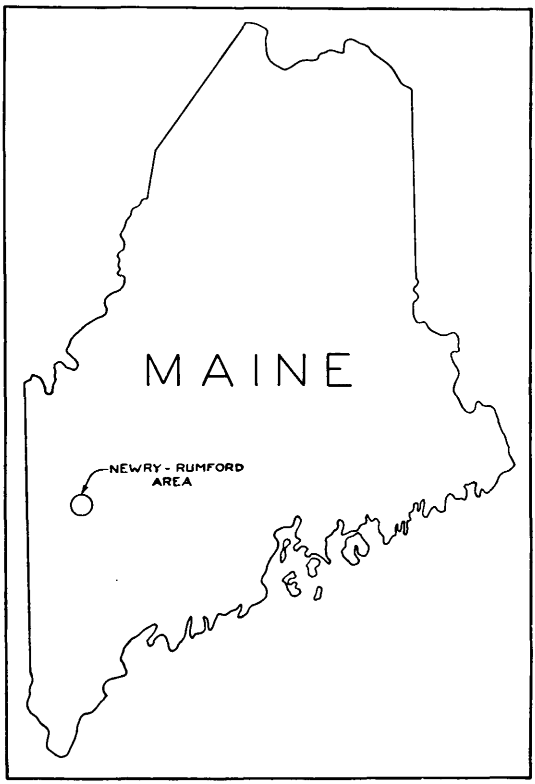


Fig. 1. Index Map, Newry-Rumford Area

time cut No. 1 and cut No. 2 (Map VI) in the Ridge pegmatite and cut No. 1 in the West pegmatite were opened. In the summer of 1947 cut No. 1 in the Central pegmatite was excavated and cut No. 3 was opened in the Ridge pegmatite.[2] The Whitehall Company ceased work at Red Hill in 1947. About 100 tons (chiefly from cut No. 3, Ridge pegmatite) were stockpiled and sold to United Feldspar Company, West Paris, Maine.

Geology

General

Red Hill is underlain by medium-grained metasediments consisting of alternating layers of quartz-mica schist and quartzite. The quartzite layers vary in abundance and range in thickness from one-quarter inch to two feet. Staurolite porphyroblasts occur locally as twinned prisms in the schist. Garnet and tourmaline crystals are present in the schist adjacent to pegmatite, but are uncommon.

The mestasediments have been isoclinally folded and the foliation is parallel to bedding on the limbs of the folds. Foliation and bedding generally range in strike from due north to a few degrees east of north. The average dip is 70°-75° eastward. Adjacent to rolls or other irregularities in the pegmatite-contacts, the attitude of foliation and bedding is variable, but tends to conform with the pegmatite-contacts. Lineation, represented by the axes of minor folds in the schist, plunges generally 40°-60° N. 60° E.

Five large pegmatites have been mapped on Red Hill, but several other smaller pegmatites are exposed in the vicinity. One of these, known as Pegmatite 507, is shown in the geologic map (Map VI). In general, the pegmatites are tabular bodies that strike north or a few degrees east of north. In strike, they are roughly parallel to the schist, but appear to dip eastward at slightly lower angles than foliation and bedding.

Rolls in the contacts of the West, Black Bear and Cliff pegmatites plunge from north to N. 30° E. at angles of 35° to 68°, parallel to the plunge of lineation in the schist. This suggests that these pegmatites may plunge north to northeastward at moderate angles. Because the Ridge and Central pegmatites are roughly similar in strike and dip to those named above, it seems likely they may have similar plunges.

[2]The names used in this report, with the term "pegmatite," serve only as a convenient means of reference and in no sense are they to be considered formal stratigraphic names.

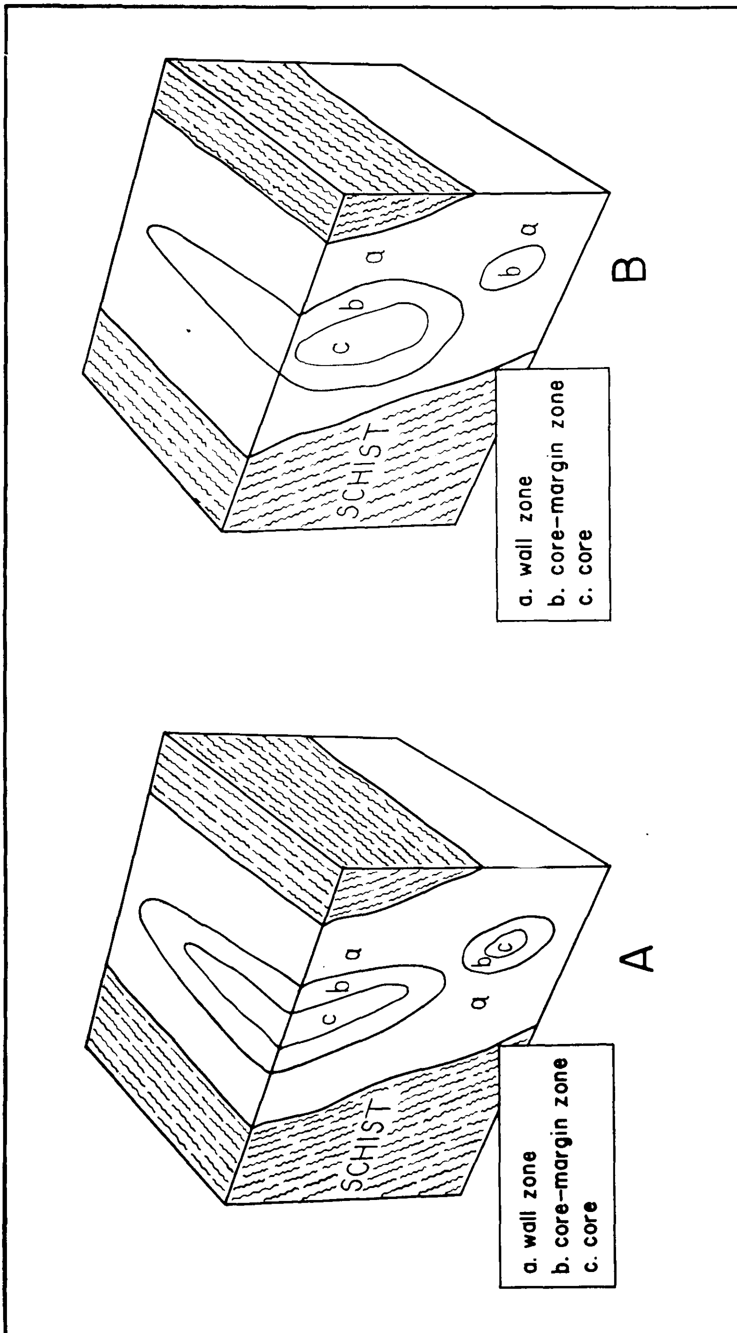


Fig. 2. Schematic block diagrams showing relations between cores and core-margin zones

Internal Structure of Pegmatites

In some pegmatites, the component minerals form essentially uniform mixtures. Others are zoned; that is, their minerals are grouped into lithologic units of contrasting composition or texture that have a systemmatic arrangement with respect to the walls of the pegmatite. In ideal development, the zones of a pegmatite are successive shells concentric around an innermost core. Brief summaries on the internal structure of pegmatites have been published recently.[3]

The names of zones used in describing the Red Hill pegmatites are defined as follows: (See Fig. 2)

1. Border zone. A narrow, fine-grained shell that constitutes the outermost zone in a pegmatite. In most places this zone is too narrow to be shown on the map.
2. Wall zone. The next zone inside the border zone.
3. Intermediate zone. Any zone that lies between the wall zone and the core. The name "core-margin zone" is used occasionally for the intermediate zone which lies just outside the core.
4. Core. The innermost zone of a pegmatite.

The term "unit" is used for any distinct mappable part of a pegmatite.

Ridge Pegmatite

Form and Attitude. The Ridge pegmatite is a slightly crescent-shaped sheet that is concave toward the east and it strikes roughly north and probably has an average dip of about 60° E. Neither end of the pegmatite is exposed, but mapping indicates that it is probably about 2,030 feet long. It has an average thickness of approximately 45 feet.

An aplitic quartz-plagioclase rock, part of which shows a faint foliation, occurs in the wall zone in several places. A large mass of this fine-grained rock occurs in the vicinity of the No. 1 and No. 2 cuts (Map VI). Other masses, too small to show on the map, occur elsewhere. The rock is light gray, fine-grained, and contains specks of garnet, pyrite, and triphylite or another bluish phosphate. Some parts

[3]Heinrich, E. Wm., "Pegmatites of Eight Mile Park, Colorado", *American Mineralogist*, vol. 33, Nos. 7 and 8, pp. 436-442, 1948.

Shainin, V. E., "Economic Geology of Some Pegmatites in Topsham", Maine, *Maine Geological Survey, Bull.* 5, 1948.

of the rock are stained light blue, probably by a phosphate. Subangular blocks of the rock were quarried during excavation of the No. 3 cut. The aplitic rock appears to occur as inclusions in the pegmatite since quartz pods and muscovite books of the wall zone commonly occur with their long dimensions perpendicular to the contact between the pegmatite and the aplitic rock.

Internal structure. Five units have been recognized in this pegmatite. These are, from the walls inward:

1) The border zone of quartz-plagioclase-muscovite pegmatite occurs in a zone one-half inch to one foot thick. The grain-size of the zone is one-quarter to one inch in diameter and the zone is estimated to contain quartz (50 per cent), plagioclase (35 per cent), and muscovite (15 per cent).

2) The wall zone of quartz-plagioclase-perthite pegmatite is from one to one hundred feet thick and in places occupies the full thickness of the pegmatite. The average grain size is one to two inches in diameter. This unit is estimated to contain quartz (50 per cent), plagioclase (25 per cent), perthite (15 per cent), muscovite (9 per cent) and accessory minerals (1 per cent). The accessories include triphylite, vivianite, carbonate (siderite?) apatite, eosphorite and an unidentified blue phosphate. Grain counts over 100,361 square inches of the zone indicate that the beryl content is 0.02 per cent.

3) The core-margin zone of quartz-perthite-beryl pegmatite has an average thickness of 4 feet. The grain size ranges from one-quarter inch to 3 feet in diameter. The unit is estimated to contain quartz (45 per cent), perthite (40 per cent), muscovite (8 per cent), and albite (some cleavelandite, 6 per cent), with the accessory minerals triphylite, purpurite, beryl, a carbonate (siderite?), and pyrite. Grain counts of 87,120 square inches of the zone indicate a beryl content of 0.21 per cent. Quartz and perthite are coarse-grained. Beryl occurs as white to pale green prisms that average approximately 2 inches in length and 1 inch in diameter.

4) Perthite-quartz pegmatite as eight core segments or pods is unevenly distributed throughout the wall zone (Map VI). The largest is 55 feet long and 15 feet wide, but few are well enough exposed to provide accurate measurements. The pods appear to be limited in extent down dip as well as along strike, but it is possible that two or

more pods may join in depth to form a larger body. The grain size of the quartz-perthite pegmatite is commonly 2 to 5 feet, and it is estimated to contain equal amounts of quartz and perthite with minor amounts of muscovite, beryl and cleavelandite. Grain counts of 49,636 square inches of the zone indicate a beryl content of 0.003 per cent. The segment of the core prospected in the No. 3 cut was richer in perthite than exposures of other segments would indicate as normal for the zone. In the No. 3 cut, the zone consists of approximately 90 per cent perthite, and 10 per cent quartz. The core is closely related genetically and in composition to the core-margin zone; the core-margin zone formed when the coarse perthite and quartz, which characterize the core, began to crystallize late in the pegmatite's history. It is possible, therefore, that a core-segment of considerable size may lie below the core-margin zone at the point indicated by coordinates N40, W10, on the geologic map (Map VI).

5) A unit of muscovite-plagioclase-quartz pegmatite, one to six feet thick, has a grain size of three-quarters of an inch to one inch, although one beryl crystal is 14.5 inches long and 5.0 inches in diameter. The unit is estimated to consist of 60 per cent pale green muscovite, 25 per cent plagioclase, 13 per cent quartz and 1.65 per cent beryl.

Only three beryl crystals were observed in 5,017 square inches of exposure of the unit and their dimensions are: 14.5 x 5.0 inches, 2.0 x 1.3 inches, and 5.0 x 1.5 inches. Although this unit has the highest indicated percentage of beryl in the pegmatite, it is extremely local and occurs chiefly in the vicinity of the No. 1 and No. 2 cuts. A very small area of this unit was observed in the headwall of the No. 3 cut but it could not be shown on the map. It lies between the core and the core-margin zone.

West Pegmatite

Form and Attitude. The West pegmatite (Map VI) is a lenticular body which strikes N. 7° E. and has an average dip of 65° E. It has a maximum thickness of approximately 145 feet near the southern end, and gradually tapers to about 5 feet at the northern end. The average thickness is about 65 feet. The exact length of the pegmatite is unknown, but mapping indicates that it is probably about 1,720 feet long. The plunge of a roll in the hanging wall at coordinates S200; W200 (Map VI) is 35° N. 17E., and lineation in the schist plunges, in general, 40°-60° N. 60 E.

Internal structure. Five zones in the pegmatite have been recognized. These are, from the walls inward:

1) A border zone of quartz-plagioclase-muscovite pegmatite, one to two inches thick, with a grain-size of one-sixteenth to one-quarter of an inch. The zone is estimated to consist of 50 per cent quartz, 40 per cent plagioclase, and 10 per cent muscovite.

2) A wall zone of quartz-plagioclase-perthite pegmatite has an average thickness of 4 feet and an average grain-size of one inch. The zone is estimated to contain 45 per cent quartz, 40 per cent plagioclase, 10 per cent perthite, and 4 per cent muscovite. Accessory minerals are beryl, purpurite, and columbite-tantalite.

Mineral counts of 19,533 square inches of the zone indicate a beryl content of 0.15 per cent. The crystals average approximately one inch in length and one-third inch in diameter. The crystals are simple euhedral, white to pale green prisms.

3) An intermediate zone of quartz-perthite-plagioclase pegmatite, one to 135 feet thick in which the grain-size is variable: individual grains range in diameter from 1 inch to 1.5 feet. The zone is estimated to contain quartz (40 per cent), perthite (40 per cent), plagioclase (15 per cent), and muscovite (5 per cent). Accessories are triphylite, sphalerite, beryl, apatite, and eosphorite, and purpurite. There are traces of pyrite. Quartz and muscovite occur commonly in parallel intergrowths; such intergrowths are rare in the wall zone.

Beryl occurs in white to very pale greenish crystals that average one and a quarter inches long and an inch wide. A crystal from the No. 1 cut contains 12.8 per cent BeO (determined from indices of refraction). Mineral counts of 68,166 square inches of the zone indicate a beryl content of 0.06 per cent.

4) A core-margin zone of quartz-perthite-beryl pegmatite occurs as small pod-shaped areas which probably represent either core-segments or envelopes which surround core-segments close to the surface (Map VI and Fig. 2).

The zone occurs in two small areas each about ten feet in diameter and except for the presence of approximately 0.2 per cent beryl, this zone can be easily confused with the core which it resembles in texture and composition.

The grain size of the unit averages one to two feet, and the zone is estimated to contain quartz (50 per cent), perthite (50 per cent), and beryl (0.20 per cent, indicated by mineral counts of 6,804 square inches of the zone). Beryl crystals are simple prisms, white to very pale green, the average diameter of which is approximately two inches. (The length is not known because the crystals were observed in cross section).

5) The quartz-perthite core occurs as separate pods unevenly distributed throughout the intermediate zone. Nine of these pods have been mapped. Few are well enough exposed to enable accurate measurements. They range from a few feet in diameter to approximately 75 feet long and 30 feet thick. They may be limited in extent down dip as well as along strike. It is possible that two or more pods may join in depth to form a larger body.

The crystals are coarse, commonly 2 to 5 feet in length. The rock is estimated to contain 48 per cent quartz, 48 per cent perthite, and 3 per cent muscovite. Accessories are triphylite and beryl. Mineral counts of 13,910 square inches of the zone indicate a beryl content of 0.10 per cent. The beryl occurs as white to very pale green euhedral prisms, with an average diameter of one and a half inches and length of five inches.

Central Pegmatite

Form and Attitude. The Central pegmatite is an irregularly shaped lens in plan; it strikes about N. 20° W. and dips 55°-60° E. It is thickest at the southern end. It has an average thickness of approximately 40 feet. The exact length of the body is unkown, but mapping indicates that it is probably about 255 feet long.

Internal Structure. Four zones in the pegmatite have been recognized. These are, from the walls inward:

1) A border zone of quartz-plagioclase-muscovite pegmatite that has an average thickness of one inch and a grain-size of one-quarter to one inch. The zone is estimated to contain quartz (50 per cent), plagioclase (40 per cent) and muscovite (10 per cent).

2) A wall zone of quartz-plagioclase-perthite pegmatite has an average thickness of ten feet and a grain-size of one half to one inch. The estimated mineral composition is quartz (45 per cent), plagioclase (25 per cent) perthite (20 per cent), muscovite (10 per cent), minor amounts of pyrite and beryl (0.02 per cent, based on a mineral count of 103,680 square inches of the zone).

Beryl occurs in scattered simple euhedral prisms, white to very pale green in color. The average length is one and a half inches and the average diameter is a third of an inch.

3) A core-margin zone of quartz-perthite-beryl has an average thickness of 2 feet and an average grain size of one to two feet. This unit is estimated to contain 60 per cent quartz, 40 per cent perthite, and 0.32 per cent beryl. The beryl content is based on a mineral count of 19,008 square inches of the zone.

Beryl occurs in white to very pale green or very pale golden prisms. The average size is 6 inches long and 2 inches in diameter. The crystals tend to occur in groups or clusters and lie on the margin between quartz and perthite. One crystal from the northern end of the core contains 12.8 per cent BeO (determined from indices of refraction).

The zone has been recognized only on the footwall margin of the core. The core-margin zone is difficult to identify unless exposures are large, because it is similar to the core in texture and composition. It differs from the core only in that it possesses approximately 0.3 per cent beryl.

4) The core of quartz-perthite pegmatite is one hundred and sixty feet long and has an average thickness of ten feet. The grain-size is one to six feet and the estimated composition is 60 per cent quartz and 40 per cent perthite. No beryl was observed in the core.

Black Bear Pegmatite

Form and Attitude. The Black Bear pegmatite is a tabular, lens-shaped body which trends north and strikes N. 5° W. It dips approximately 60° E. The exact length is not known, but mapping indicates that it is probably about 405 feet. The average thickness is 35 feet. (Map VI).

At coordinates N125; E300, there is thumb-shaped bulge (Fig. 3) in the hanging wall. Schist in contact with pegmatite is exposed only on the underside of the bulge. The schist has been altered by pegmatitic solutions to a layer of fine-grained, white to gray aplitic quartz-plagioclase (?) rock in which relic foliation of the schist is preserved. The thickness of this granitized layer is 3 to 4 inches. Separating it from unaltered schist is a layer, one-half to three-quarters of an inch thick, of small white to pale green, simple, euhedral beryl prisms. The crystals average half an inch in length and 0.2 inch in diameter.

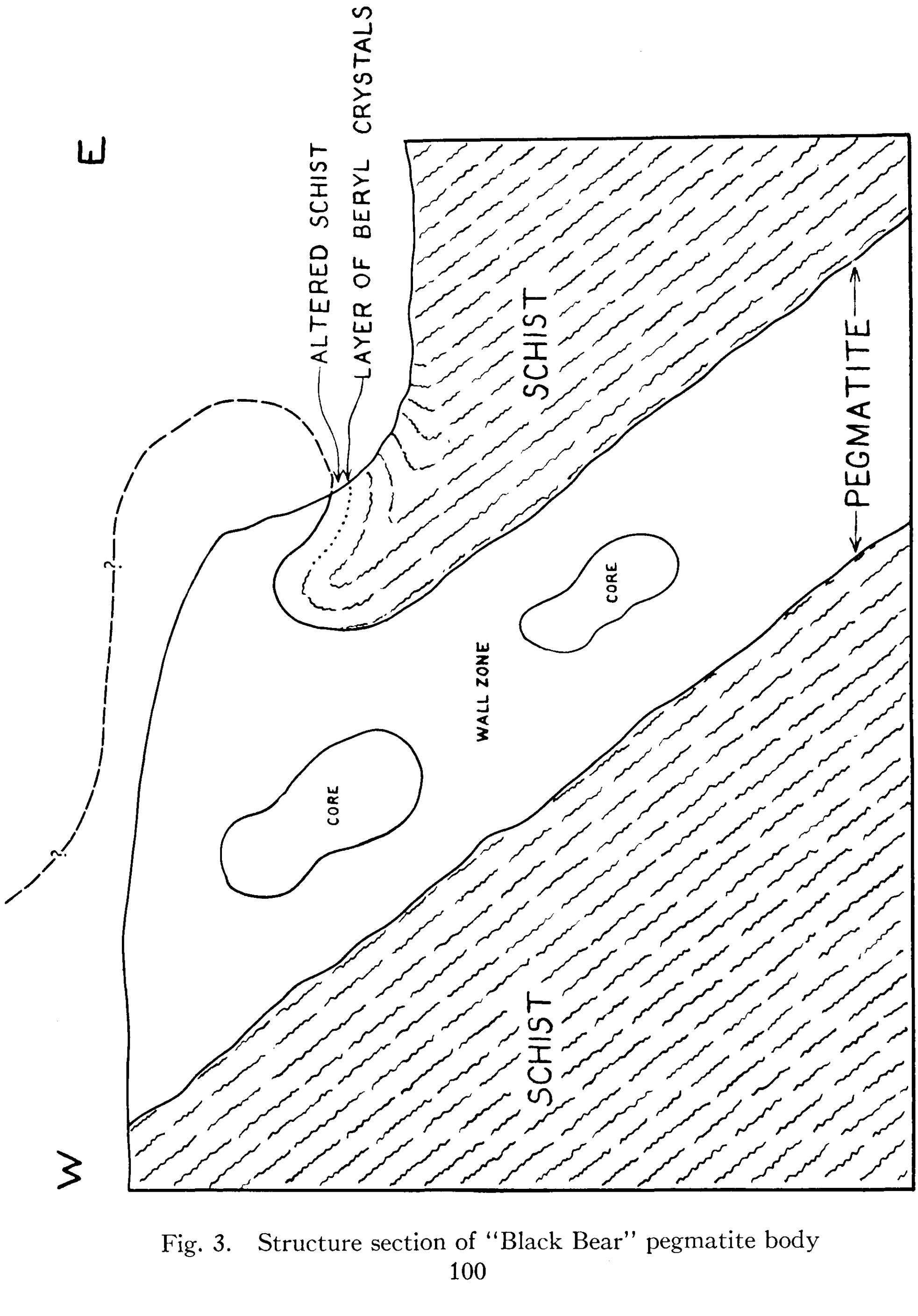


Fig. 3. Structure section of "Black Bear" pegmatite body

Approximately 480 beryl crystals are exposed in this layer. In places the crystals overlap to form an almost unbroken sheet in which the c-axes of the prisms are subparallel to the foliation. Foliation in the schist wraps around the beryl crystals on the outside (schist side) of the layer. The beryl-rich layer contains approximately 75 per cent beryl. Feldspathized and unaltered schist make up the remainder. A beryl crystal from the beryl-rich layer in the schist was estimated to contain 13.25 per cent BeO by measurement of its indices of refraction. This is higher than any BeO content recorded for crystals in the Ridge, West and Central pegmatites.

The feldspathized and beryl-rich layers are exposed for a strike-length of 20 feet only adjacent to the under side of the bulge in the locality described above. Both layers are missing in other places where the contact is exposed. Unless evidence were available indicating a more extensive occurrence of this very local deposit, beryl reserves in the schist should be considered as negligible. Further studies of this beryl occurrence, including spectrochemical analysis of schist samples, are now under way.

Internal Structure. The following zones were recognized in the pegmatite, from the walls inward:

1) A border zone of quartz-plagioclase-muscovite pegmatite is two inches thick, and has a grain-size of one-sixteenth to one-half inch. The zone is estimated to contain: quartz (50 per cent), plagioclase (40 per cent), and muscovite (10 per cent). Accessory minerals are garnet and beryl. Beryl constitutes approximately 0.05 per cent of the zone. This figure is based on a beryl count of approximately 15,000 square inches of the zone.

2) The wall zone of quartz-plagioclase-perthite pegmatite is four inches to thirty-five feet thick and has an average grain-size of one inch. The estimated mineral content is: quartz (50 per cent), plagiolase (25 per cent), perthite (20 per cent), and muscovite (5 per cent). Accessory minerals are garnet and beryl. A mineral count of 5,616 square inches of the zone indicates a beryl content of 0.03 per cent. The beryl crystals average half an inch in length and 0.4 inch in diameter.

3) The core of quartz-perthite pegmatite occurs as separate pods unevenly distributed throughout the wall zone. Two of these pods have been mapped. One measures eight by three feet and the other,

poorly exposed, is at least ten feet in diameter. The average grain-size of the minerals in this unit is one foot and the unit contains equal amounts of quartz and perthite.

Cliff Pegmatite

Form and Attitude. The Cliff pegmatite appears to be a lens-shaped body that strikes approximately north and dips about 55 degrees eastward. The exact length of the pegmatite is unknown, but mapping indicates that this pegmatite is probably about 210 feet long. It is probably about 70 feet thick (true thickness) at the center of the lens at the surface.

Internal Structure. Three zones have been recognized, and they are, from the walls inward, as follows:

1) A border zone of quartz-muscovite-plagioclase pegmatite that is one to three inches thick and has a grain-size of one-sixteenth to one-quarter inch. It is estimated to contain quartz (60 per cent), muscovite (30 per cent), and plagioclase (10 per cent).

2) A wall zone consisting of quartz-plagioclase-perthite occupies the full thickness of the pegmatite except for the border zone and core. The average grain-size of this unit is one inch and the mineral content is estimated to be: quartz (40 per cent), the plagioclase (35 per cent), perthite (20 per cent), muscovite (5 per cent), and beryl (0.07 per cent). The content of beryl is based on a mineral count of 7,308 square inches of the zone. The crystals average one inch in length and 0.3 inch in diameter. They appear to occur in groups or clusters.

3) The core of quartz-perthite pegmatite appears to be a single body approximately 60 feet long and 30 feet thick. The average grain-size is one to two feet and the zone is estimated to contain quartz (60 per cent), perthite (38 per cent), and muscovite (2 per cent).

Beryl Reserves

Basic data contained in the geologic map and mineral counts of surface exposures permit inferences as to the reserves of beryl in the pegmatites. The inferred reserves, calculated to a depth of 50 feet, constitute approximately 520 tons of beryl. No indications have so far been found that the pegmatites terminate at shallow depth; nevertheless, the bodies may end, or their thickness or zonal structure may change in depth. Consequently, core-drilling is required to give assurance that the bodies actually exist in depth with the characteristics noted at the surface. Sites for proposed diamond-drill holes that would provide desirable geologic information are shown on Map VII.

SHORE STUDIES

By J. M. Trefethen

In any evaluation of Maine's natural assets, the shore zone ranks high indeed. Many will agree that nowhere else in the United States can be found its scenic equal. The potential of tidal power, and the utilization of our natural harbours and coastal thoroughfares are, of course, well known. In addition to these physical aspects, however, are biologic assets. Although perhaps less widely recognized, thriving and economically significant industries are based on the biological resources of the shore zone. Among these the harvesting of the soft shell clam, *Mya arenaria*, is outstanding. According to a bulletin of the Maine Department of Sea and Shore Fisheries ("The Maine Clam," by Robert L. Dow and Dana E. Wallace) the annual dollar value of the clam harvest has increased sevenfold in the past decade. Based on retail prices, the value of clam production is estimated by the Department of Sea and Shore Fisheries to be not less than $25,000,000, of which some one to two million dollars are paid directly to the producers.

During the course of its biological research, the Maine Department of Sea and Shore Fisheries has found that some clam flats have deteriorated and that others have improved as habitats for the clam. Because there are, possibly, factors of the physical environment which can be correlated with the productivity and growth of clams, geological investigations have been cooperatively undertaken by the Maine Geological Survey and the Maine Department of Sea and Shore Fisheries. The first of this projected series of cooperative geological investigations was begun in the field season of 1948. Although laboratory work has yet to be completed, the following preliminary report by Mr. Donohue indicates the scope of the research as currently outlined, and something of the field approach. Investigations of this type are in a pioneering stage. So far as known this is the first state sponsored investigation of this particular kind undertaken in this country.

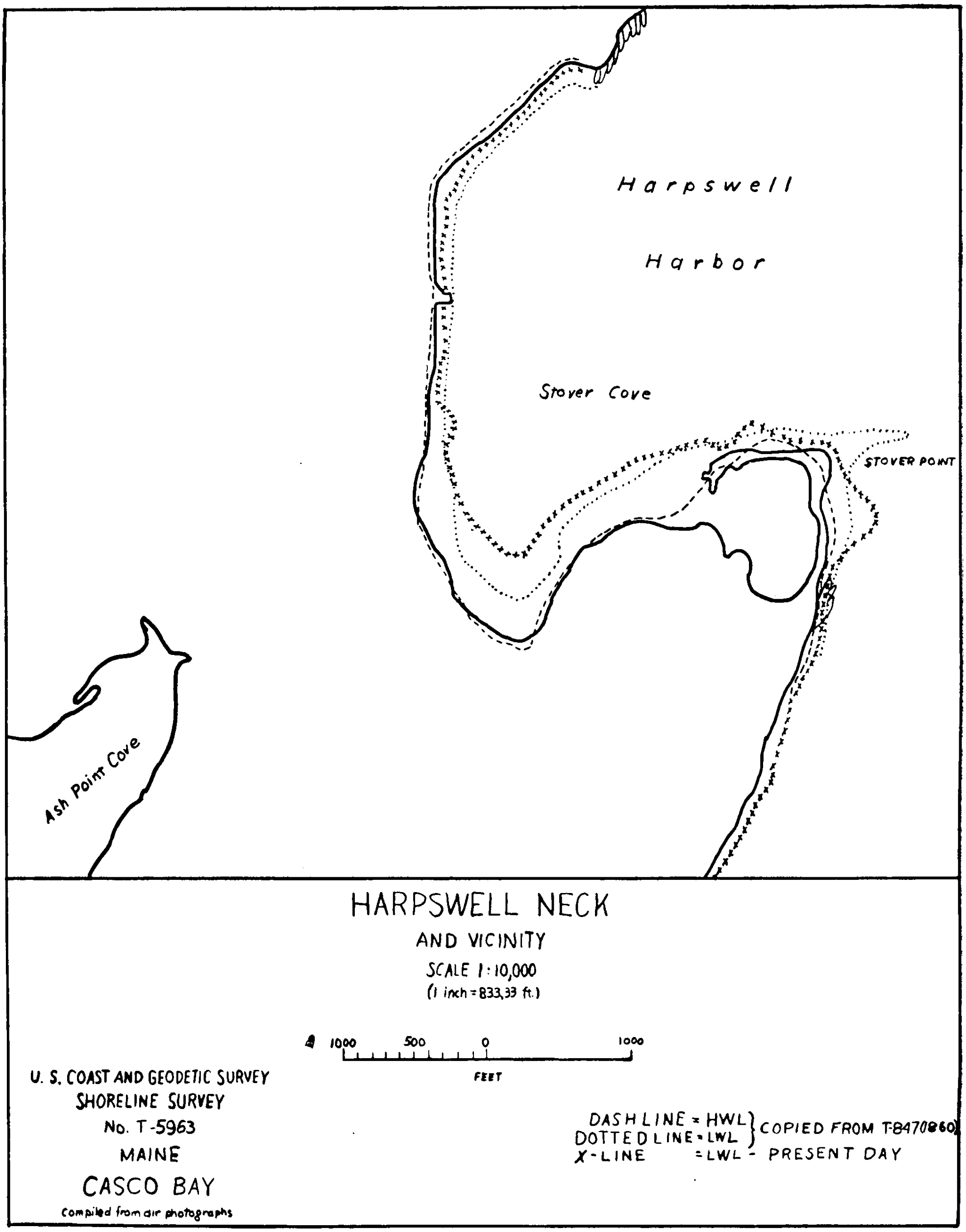


Fig. 1. Comparison of charts made in 1860 and 1941 of Harpswell Neck Area

Shore Studies--Stover's Cove, South Harpswell, Maine

By John J. Donohue

Introduction:

During the months of July, August and part of September, 1948, a field investigation of the sediments of Stover's Cove, South Harpswell, Maine, was conducted. It is hoped that the investigation will yield information pertinent to the growth of the *Mya arenaria* (soft shell clam).

Stover's Cove is located at the distal end of the east shore of the Harpswell peninsula (commonly called Harpswell Neck) in the town of South Harpswell, Maine.

The sediments of the Stover's Cove shore zone can be grouped as follows:

1. The main spit consisting of sand and mixed pebbles grading into a heavy cover of large pebbles and mixed cobbles in the direction of low tide.
2. An area of glacially striated bed rock.
3. An area of silty sand and broken shells.
4. An area of storm spits consisting of coarse to fine sand and grading into a heavy cover of medium to large pebbles.
5. An area of "clay boils."
6. A silt area at the head end of the cove dissected by fresh water drainage.
7. An area of gradationally distributed sediments which range from sand with small pebbles to a heavy cover of large pebbles and small cobbles.
8. An area of boulder pavement.

A comparison of U. S. Coast and Geodetic Survey shore line maps, (Fig. 1) 1860 and 1941, shows marked changes in the positions of high and low tide markings. From these charts it appears that the cove shore zone has been aggraded.

The Field Problem:

The problems of the field investigation are multiple. Clams live in a soil environment—hence, a study of the sediments between high and low tides is indicated. That these unconsolidated sediments are subject to physical change, by wave and current action, and to chemical change, by percolating sea water, fresh water, decomposition of organic matter and waste products of the living organisms is evident, and must be considered in the program of field investigation.

The aspect of physical change of the sediments has been approached by mapping their present surface distribution and by detailing many soil profiles. Penetrometer tests of the sediments at many places have also been made. The study of chemical aspects of the sediments has been limited so far to only one measurement which could be taken easily in the field, the pH of the soil samples. A determination of the organic matter has been left for more detailed laboratory studies. The reason for making precise pH measurements in the field is because the measurements have to be taken within a few hours to avoid securing an altered pH reading brought about by temperature changes and organic decomposition. It is believed that the pH of the soil is an important factor in the thriftiness and growth of *Mya arenaria.*

Field Procedure:

A provisional field classification was established for the sediments present which is subject to revision after laboratory sieving and hydrometer analysis. A modification of Wentworth's Scale was employed in classifying pebbles, cobbles and boulders.

A field laboratory for electronic pH meter recordings, map work, microscopic work and sample preparation was set up a few miles from the cove. Samples were stored and properly marked for future laboratory work to be done at the State Geological Laboratories at the University of Maine. Clam counts, size measurements, age determinations and dissections along with other relavent biological work was also done at the field laboratory.

Before a systematic collection of soil samples, water samples, penetrometer recordings, clam population data, test pits and biological specimens could be collected, a large scale map 1/240 (1″ = 20′) with a contour interval of one foot was made. This mapping was done with a telescopic alidade and a plane table.

A series of maps is under preparation which will include:

A. Topography

B. Distribution and classification of surface sediments.

C. Distribution and classification of sub-surface sediments, to a depth of one and one-half feet below the surface.

D. Contouring of the soil pH.

E. Contouring of the penetrometer recordings.

F. *Mya arenaria* colonization.

G. The location of test pits from which soil samples, Penetrometer recordings, soil profiles, *Mya* counts, and other biological specimens were taken.

The final classification of the sediments involved can only be determined by detailed laboratory analysis, i. e., sieving and hydrometer analysis. Such analysis is at present being conducted at the State Geological Laboratories at the University of Maine. Sediment samples were taken from depths greater than that occupied by *Mya arenaria* in order to secure some information concerning those sediments as well as those of the actual clam habitat itself.

It is believed that the acidity and alkalinity (pH) of the soil in which the Mya lives has a direct bearing. Therefore, detailed preparation of soils and exacting methods of determining the pH of soil samples was made in the field laboratory within a few hours after the samples were collected. Samples were sealed in air-tight jars and the temperature change of the samples was never greater than 2°C. from the time the sample was collected until its pH was determined by an electronic pH meter. The value of their measurements cannot be determined until the completion of the laboratory work and the correlation of the various data with the *Mya arenaria* counts. However, it was noted in the field that differences in the pH of certain of the soil samples was accompanied by differences in the sizes of Mya arenaria of the same ages. How strongly this will be bourne out in the final analysis cannot be stated in this preliminary report.

Penetrometer recordings were taken at test pit sites through the various horizons. It is possible that these recordings will be of value in determining the ability of the clam to burrow into certain soils of a known compactive resistance. Such recordings were taken under three main conditions (a) as the tide was retreating, (b) as the tide was advancing, and (c) when the test location was under water. As a matter of interest, the burrowing rate of the *Mya* was measured by timing a number of clams burrowing from the surface down into soil in one of the areas in which the compactive resistance of the soil was known. Time did not permit this approach to the problem over other areas, but it is thought that the combined recordings of the compactive resistance of the soil and the *Mya* population counts and growth rates, in any one of the test pits, will yield the necessary information not only of the ability of the *Mya* to burrow through soils of certain compactive resistance, but also of its ability to extend its siphon, in its quest for food, through a soil of known compactive resistance. Once the siphon hole has been made by the *Mya* this spihon hole remains for the duration of the life of that clam, unless unnaturally disturbed. The penetrometer recordings may prove of value in determining those soils, of certain compactive resistance, into which the *Mya* can imbed itself by burrowing thus aiding in the selection of areas for seeding. Local colonization of the *Mya* which is easily apparent by visual inspection of the surface sediments was mapped in detail. A concentration of such colonization was found in the silted area of the cove. It is logical that such colonization should take place in this area because the spat (seed clams) transported into the cove by wave and current action can imbed itself easily in this thick muck and it is also subject to less intense wave and current action. This area is apparently one of aggradation. Mapping of clam colonizations will prove of value in the comparison of growth rates and death rates of the clam in thickly populated and congested areas with those growth rates and death rates of the less thickly populated areas. Such a comparison may afford data on organic, physical and biological factors that may have a direct influence on the survival and growth of the clam.

Laboratory Work:

At this time, the data bearing on the problem are incomplete because of the detailed laboratory work that must yet be accomplished. Detailed investigations of samples collected in the field are now under way at the Maine Geological Survey Laboratories at the University of Maine. This investigation will include:

A. Comparative pH recordings (comparing the pH of soil samples as they occurred in their natural environment with that of the pH of the washed sample)

B. Mineralogical analysis.

C. Determination of organic content.

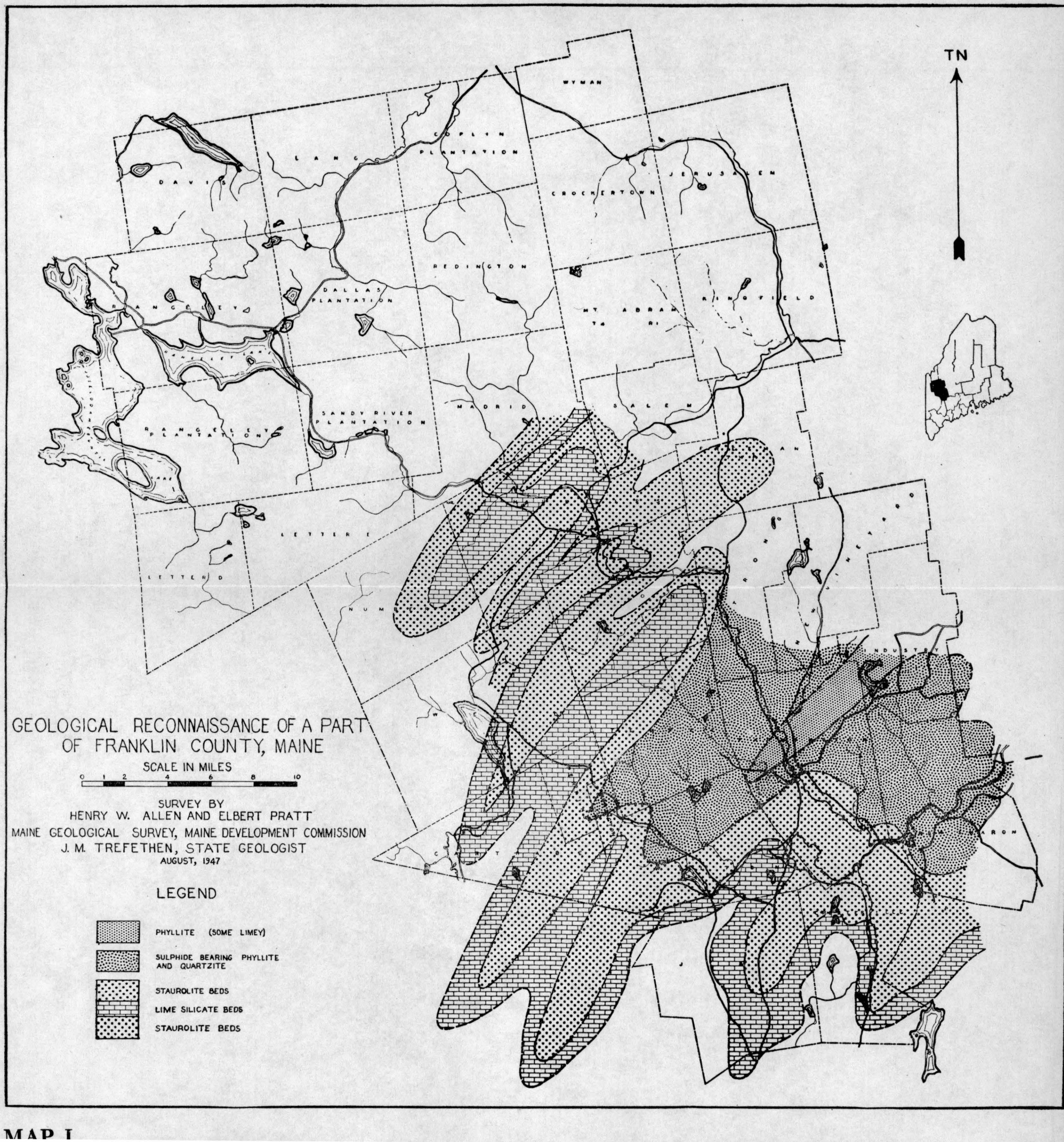
D. Mechanical analysis of the sediments.

   1. Size analysis
   2. Shape analysis
   3. Mass property analysis (Plasticity, etc.)

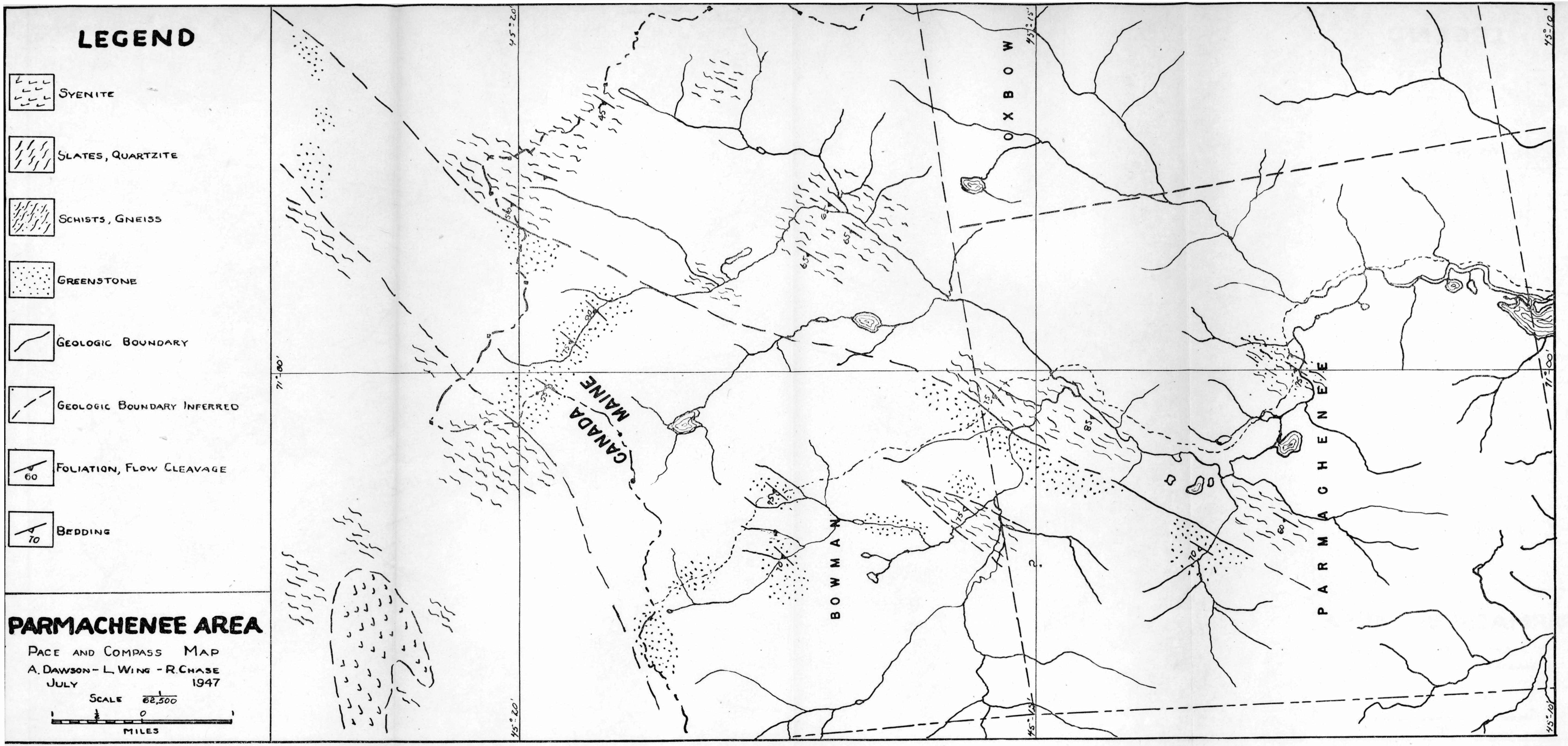
E. Water analysis ($H_2S + CO_2$ quantitative determinations.)

The crucial field area of this investigation appears to be the silt area and those areas immediately adjacent to it. Included as part of this report, is a map (Map VIII) of this area showing topographic contours and the surface distribution of the sediments of this area. This illustrates the field approach of these studies.

It is fully realized that the problems of this investigation are complex and that generally valid conclusions cannot be presented for solving the problem of the growth rates and death rates of the *Mya arenaria* by the investigation of a single area or by geological investigations alone, but it is hoped that the field work and laboratory work currently underway will offer certain information that will be of value. The ultimate answers to the practical questions posed by the maintenance and growth of clam production must be derived from an integrated biological-geological program of long continued research. The study reported upon here in its initial stages is but a beginning.

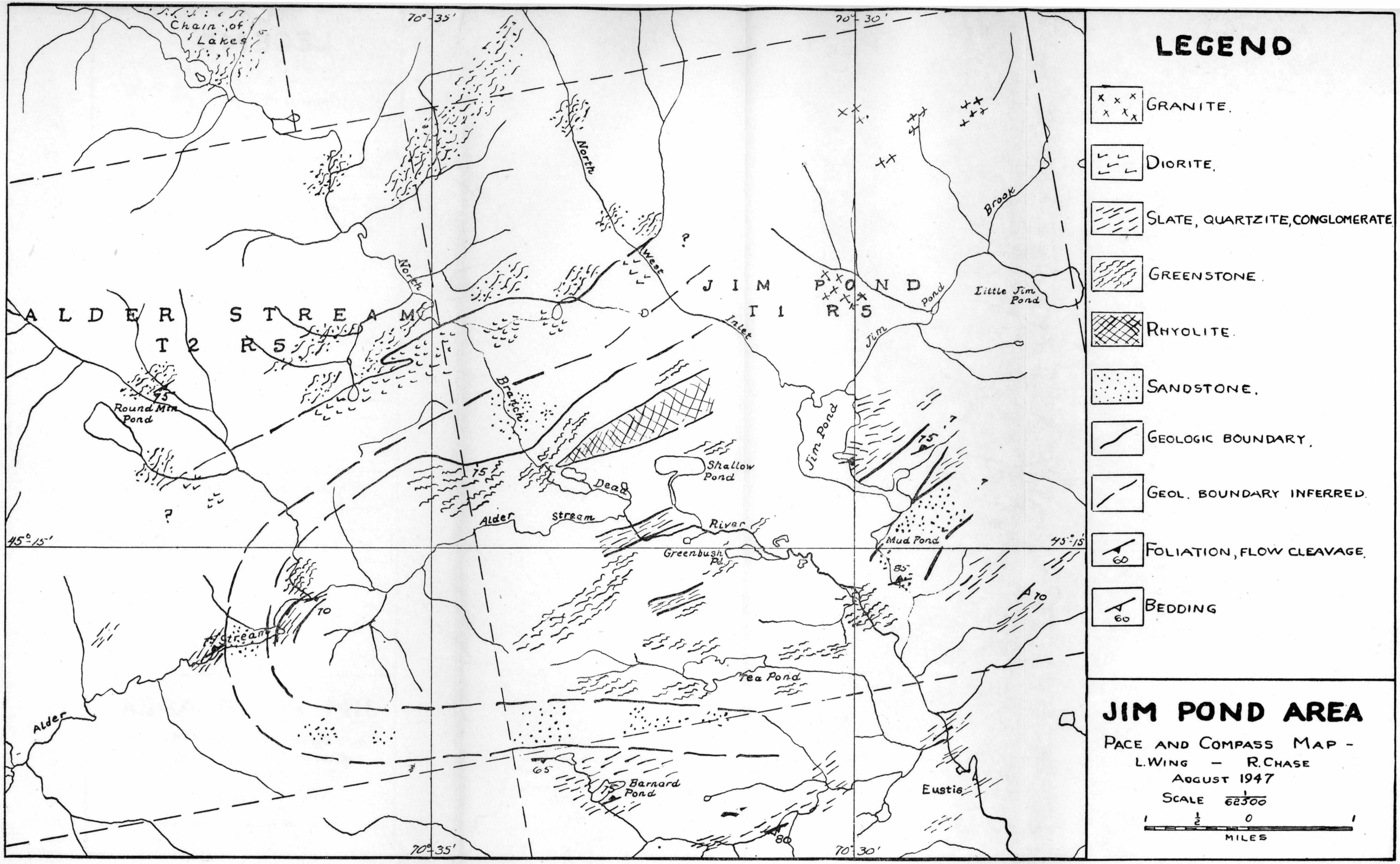

GEOLOGICAL RECONNAISSANCE OF A PART
OF FRANKLIN COUNTY, MAINE
SCALE IN MILES
0 1 2 4 6 8 10
SURVEY BY
HENRY W. ALLEN AND ELBERT PRATT
MAINE GEOLOGICAL SURVEY, MAINE DEVELOPMENT COMMISSION
J. M. TREFETHEN, STATE GEOLOGIST
AUGUST, 1947
LEGEND
PHYLLITE (SOME LIMEY)
SULPHIDE BEARING PHYLLITE AND QUARTZITE
STAUROLITE BEDS
LIME SILICATE BEDS
STAUROLITE BEDS
TN
WYMAN
DAVIS
LANG
COPLIN PLANTATION
CROCKERTOWN
JERUSALEM
REDINGTON
DALLAS PLANTATION
RANGELEY
KINGFIELD
RANGELEY PLANTATION
SANDY RIVER PLANTATION
MADRID
SALEM
INDUSTRY

MAP I

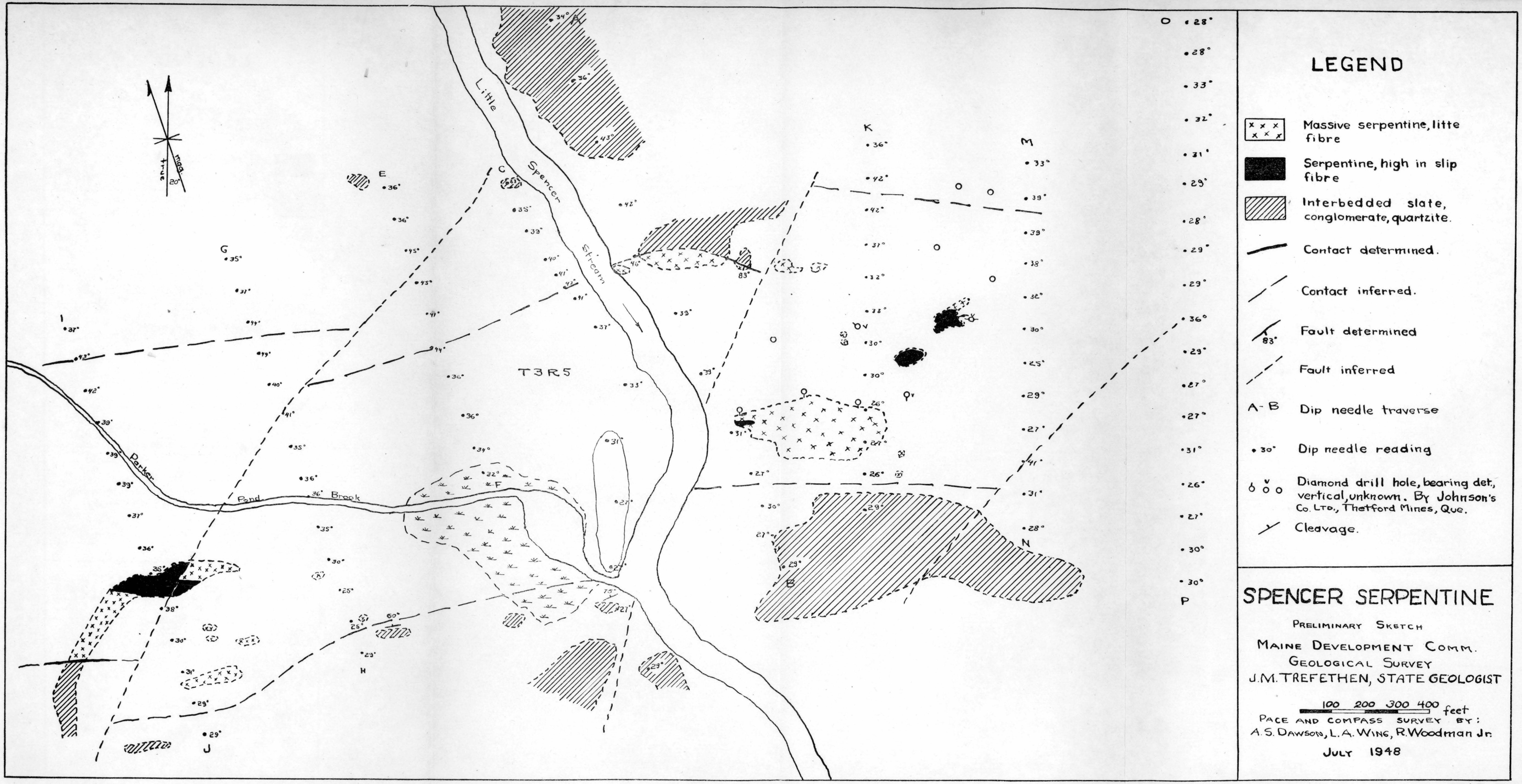


LEGEND
Syenite
Slates, Quartzite
Schists, Gneiss
Greenstone
Geologic Boundary
Geologic Boundary Inferred
Foliation, Flow Cleavage
Bedding
PARMACHENEE AREA
Pace and Compass Map
A. Dawson - L. Wing - R. Chase
July 1947
Scale 1/62,500
Miles
CANADA
MAINE
OXBOW
BOWMAN
PARMACHENEE

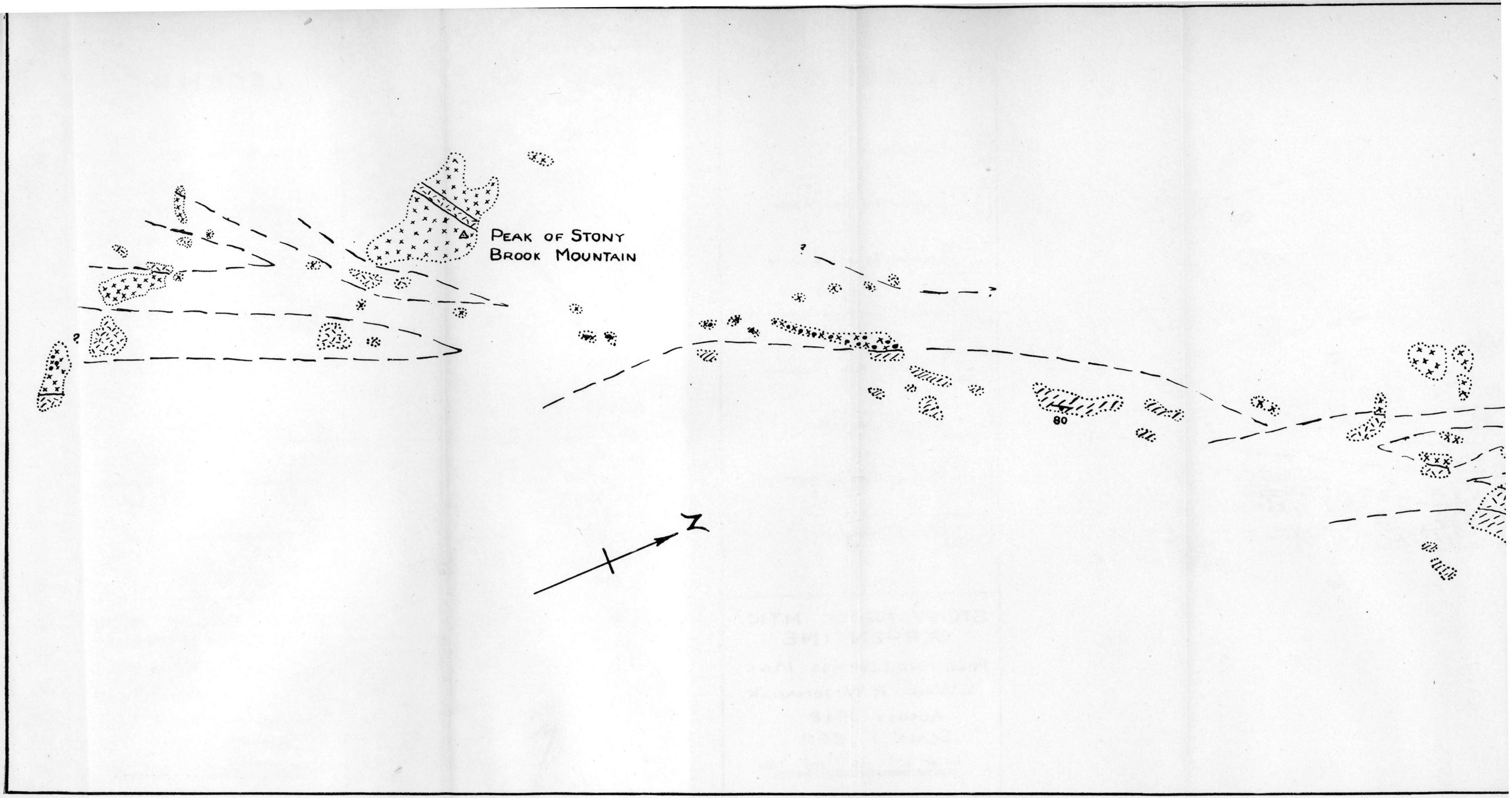
MAP II


LEGEND
GRANITE.
DIORITE.
SLATE, QUARTZITE, CONGLOMERATE
GREENSTONE
RHYOLITE.
SANDSTONE.
GEOLOGIC BOUNDARY.
GEOL. BOUNDARY INFERRED.
FOLIATION, FLOW CLEAVAGE.
BEDDING
JIM POND AREA
PACE AND COMPASS MAP -
L. WING - R. CHASE
AUGUST 1947
SCALE 1/62500
MILES
ALDER STREAM
T2 R5
JIM POND
T1 R5
Chain of Lakes
North
West
Inlet
North Branch
Jim Pond Brook
Little Jim Pond
Jim Pond
Round Mtn Pond
Shallow Pond
Dead River
Alder Stream
Greenbush Pd.
Mud Pond
Tea Pond
Barnard Pond
Eustis
Alder
Stream
70° 35'
70° 30'
45° 15'

MAP III

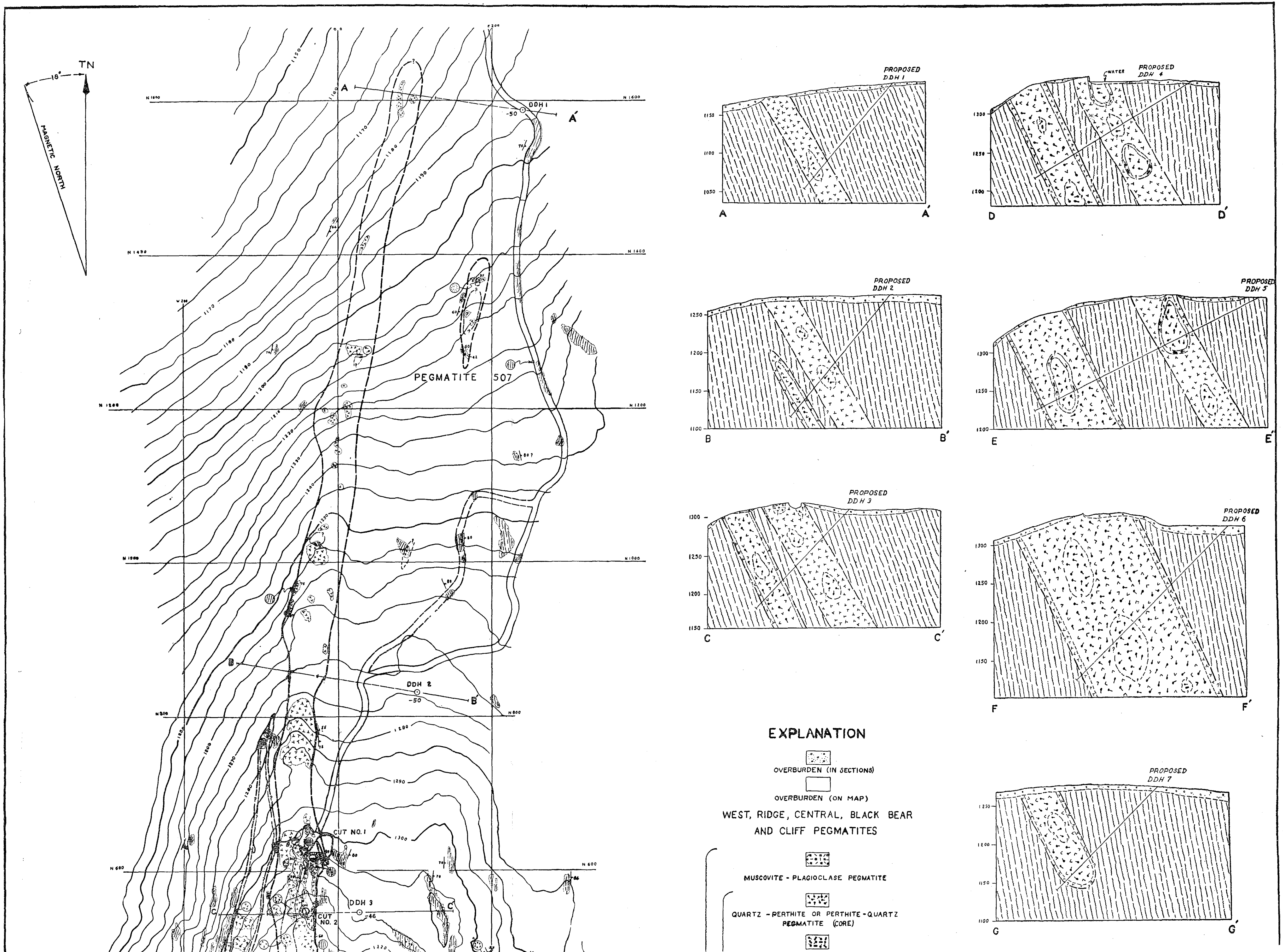

LEGEND
Massive serpentine, litte fibre
Serpentine, high in slip fibre
Interbedded slate, conglomerate, quartzite.
Contact determined.
Contact inferred.
Fault determined
Fault inferred
A-B Dip needle traverse
Dip needle reading
Diamond drill hole, bearing det, vertical, unknown. By Johnson's Co. Ltd., Thetford Mines, Que.
Cleavage.
SPENCER SERPENTINE
Preliminary Sketch
Maine Development Comm.
Geological Survey
J.M. TREFETHEN, STATE GEOLOGIST
100 200 300 400 feet
Pace and compass survey by:
A.S. Dawson, L.A. Wing, R. Woodman Jr.
July 1948
Little Spencer Stream
Parker Pond Brook
T3R5
true mag. 20°

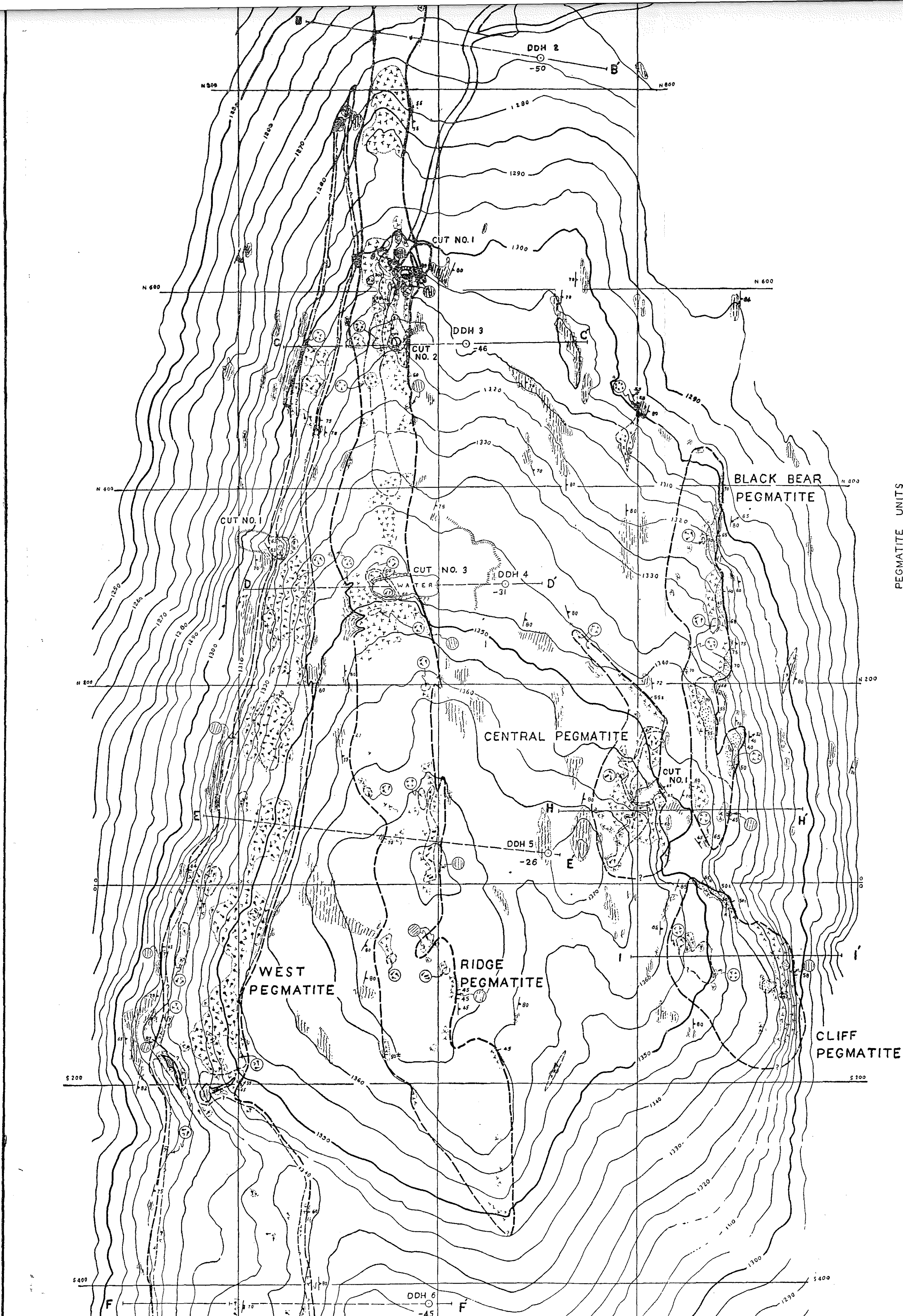
MAP IV



MAP V


LEGEND
Serpentine
Serpentine with Fiber
Diorite - Quartz Diorite
Interbedded Slate - Quartzite
Foliation - Flow Cleavage
Geologic Boundary
Geologic Boundary Inferred
Outcrop Boundary
STONY BROOK MTN.
SERPENTINE
Pace and Compass Map
L. Wing - R. Woodman Jr.
August 1948
Scale 1": 200
100' 50' 0' 100' 200' 300'
65
65
65
60


TN
18°
MAGNETIC NORTH
PEGMATITE 507
DDH 1
DDH 2
DDH 3
CUT NO. 1
CUT NO. 2
PROPOSED DDH 1
PROPOSED DDH 2
PROPOSED DDH 3
PROPOSED DDH 4
PROPOSED DDH 5
PROPOSED DDH 6
PROPOSED DDH 7
WATER
A A'
B B'
C C'
D D'
E E'
F F'
G G'
EXPLANATION
OVERBURDEN (IN SECTIONS)
OVERBURDEN (ON MAP)
WEST, RIDGE, CENTRAL, BLACK BEAR AND CLIFF PEGMATITES
MUSCOVITE - PLAGIOCLASE PEGMATITE
QUARTZ - PERTHITE OR PERTHITE - QUARTZ PEGMATITE (CORE)



EXPLANATION

OVERBURDEN (IN SECTIONS)

OVERBURDEN (ON MAP)

WEST, RIDGE, CENTRAL, BLACK BEAR AND CLIFF PEGMATITES

PEGMATITE UNITS

MUSCOVITE - PLAGIOCLASE PEGMATITE

ZONES

QUARTZ - PERTHITE OR PERTHITE - QUARTZ PEGMATITE (CORE)

QUARTZ - PERTHITE - BERYL PEGMATITE (CORE - MARGIN ZONE)

QUARTZ - PERTHITE - PLAGIOCLASE PEGMATITE (INTERMEDIATE ZONE)

QUARTZ - PLAGIOCLASE - PERTHITE PEGMATITE (WALL ZONE)

QUARTZ - MUSCOVITE - PLAGIOCLASE PEGMATITE (BORDER ZONE)

PEGMATITE 507

QUARTZ - PLAGIOCLASE - PERTHITE PEGMATITE (APPARENT CORE)

QUARTZ - MUSCOVITE - PLAGIOCLASE PEGMATITE (WALL ZONE)

QUARTZ - MUSCOVITE - PLAGIOCLASE PEGMATITE (BORDER ZONE)

QUARTZ VEIN

APLITIC GRANULITE

SCHIST AND QUARTZITE, INTERBEDDED

STRIKE AND DIP OF FOLIATION

STRIKE AND DIP OF JOINT

PLUNGE OF LINEATION WITH STRIKE AND DIP OF FOLIATION

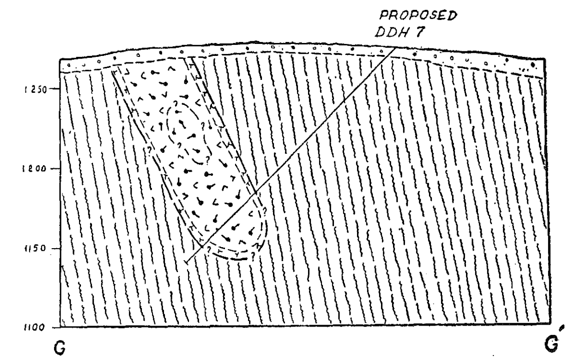
PLUNGE OF AXIS OF ROLL IN PEGMATITE CONTACT

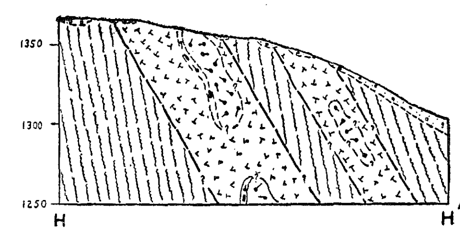
CONTACT WITH DIP (HEAVY LINES USED FOR CONTACT OF PEGMATITE WITH WALL ROCK)

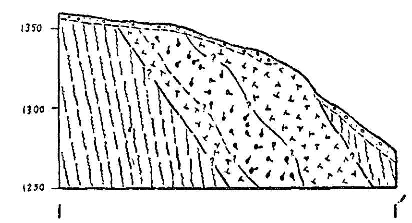
VERTICAL CONTACT

INFERRED CONTACT

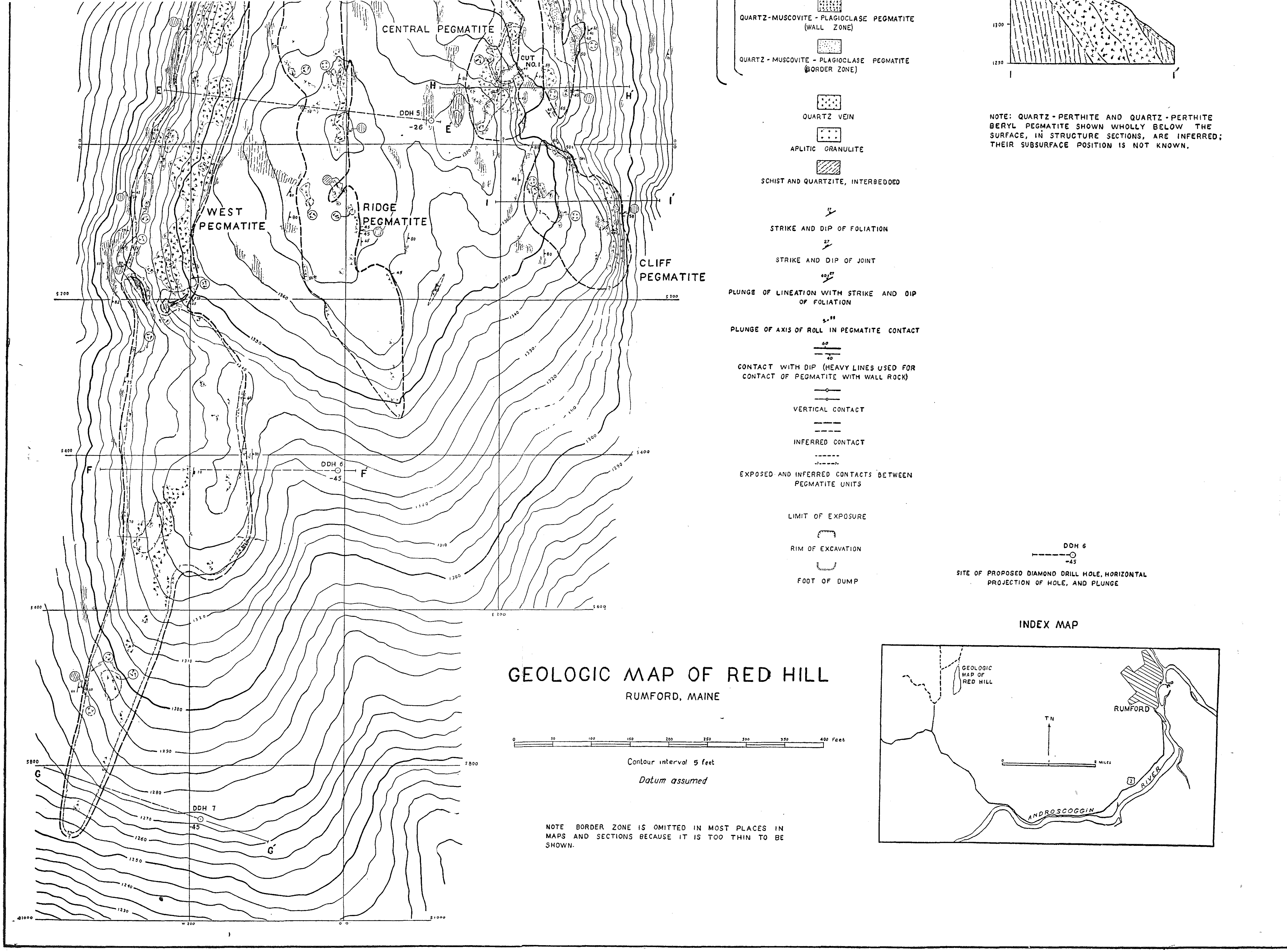
EXPOSED AND INFERRED CONTACTS BETWEEN







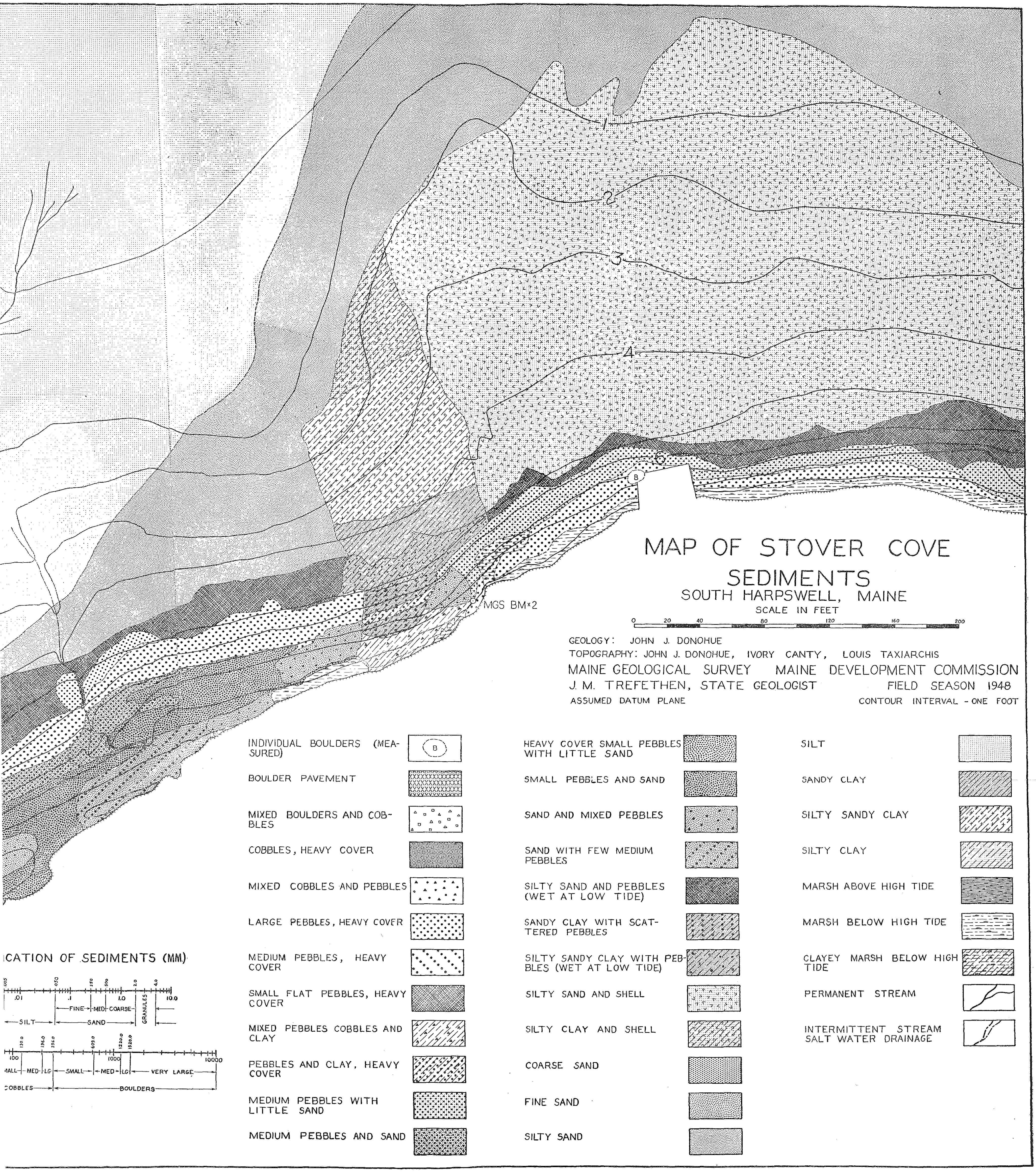
NOTE: QUARTZ - PERTHITE AND QUARTZ - PERTHITE BERYL PEGMATITE SHOWN WHOLLY BELOW THE SURFACE, IN STRUCTURE SECTIONS, ARE INFERRED; THEIR SUBSURFACE POSITION IS NOT KNOWN.



TOPOGRAPHY BY V. E. SHAININ, K. A. BIEHL, P. L. CLOKE, W. J. CROPPER, H. P. BEACH, J. J. DONOHUE, H. H. ADLER, E. W. PERKINS, W. H. CONDON
SURVEYED 1946-1948
MAPPED BY TELESCOPIC ALIDADE AND TRANSIT

MAP VI

BOULD.
CONC.
0
1
2
3
4
5
6
MGS BM 1
TN
CLASSIFICATION OF SEDIMENTS
.005
.050
.250
.500
2.0
4.0
.001
.01
.1
1.0
FINE
MED
COARSE
GRANULES
CLAY
SILT
SAND
22.0
38.0
64.0
130.0
196.0
256.0
609.0
1220.0
1520.0
10
100
1000
SMALL
MED
LG
SMALL
MED
LG
SMALL
MED
LG
PEBBLES
COBBLES
BOULDERS


1
2
3
4
6
B
MGS BM×2
MAP OF STOVER COVE
SEDIMENTS
SOUTH HARPSWELL, MAINE
SCALE IN FEET
0 20 40 80 120 160 200
GEOLOGY: JOHN J. DONOHUE
TOPOGRAPHY: JOHN J. DONOHUE, IVORY CANTY, LOUIS TAXIARCHIS
MAINE GEOLOGICAL SURVEY MAINE DEVELOPMENT COMMISSION
J. M. TREFETHEN, STATE GEOLOGIST
FIELD SEASON 1948
ASSUMED DATUM PLANE
CONTOUR INTERVAL - ONE FOOT
INDIVIDUAL BOULDERS (MEASURED)
BOULDER PAVEMENT
MIXED BOULDERS AND COBBLES
COBBLES, HEAVY COVER
MIXED COBBLES AND PEBBLES
LARGE PEBBLES, HEAVY COVER
MEDIUM PEBBLES, HEAVY COVER
SMALL FLAT PEBBLES, HEAVY COVER
MIXED PEBBLES COBBLES AND CLAY
PEBBLES AND CLAY, HEAVY COVER
MEDIUM PEBBLES WITH LITTLE SAND
MEDIUM PEBBLES AND SAND
HEAVY COVER SMALL PEBBLES WITH LITTLE SAND
SMALL PEBBLES AND SAND
SAND AND MIXED PEBBLES
SAND WITH FEW MEDIUM PEBBLES
SILTY SAND AND PEBBLES (WET AT LOW TIDE)
SANDY CLAY WITH SCATTERED PEBBLES
SILTY SANDY CLAY WITH PEBBLES (WET AT LOW TIDE)
SILTY SAND AND SHELL
SILTY CLAY AND SHELL
COARSE SAND
FINE SAND
SILTY SAND
SILT
SANDY CLAY
SILTY SANDY CLAY
SILTY CLAY
MARSH ABOVE HIGH TIDE
MARSH BELOW HIGH TIDE
CLAYEY MARSH BELOW HIGH TIDE
PERMANENT STREAM
INTERMITTENT STREAM SALT WATER DRAINAGE
ICATION OF SEDIMENTS (MM)
.01 .1 1.0 10.0
FINE MED COARSE
GRANULES
SILT
SAND
100 1000 10000
SMALL MED LG SMALL MED LG VERY LARGE
COBBLES
BOULDERS

MAP VII

MAINE GEOLOGICAL SURVEY PUBLICATIONS

Reports

"First Annual Report on the Geology of the State of Maine"
by Lucius H. Merrill and Edward H. Perkins, 1930. *(Out of stock)*

"State Geologist's Report on the Geology of Maine 1930-32"
by Joseph C. Twinem and Edward H. Perkins. *(Out of stock)*

"Preliminary Geological Map of Maine"
by Arthur Keith and Edward H. Perkins, 1933.

"Report of the State Geologist, 1942-43"
by Joseph M. Trefethen

"Report of the State Geologist, 1943-44"
by Joseph M. Trefethen

"Report of the State Geologist, 1945-46"
by Joseph M. Trefethen

"Report of the State Geologist, 1947-48
by Joseph M. Trefethen

Bulletins

"Domestic Fuel Possibilities of Maine Peat"
by Joseph M. Trefethen and Robert B. Bradford, 1944.

"Geology of the Katahdin Pyrrhotite Deposit and Vicinity, Piscataquis County, Maine"
by Ralph L. Miller.

"Petrology of the Columbia Falls Quadrangle, Maine"
by Ruth D. Terzaghi.

"Geology of the Aroostook County, Maine, Manganese Deposits"
by Ralph L. Miller.

"Economic Geology of Some Pegmatites in Topsham, Maine"
by Vincent E. Shainin.

"Water in the Ground"
by Joseph M. Trefethen (in preperation)

Copies obtainable on request to the Maine Development Commission, Augusta, Maine.