STUDIES OF THE NEWBURY MINING AREA

by

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ABSTRACT

This thesis is the report of a detailed investigation of the lead-silver mines of the Newbury-Newburyport Area, Essex County, Massachusetts. An account of the mining history of the area, principally of The Chipman Mine, is included to give some indication of the character of mining operations in the area.

The aim of the work was the determination of the geologic control of the numerous mineral deposits which occur throughout the area by means of geological and geochemical means. The results indicate that there are four main lithologies, which in order of their age from youngest to oldest are: serpentine limestone, quartz-hornblende schist and quartzite, gabbro-diorite, and granite altered to gneiss. The first two are ancient sediments which were intruded by the gabbro-diorite and later re-intruded by the granite with the formation of mineral deposits in the metamorphosed sediments. The major concentrations of ore minerals are found in quartz veins occurring in irregular quartzite bodies of probable sedimentary origin.

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INTRODUCTION

The subject of this thesis is an integrated exploration program utilizing geological, geochemical, and geophysical methods. The area chosen for this work is the Chipman Mine Area, Newbury, Massachusetts. This location was chosen primarily for its accessability to the Massachusetts Institute of Technology and for its known mineralization.

From 1874 to 1882 there was extensive mining of lead-silver ore in the region determined by Newbury and Newburyport. Of the thirty or more mines operated here The Chipman Mine was by far the largest, and the only one to show more than limited commercial success. In fact it has been reopened and operated profitably since it first closed down in 1880. The history of this mine, and of the region, will be discussed more fully under the section devoted to mining history.

The primary aim of this study is to determine, if possible, the origin and controlling factors of the lead-silver deposits of this region, with an eventual aim of economic evaluation.

PROPOSED PROGRAM

ORIGINAL PROSPECTUS

The original program was laid out to parallel an actual exploration problem as closely as possible. Preliminary research was to be carried out in libraries in an effort to learn as much as possible about the mining history and geology of the area.

The library research was to be followed by extensive, detailed field geology and mapping. This portion of the program would have as its immediate objective the determining of the geological factors controlling the mineralization of The Chipman Lode. The secondary objective would be the confirming or modification of previous work done in this area. In addition, geological mapping should outline any other possible locations of environments similar to that of The Chipman Lode.

A geochemical program would supplement the geological work to further localize areas of possible mineralization. This program would consist of two steps, first reconnaisance by stream sediment sampling, and second geochemical prospecing by patterns of soil sampling.

The geophysical work would involve one of two methods. If the geological and geochemical work showed any areas favorable for mineralization, the areas would be explored with an induced polarization survey. If no favorable areas were indicated and there were no areas of curiosity, a magnatometer survey would be run to aid in geological correlation.

FINAL PROSPECTUS

Unfortunately the winter of 1955-1956 was an unusually severe and long one. The snow was several feet deep in a blanket over the entire area as late as early April. Several attempts were made to start field work in March, but all to no avail. With only a few days available for field work, the program had to be drasticly altered.

First, the geophysical program was eliminated because it would be the most time consuming part of the field work and could not be intelligently directed without the knowledge to be gained from the other two programs.

Second, the geochemical program was altered in hopes that it might still be completed in the remaining time. The new program would consist of reconnaisance sampling of stream sediments and detailed reconnaisance sampling of soils around the periphery of seeps and marshes.

The library and geological programs were, of course, retained unchanged except that more emphasis was placed on the library work.

MINING HISTORY

HISTORY OF THE AREA

The early history of mining in the Newbury Area is clouded and all but lost in antiquity. There are many tales of Revolutionary soldiers' making lead bullets from ore found in the hills. There is no way of authenticating such tales; however, like most local legends they are probably fiction based on fact.

There are more authenticated tales of early mining. The earliest settler of Newburyport was John Watts, and he reportedly mined silver from "Watts' Hole" located on the south shore of the Merrimac River about three miles upstream from the Newburyport business district. It is believed that Watts' Hole was the source of silver used in the money coined by Hull, the Colonial Massachusetts Mint Master. Hull certainly had access to a good supply of silver; when he gave his daughter in marriage, he balanced her weight in silver.[1]

During Revolutionary times the Moultons, a family of blacksmiths situated near Watts' Hole, turned to silversmithing. They manufactured principally silver buckles and ornaments. Since that day silversmithing has been an important industry in Newburyport. Their source of silver was undoubt-

1. Green, Frederick E., "About Newbury and Vicinity Mines", Manuscript on file with Peabody Museum, Salem, Massachusetts, p. 2.

edly Watts' Hole.[2]

During the mining excitement in the 1870's another old mine hole was found and reopened on the north side of the Merrimac River. This mine was located at Pow Wow Hill in Amesbury. Some semi-precious stones were found and limited amounts of lead ore, but the only information obtainable about the old mine was that it was there when the first Englishmen came. The Indians said that it was made by French trappers and voyageurs.[3]

Another legend concerns an Indian, Indian "Bill" as he was called. He used to come to the old bog iron smelting furnace above Byfield Falls and exchange silver suggets for rum. He always had his pockets full of these nuggets, but nobody ever found out where he got them. It probably came from the flats of the Fatherland Farm on the south shore of The Parker River downstream from the furnace. Placer silver was found there in the '70s and again in 1897.[4]

The modern history of mining in the Newbury Area begins with Edward L. Rogers of Byfield. Rogers was a ne'er-do-well

2. Ibid., pp. 2-3

3. Ibid., p. 2

4. Ibid., p. 2

who liked to hunt, shoot, and drink to the exclusion of much else. He supported his family by doing odd jobs, mostly for Albert Adams who lived on Scotland Road near Byfield. Sometime between 1868 and 1870 Rogers found a strange stone in a pasture on the ridge south of Scotland Road. The stone was very heavy and glittered; it looked almost as though it were made of metal. He took this to his employer, Mr. Adams.

Adams immediately realized that there might be some value to Rogers' find. Accordingly he bought and studied books on geology and mineralogy. While he was studying Mr. Adams also took many long walks by moonlight in the pastures along the ridge behind Scotland Road.[5]

In 1872 he found a large piece of float ore in the pasture of Richard T. Jacques. In December he had that ore assayed by a Newburyport chemist, Castelhun. Mr. Castelhun's report confirmed Adams' suspicions. The first assay showed 70% lead and later assays showed 0.19% silver, undetermined gold, and some antimony.[6]

On May 22, 1874 Adams purchased the pasture in which he had found the ore, paying Mr. Jacques $350.00. Adams then be-

5. Ibid., pp. 4-5

6. Brockway, Charles J., "Mineral Deposits in Essex County, Especially in Newbury and Newburyport", William H. Huse & Company, Newburyport, Massachusetts, 1875, pp. 5-6

gan digging in earnest. In some of the many holes ore was found. One of these holes was extended to 16 feet and many large, rich samples were recovered; some assayed over $1000 per ton.[7]

Reports of the find were printed in the Boston papers and attracted the attention of William W. Chipman. Convinced of the possibilities of the area Chipman, in combination with E. P. Shaw, a local businessman, and Eldridge Kelley, a Newburyport dentist, bought the Jacques pasture from Adams for $100,000 on July 28, 1874.[8]

Few people yet believed that the region held any promise for mining, so Chipman invited Prof. Robert H. Richards of The Massachusetts Institute of Technology to view the workings. Prof. Richards looked at the float ore in place and recommended trenching to the northwest to intersect the vien in rock. He also took three samples for assaying. The results in 1874 values were:

#1 Course Galena
$63.13 silver/ton
Rich in lead

#2 Fine Galena
$84.26 silver/ton
50% lead

7. Green, F. E., op. cit., p. 5

8. Brockway, C. J., op. cit., pp. 6-8

#3 Tetrahedrite, Pyrite, and Galena

$1,422.00 silver/ton
145.12 gold/ton

27% copper

Prof. Richards felt that sample number two was representative of the mine.

Instead of trenching along Prof. Richards recommended line the operators dug random pits northward from the original pit. Luck was with them, and they uncovered an ore shoot a few inches wide. Prof. Richards was again called and pointed out the fact that they had not prospected all the way to the north wall of the vein. Further digging to the north uncovered an ore shoot about one foot wide. Another pit west of this one exposed an ore shoot over three feet wide. The Chipman Shaft was sunk at this spot.

On November 1, 1874 Dr. Kelley had a hole drilled through the ore shoot, and the dust was saved for assay. The results were:

Lead	$ 69.84 /ton
Silver	72.87 "
Gold	154.14
	$ 246.85 /ton

Converted to present prices these figures yield:

Lead	$ 267.00 /ton
Silver	53.52 "
Gold	262.12 "
	$ 583.54 /ton

Prof. Richards felt that this was the most representative assay up to that time.[9] It is easy to see that optimism would be the order of the day.

Meanwhile, in June E. Moody Boynton had purchased the land adjoining the Chipman property on the west. In October he started sinking a shaft only 100 feet southwest of the Chipman shaft. He cut the ore shoot between 40 and 60 feet below the surface.

Probably few people connected with the great mining excitement of 1874-1880 were more colorful than Moody Boynton. He was the inventor and manufacturer of a special crosscut saw which brought him a fortune. He was also one of the few men who made money from the mines. But railroads and politics broke him, and he died penniless. A flamboyant and loquacious man, he spoke often of the "not millions but billions" of dollars in silver waiting to be mined. He swore he was going to follow the vein all the way to China. Mr. Boynton also holds the record for the shortest term in the Massachusetts Legislature. He was unseated by his fellow representatives in his first day.

In December 1874 a report from the Balbach & Sons Smelter in New Jersey on 4½ tons of Chipman ore was published

9. Richards, Robert H., "On a Newly-Discovered Lead Vein in Newburyport, Massachusetts", Proc. Boston Society of Natural History, Volume XVII, Nov. 18,1874

in the Newburyport Herald. The figures quoted were:

Lead	3420	lbs.
Silver	210.7	ozs.
Gold	--	

The silver and gold from this lot were refined and returned to Newburyport. The silver in a block stamped $272 and the gold in a nugget stamped $22 were put on display in the window of a local druggist.

This was proof enough for even the most adamant skeptic. The silver rush was on. Land speculators descended on Newburyport in hordes, but the cautious old yankees of the area didn't trust them. Instead they put their faith in Chipman, Shaw, and Kelley. After all, Shaw and Kelley were local men and Chipman had shown his faith in the mines from the very beginning. Such trust was unwise.

Take for example the case of John Smith. He owned a farm about half a mile northeast of the Chipman Mine along the strike of the vein. Smith bonded his land to the Chipman interests for one dollar in hopes that they would develope it. Apparently they were not interested in development. Minutes after the papers were passed the Chipman group sold the bond to The Lawrence Company for $10,000.

When The Lawrence Company's engineer Mr. Kempton moved a diamond drill onto the Smith farm, Smith was furious. He felt he had been deliberately cheated. When he complained to Kelley and Shaw, they agreed he should receive some-thing and offered him $3,000.00 if Chipman consented. He did not consent. Pressing a lump of Chipman ore into Smith's hands, he told him that it would be foolish to take $3,000.00 as against the millions the Lawrence Company would earn for him by taking just such ore out of the ground.

But no such ore was taken out of the ground. The diamond drill cut ore at 97 feet and shaft sinking was begun immediately. Late in January, for some strange reason now lost in antiquity, Mr. Kempton ceased operations at 55 feet and moved his crew and diamond drill across the road to the east to the farm of Robert A. Smith.

During February 1875 land speculation reached a peak and leveled off. Chipman, Shaw, and Kelley began acquiring land in the direction of Byfield. They bought the Kent Farm of 300 acres and shortly resold it at a handsome profit. They also sold an 8 acre plot to the Portland Minerals Company. It is interesting to note that the Chipman group did not attempt to develop any of the properties they acquired; instead they sold them as quickly as possible.

It is beyond the scope of this paper to pass on the business ethics of the mining promoters in the Newbury Area. These details are listed only to show the history of the area and to indicate the type of work that was carried on.

In March a mining engineer from Nevada and New Mexico visited the area. He gave a rather picturesque evaluation of the Robert A. Smith Mine. "If there were a little sprinkling of sagebrush and sand, one might imagine himself in the wilds of Nevada or New Mexico."

In February 1875 the Chipman and Boynton Mines were combined to form the Merrimac Mining Company. In May, the Newburyport Silver Mining Company, George S. Comstock, Treasurer, was formed with some New York backing. This company bought the Chipman Mine for $1,000,000, the largest land settlement ever recorded by the Essex County Registrar of Deeds.

Meanwhile shafts, mostly prospecting shafts, had been started on a number of properties. Luther Noyes discovered a vein on his farm south of the Downfall. To his dying day Noyes refused to deal with the mining promoters. He stoutly proclaimed, "If there is silver on Luther Noyes' land, Luther Noyes will get it." Either Luther Noyes did not get it or there wasn't any of it there. He died too poor to afford a headstone to mark his grave.

One three compartment mining shaft was sunk during this period. On land owned by Asa T. Newhall north of Turkey Hill ore was discovered, supposedly good ore in commercial quantities and a group from Providence, Rhode Island set out to mine it. The shaft was sunk beside the deposit but, no crosscuts were driven to the supposed ore body. The project was abandoned for lack of funds.

By June 1875 there were 250 to 300 mines engaged in mining many small operations from the south bank of The Parker River to the town of Salisbury, Massachusetts.

After June of 1875 the land speculation diminished slightly and the area settled down to more serious mining. Although there was still a great deal of land speculation, most people seemed to be more interested in mining. Unfortunately there was a shortage of mining engineers; most of the work was carried on under construction men, mechanics, and even farmers and local shopkeepers.

In spite of this a number of mines operated successfully from 1875 to 1880. Next in importance after the Chipman Mine was the China Mine near Downfall and Middle Streets. This property was bought by Mr. Hammond, a Salem china merchant for an estimated $100,000. The mine operated for five years regularly employing about 40 miners.

This mine suffered from two large problems. The ore was of a low enough grade to require concentrating for very profitable operation. In addition the shaft was next to a marsh and the water problem was severe. When the mine was shut down, the pumps had to be abandoned in the shaft as water flooded the mine before they could be removed.

The German Gilberry Mine was operated on a marginal basis from 1876 to 1880. This mine, regularly employing less than forty miners, was located on the Gardner Farm near the old Newburyport Turnpike. Old records indicate that the ore was in a number of small veins and veinlets rather than in a large ore shoot.

Although there were hundreds of other workings in the Newbury Area the only other one which operated with any measure of success was the Saratoga Mine. Owned by E. P. Shaw of the Chipman Group this mine was located in the Downfall, and as practically all of the other operations, closed down in 1880.

From 1880 to 1882 there were occasional attempts at mining, but all operations were short lived, and the area was abandoned.

In 1897 an old mine on the Ambrose Farm on the north bank of The Parker River was reopened. The same group prospected along the south bank of the river and carried out some placer mining on the Fatherland Farm. However, like so many other attempts this one ended abruptly because of insufficient funds.

In 1911 another attempt at mining was made in the area. The Essex Mining and Development Company started operations southwest of the Chipman Mine. Under the direction of Alva Bixby, City Engineer from Lynn, two miners tried to sink a shaft in the middle of a poorly drained marsh. They labored most of the summer at this without any success and finally brought more men in and moved to a spot next to a ledge by the side of the marsh. The shaft was sunk over 100 feet and a crosscut driven 50 feet under the marsh.

Little is known of the work or the results. Mr. Bixby had a large board fence erected around the property to keep reporters out, and he refused to discuss the work with anyone. One man who visited the camp reported that living and working conditions were very crude. He saw a little girl who lived there whittling on sticks of dynamite with a rusty kitchen knife.

When the camp was closed down, Mr. Buch, the engineer who succeeded Mr. Bixby, stoutly maintained that no ore had been found. However, it is reported that considerable ore was taken from a hole on the north adjoining Coffin property. This ore was stored in bags in the barn on the then Goodrich Farm, and it was still there when the Chipman Mine was reopened in 1919.

The Chipman Mine was reopened and operated until 1921, and it must have been profitable for some. This will be discussed more fully under the section on The Chipman Mine.

While the Chipman Mine was open prospecting was begun again in the surrounding area. Nothing of any great value was found, however, and just as in 1880 the closing of the Chipman signalled the stopping of all other operations.

Since 1922 there have been a number of operations connected with The Chipman Mine. These will also be discussed below.

THE CHIPMAN MINE

Geology

The Chipman Lode is located in an area of high regional metamorphism. The vein is associated with a sequence of four series of metamorphosed sediments. The upper of these outcrops on the Highfield Ridge where the mine is located. There is an igneous complex to the north and south of the vein. The geological relationship will be discussed in more detail below.

Mineralogy

The ore minerals of The Chipman Lode are galena with silver, tetrahedrite with silver, chalcopyrite, some sphalerite, little stibnite, and traces of gold. The gangue minerals are quartz, siderite, pyrite, little arsenopyrite, little pyrrhotite, calcite, and some epidote and serpentine.

Classification of Mineral Deposit

The above mineral assemblege is typical of mesothermal lead-silver deposits.[10] Furthermore, the Chipman Vein falls into one of two sub-divisions of this class. The first of

10. Lindgren, Waldemar, "Mineral Deposits", Fourth Edition, McGraw-Hill Book Co., New York, 1933, pp 565-574

these is Tetrahedrite-Galena-Siderite Veins of the Wood River, Idaho type. The second is Galena-Siderite Veins of the Coeur d'Alene, Idaho type. The distinction between these two types depends on the relative abundance of tetrahedrite, pyrite, and pyrrhotite. These abundances were not determined; however, since the mine is recorded as a silver mine obtaining its values principally from over-rich tetrahedrite, the deposit is probably of the Wood River type.

Commercial History

The Chipman Mine was the first discovery in The Newbury Area, and its early history has been discussed under the history of the area. However, the early development of the mine was not entirely free from difficulty. When Richard Jacques learned of the real worth of the pasture he had sold to Adams, he moved to set aside the deed. On January 12, 1875 Judge Endicott issued an injunction to the operators, and all mining was ceased. The case was set to be heard before the full bench of The Superior Court the following April. In March the operators settled the claim rather than face long delays while Adams fought the case. Jacques received $25,000.[11]

Following the sale of the property to New York and Boston interests in May 1875 routine mining was carried out,

11. Green, F. E., op. cit., p 11
Brockway, C. J., op. cit., pp 14-17

and no notable business events are recorded. In 1877 and 1878 New York interests became interested in the mine. Mining engineers and professors from Columbia were hired to evaluate the property. They reportedly blocked out two ore bodies valued at $100,000 each. On the strength of this report the New York group bought the mine in early 1878.

On March 13, 1878 a new mill was installed and put into operation, but a few days later the mine shut down. It was opened again on April 15 with a new Conkling Concentrater in operation. This time the mine remained open for one week closing April 22. Everyone thought that this was a freeze out and that the New York group with all its new equipment would surely reopen the mine. They did reopen it on May 2nd; however, on June 11, 1878 the mine was closed with the following announcement, "The Merrimac having tried its new machinery with success are devoid of ore and will be no more mined."

Although the mine was shut down, men were kept on the property, and at least some maintainence work was done. In 1880 these men left and the mine was officially closed. On September 17,1881 the reduction works were sold and shipped to Georgia, and on May 25, 1882 the mine was sold for back taxes to the former treasurer of the company Benjamin T. Seeley of New York.[12]

12. Green, F. E., op. cit., pp 19-19a

In the summer of 1919 men arrived under the direction of Engineer Todd Weedworth to reopen the mine. Meanwhile Frank Blair & Company, stockbrokers of Boston, carried on an advertising campaign in the newspapers to sell stock in the new company. This was supposed to be a sure thing; reliable engineers from the old days reported large ore-bodies never removed. In a very short space of time more than $200,000 was raised. At this point a Boston stock-broker was found murdered after a night of revelry; invest-igation showed him to be in possission of several thousand shares of the stock. The state ordered an immediate inves-tigation, and the company was unable to raise any additional funds for the remainder of its life.[13]

The state investigation passed on the truth of the com-pany's prospectus and reportedly found no evidence of fraud.[14] However, there is some evidence of misuse of funds. Mining was carried on, successful mining. The old workings were ex-tended to the southwest and considerable ore removed. From one pod near the shaft and close to the surface ore valued at $138,000 was taken out.[15] The company paid no dividends

13. Ibid., pp 21-24

14. Personal communication from Howard Blackwell.

15. Personal communication from Mr. Kilgore, foreman of the mine, 1919 to 1921. Kilgour

on its stock; in fact, the stock was made assessable in an attempt to raise more money. In spite of all this they went bankrupt during the 1921 drop in metal prices and the company failed on March 6, 1921. Attachments were served immediately, but none was ever recovered, not even for back wages because the mine had been heavily mortgaged to a group of Boston politicians.[16]

At the auction following bankruptcy the mine and all its machinery were purchased by Horton Batchelder for a few thousand dollars. Batchelder was not primarily a mining man; he was a mineral engineer or chemist. Although he hoped to operate the mine his immediate interest was a new method of extracting metal from ores.[17] He experimented with the material on the dump for some time, presumably with success. However, before he could start actual mining he died, and his plans died with him for he had worked alone, and no one was left to carry on the work.[18]

In January 1925 unknown interests employed an engineer by the name of Kerr to evaluate the property. Mr. Kerr employed some of the old miners in the area under the direc-

16. Green, F. E., op. cit., p 24

17. Ibid., p 24

18. Personal communication from Howard Blackwell and Mr. Kilgore.

tion of Mr. Kilgore and unwatered the mine. Exploratory work was carried out only near the surface, and the mine was not completely unwatered. However, Mr. Kerr seemed satisfied; he reportedly uncovered new ore. He then put the machinery in proper shape for storage and shut the mine down. When he left, Mr. Kerr told Mr. Kilgore that he would be back shortly to reopen the mine and start full-scale operations, but he was never heard from again.[19]

Following this the mine was sold to a Newburyport junk dealer by the name of Checkoway for taxes. Mr. Checkoway removed the machinery for scrap, but he made no attempt to prospect or develope the property. Shortly afterwards a woods fire burned down the buildings and collapsed the head-frame into the shaft. All that remains is a pile of debris around and in the top of the shaft and a pile of low grade ore and waste.

In January 1929 a young mining engineer, W. S. Black, from Arlington, Massachusetts, began exploration in the area. He obtained options on the surrounding properties and conducted electromagnetic surveys over an area of two square miles.[20] The report submitted by the Radiore Company on the survey was favorable, and mining operations were to be started when

19. Green, F. E., op. cit., p 24
Personal communication from Mr. Kilgore

20. Green, F. E., op. cit., p 26

Mr. Black died suddenly of a hemmorage. The report and all the records incidental to Mr. Black's work were retained by his widow, but she lost them when she moved. The Radiore Company has no copies of the report either as all their old records were destroyed in a fire during the forties.[21]

The mine is presently owned by Mr. Howard Blackwell of Cambridge. For years he has hoped to interest someone in developing the property, but has been unable to find anyone who meets his standards of honesty, skill, and wealth.

21. Personal communication from Howard Blackwell.

GEOLOGY

GEOLOGY OF THE NEWBURY AREA, NORTHEAST ESSEX COUNTY

The Newbury Basin of Essex County is a region consisting mainly of very swampy marshland with sharp, but low scattered hills irregularly spaced throughout. Through the center of this region, in a general northeast-southwest direction, runs a low rugged line of hills with one main ridge, known locally as the Highfield Ridge. This ridge is surrounded mainly by marsh which extends east to Plum Island Sound and northwest to The Merrimack River. The Highfield Ridge and its immediate surroundings are in the center of the mineralized area that is the subject of this thesis.

Clapp[22] lists four major rock types for the Newbury Area; they are Salem gabbro-diorite, Andover granite, amphibolite schists of questionable origin, and metamorphosed sediments. The normal Salem gabbro-diorite varies from a fine to medium grained rock and is often gneissic. In many places it is locally metamorphosed to high degree showing complete recrystallization and schistose structure. It is composed chiefly of calcic plagioclase, hornblende, augite or diallage, and biotite with accessory minerals. In its

22. Clapp, Charles H., "Geology of the Igneous Rocks of Essex County Massachusetts", U. S. G. S. Bulletin 704, G. P. O., Wash., D. C. 1921

unaltered form the feldspar occurs in euhedral lathes with interstitial dark minerals. In its altered form, however, the structure first becomes massive and the hornblende alters to chlorite giving the rock a greenish cast of varying intensity.[23]

The normal Andover granite is typically a fairly course grained rock consisting of feldspar and abundant quartz (often 35% or more) with biotite and muscovite. It is commonly gneissic, but shows only slight alteration; the feldspar is unclouded and the original mafic minerals are preserved with very little change.[24] It has been suggested that the superabundance of quartz might be indicative of a granitized sediment, but the association of large numbers of pegmatites with the Andover granite would seem to rule this possibility out.

The amphibolite schists are presumed to be of sedimentary origin; however, this is not a certainty. As Clapp points out, the Salem gabbro-diorite alters to a true basic plagioclase-hornblende or amphibolite schist under extreme metamorphism, especially where it is associated with Andover granite. In such cases it is virtually impossible to de-

23. Ibid., pp 21-22

24. Ibid., pp 27-29

termine a definite contact.[25]

The metamorphosed sediments are made up of four types. The first is the amphibolite schist discussed above, which locally grades into a quartz-hownblende schist. The second is a massive, very fine grained black rock showing sedimentary structure and laced with a system of fine veinlets of pure quartz. The rock exhibits absolutely no cleavage along the veinlets indicating that they were present before recrystallization. This is probably a remetamorphosed serpentine rock.

The third and fourth metasediments are a slate with inconspicuous outcrops and a course quartzite. The quartzite is entirely recrystallized and characteristicly coarse grained; it is associated with the slates. The strike of these sediments is northeast-southwest, and the dip, where obtainable is to the northwest.

A section of Northeastern Essex County from The Parker River to The Merrimack River begins with eruptive rocks underlying the marshlands along The Parker. Clapp does not designate the rock type beyond naming them "effusive igneous" rocks. However, Sears[26] calls them rhyolites. Only one very poor outcrop of this material was found. The rock was red

25. Ibid., p22

26. Sears, John H., "Geology of Essex County Mass." Essex Institute, Salem, Mass., 1905, Geological Map.

with a fine grained, angular texture such as a rhyolite tuff.

North of the rhyolite is a narrow section of diorite and grano-diorite which is followed by a thick section of Salem gabbro-diorite, mostly altered. The Salem gabbro-diorite is bounded by the metasedimentary series of slate, quartzite, serpentine rock and hornblende schist. The contact between the gabbro-diorite and the slate is gradational and all but lost in most places. North of the metasedimentary sequence is more Salem gabbro-diorite which is bounded on the north by a possible fault and a series of grano-diorites and diorites.

A metamorphosed limestone is apparently included in the southern section of gabbro-diorite and possibly underlies much of the area. It outcrops at Devil's Den, an old quarry, about 1½ miles southeast of The Highfield Ridge. The limestone is highly metamorphosed with large patches of serpentine and asbestos. The mineral assemblage, wollastonite, tremolite, vesuvianite, diopside, large patches of brown garnet, chromite, pyrite, and chalcopyrite, is indicative of contact metamorphism. In addition a piece of extremely hard and very pure graphite was found here. Sears[27] feels that this limestone is not of sedimentary origin but, was derived from the gabbro-diorite, with which it is in contact, by the decomposition of diallage and augite. He also cites psuedomorphs in the serpentine. However, this theory would

27. Ibid., p 133

require that the limestone be derived from the intrusive which in all probability caused the contact metamorphism. Since there is no other intrusive associated with the rocks at Devil's Den, the metamorphism probably could not have been the result of any other intrusion. Therefore, the limestone was probably part of the ancient sedimentary sequence that was intruded by the Salem gabbro-diorite.

The Luther Noyes Nickel Mine about one mile south of Highfield Ridge also exhibits minerals characteristic of contact metamorphism, such as wallastonite, tremolite, diopside, and chromite, as well as low temperature minerals such as marcasite.[28] The country rock of this area is also gabbro-diorite, but there is some evidence of granitic intrusion such as alteration of the gabbro-diorite and considerable quartz veining with associated feldspars. It is distinctly possible that the contact metamorphism here is not the result of the gabbro-diorite intrusion.

The geologic history of this section is a sequence of two intrusions in an ancient sequence of sediments. The gabbro-diorite was the initial intrusion, and this in turn was re-intruded by the Andover granite. The gabbro-diorite intrusion is believed to be associated with The Taconic Revolution. This was followed by a period of erosion and deposition of eruptive volcanics. The intrusion of the An-

28. Ibid., pp 230-252

dover granite probably came at the end of the Paleozoic.

GEOLOGY OF HIGHFIELD RIDGE

The Highfield Ridge, as pointed out above, is a line of low, rugged hills trending roughly northeast-southwest standing out of marshland. The maximum elevation of the ridge is 75 feet above sea-level, and the maximum relief is 50 to 60 feet. At its northeastern end the ridge forms a single crest, but towards the southwest it widens to a series of low, rugged hills interspersed with small marshes. Throughout the area has the appearance of a random mixture of closely spaced hills and swampy marshland. The edges of the marshes are usually covered by dense thickets while the hilltops are open to the north but present a progressively denser growth of large evergreens and small saplings southward.

The one distinguishing feature of the areal geology is its complexity. Although apparently the rocks are largely of sedimentary origin, the extreme metamorphism which the area has undergone makes it, in many cases, almost impossible to draw any definite dividing lines between the apparent lithologies. The prominent surface outcrops represent two main rock types. The first is a quartz-hornblende granite, usually gneissic, with a medium to coarse texture. The second is a quartz-augite-hornblende rock of varying structure. On the south flank of the ridge this rock has a fine grained massive texture, but on the crest of the ridge it exhibits

29. Clapp, C. H., pp 33-35

a strong planar stucture as a schist.

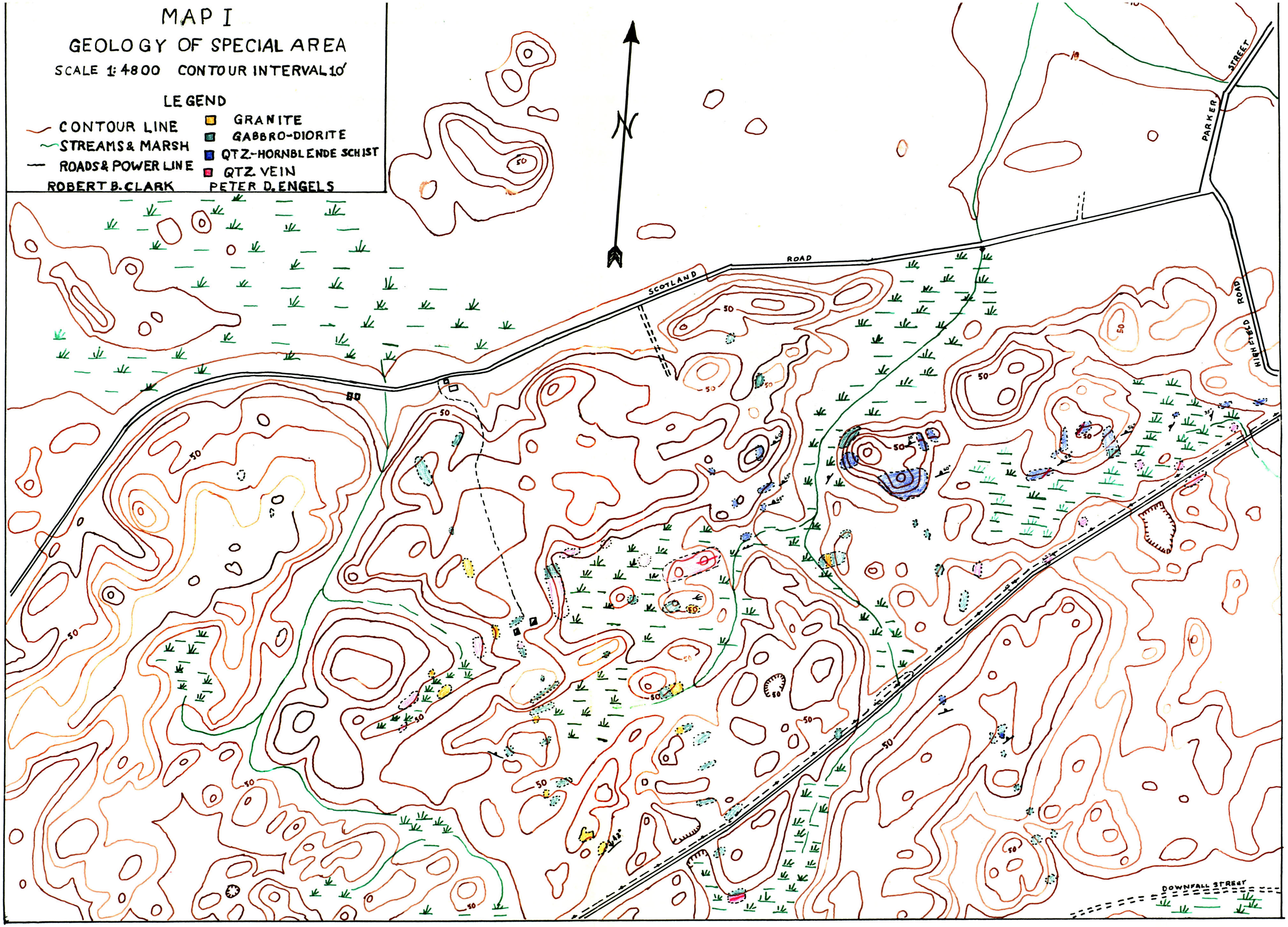
Between these two types is a low swampy area with occasional outcrops of coarse quartzite. At one point on the north side of the quartzite for about 200 feet along the strike the remetamorphosed serpentine rock outcrops prominently, but nowhere else in the area is it well exposed. On the south contact of the quartzite one small outcrop of slate was found.

The granite gneiss is undoubtedly the Andover granite. The lineations are not uniformly directed but gradually assume different directions. Where it appears in association with The Chipman Vein, the lineations are uniformly concurrent with the strike of the vein. There is considerable evidence that the quartz-hornblende-augite rock is altered Salem gabbro-diorite. About one mile west of the mine area there are outcrops of unaltered Salem gabbro-diorite which grades into the quartz-hornblende-augite rock.

In addition the area is intruded by veins and patches of Andover granite. As is pointed out above the alteration product of the Salem gabbro-diorite is a massive quartz-hornblende-augite or chlorite rock. At the northeastern end of the ridge the gabbro-diorite is in contact with the amphibolite-schists to the north. As pointed out by Clapp it is impossible to find an actual contact in this area; the rocks gradually become schistose in a northern direction.

The definite origin of the amphibolite-schist cannot be determined by field relations alone. On the north the schists are bounded by more gabbro-diorite which might lend support to their being derived or altered from this intrusive rock. Southwest along their strike the schists grade into the granite gneiss. This graduation is extremely slow; the schists simply take on a more granitic character until they become granite.

The Chipman Vein outcrops at the surface in the quartzite. The vein strikes with the trend of the country, N 60 E and dips nearly vertical. Between 100 and 150 feet below the surface it angles to the southwest, but the decrease in dip is not recorded.


MAP I
GEOLOGY OF SPECIAL AREA
SCALE 1: 4800 CONTOUR INTERVAL 10'
LEGEND
CONTOUR LINE
STREAMS & MARSH
ROADS & POWER LINE
GRANITE
GABBRO-DIORITE
QTZ-HORNBLENDE SCHIST
QTZ. VEIN
ROBERT B. CLARK
PETER D. ENGELS
N
SCOTLAND ROAD
PARKER STREET
HIGHFIELD ROAD
DOWNFALL STREET

GEOCHEMICAL EXPLORATION

ELEMENTS OF INTEREST AND METHOD USED

The metals surveyed for were copper, lead, and zinc, and the method used is the one outlined by Huff.[30] This is a semiquantitative analytical method using dithizone to detect the presence of the metalic ions in a solution of digested soil or sediment. The results obtained are a proportional indication of the total of the three metals present. It is possible to obtain values for each of the metals separately; however, this involves using reagents which are not well adapted to field techniques, such as cyanide for lead determination. The method will be discussed more fully in the Appendix under Geochemical Method.

RECONNAISANCE AND RESULTS

The initial broad reconnaisance was carried out by sampling stream sediments around the area. The ultimate aim of such a program is the separating of mineralized areas and background areas. Traverses were run along Scotland Road, The Boston and Maine Railroad right of way, and Orchard and Middle Streets. These particular traverses were chosen to circle one area of known intensive mineralization and one area of suspected less intensive mineralization.

30. Huff, L. C., "A Sensative Field Test for Detecting Heavy Metals in Soil or Sediments", Econ. Geol., vol. 46, 1951, pp 524-540

The results of these traverses are listed in Table 1; all values are normalized to correspond to a strength of 0.001% dithizone. The locations from which the samples were taken are shown on Map II at the end of this section. The samples taken along the old railroad right of way are liable to be unreliable. This roadbed was in use by the mines in the 1870's and is undoubtedly a source of contamination. The samples were taken at distances varying from 10 feet to 100 yards from the roadbed, and any sample which was felt to be suspect is marked questionable (?).

Unfortunately high water in the marsh areas resulting from the large quantities of melt water because of late snows prevented any sampling in those areas or along their normal peripheries. Such surveys would have proved most interesting since the geological work has shown that the definite sedimentary sequences and The Chipman Vein outcrop in just such areas.

INTERPRETATION OF RESULTS

The geochemical exploration did not serve to separate areas of high probability of mineralization from areas of low probability. No area of background intensity was found in The Newbury Area. The only conclusion that can be reached on this basis is that the entire area is one of disseminated if not concentrated mineralization. Reconnaisance over a wider region and more detailed sampling within the area would be necessary before any more definite conclusions could be drawn.

TABLE I

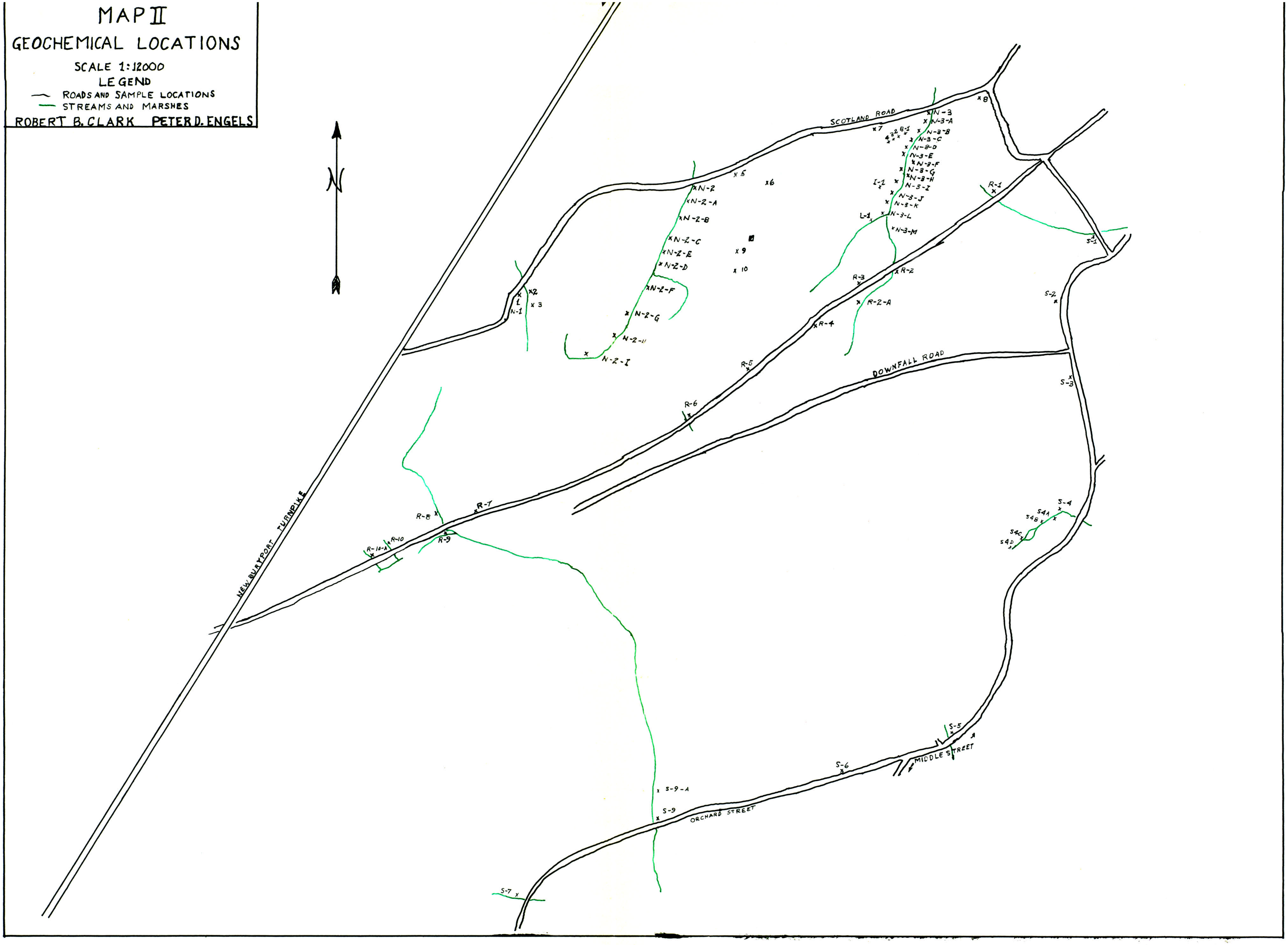
GEOCHEMICAL VALUES

Locations are shown on Map I. All values are tabulated as c.c. of 0.001% dithizone required to titrate to blue endpoint.

SAMPLE NO.	VALUE	REMARKS
1	22	No endpoint ?
2	6	
3	3½	
4	9	
5	16	
6	8	
7		
8	20	No endpoint
9	100	Copper present
10	35	Copper present
N-1	11	
N-2	6	
N-2-A	10	
N-2-B	16	
N-2-C	40	Copper present
N-2-D	16	
N-2-E	30	
N-2-F	9	
N-2-G	2	
N-2-H	4	
N-2-I	8	
N-3	6	
N-3-A	5	
N-3-B	2	
N-3-B-1	6	
N-3-B-2	4	
N-3-B-3	9	
N-3-B-4	2	
N-3-C	5	
N-3-D	19	
N-3-E	6	
N-3-F	18	
N-3-G	34	
N-3-H	4	
N-3-I	20	

TABLE I (continued)

SAMPLE NO.	VALUE	REMARKS
N-3-I-1	20	
N-3-J	16	
N-3-K	16	
N-3-L	12	
N-3-L-1	21	
N-3-M	14	
R-1	23	No endpoint (?)
R-2	11	
R-2-A	22	(?)
R-3	50	Spring on north side of road
R-3-A	6	
R-3-B	12	
R-4	22	
R-5	20	
R-6	24	
R-7	20	
R-8	10	
R-9	4	
R-10	17	
R-10-A	23	No endpoint
S-1	7½	
S-2	6	
S-3	19½	
S-4	12	
S-4-A	8	
S-4-B	2	
S-4-C	14	A, B, C, D, taken in
S-4-D	2	stream thru farmer's yard
S-5	10½	
S-6	4½	
S-7	16½	
S-8	12	
S-9	1	These two taken in tidal
S-9-A	1	marsh



MAP II
GEOCHEMICAL LOCATIONS
SCALE 1:12000
LEGEND
ROADS AND SAMPLE LOCATIONS
STREAMS AND MARSHES
ROBERT B. CLARK PETER D. ENGELS
N
SCOTLAND ROAD
DOWNFALL ROAD
NEWBURYPORT TURNPIKE
MIDDLE STREET
ORCHARD STREET
N-1
N-2
N-2-A
N-2-B
N-2-C
N-2-E
N-2-D
N-2-F
N-2-G
N-2-I
N-3
N-3-A
N-3-B
N-3-C
N-3-D
N-3-E
N-3-F
N-3-G
N-3-H
N-3-I
N-3-J
N-3-K
N-3-L
N-3-M
I-1
L-1
R-1
R-2
R-2-A
R-3
R-4
R-5
R-6
R-7
R-8
R-9
R-10
R-10-A
S-1
S-2
S-3
S-4
S4A
S4B
S4C
S4D
S-5
S-6
S-7
S-9
S-9-A

CONCLUSIONS

This investigation has shown that originally the region was sedimentary; the oldest formation is a metamorphosed serpentine limestone whose origin remains undetermined, but which is extensively mineralized and shows considerable evidence of contact metamorphism. Above this was originally a series of sandstones and shales, now metamorphosed to schist, slate, and quartzite. This metamorphism was initially caused by the intrusion of the Salem gabbro-diorite; however, whether there was any extensive mineralization connected with this intrusion could not be determined. After a long period of erosion, the whole area was re-intruded by the Andover granite resulting in extensive remetamorphism and mineralization throughout the region. It is this last intrusion that has resulted in the formation of the mineral deposits with which this thesis is concerned.

Since the last intrusion, extensive erosion and glacial action have removed most of the old sediments, so that the remaining sequences are merely scattered and unconnected roots in close association with the intrusive rocks. These roots are apparently not confined to The Highfield Ridge, but occur scattered throughout the countryside at such locations as Devil's Den and Devil's Basin resulting in many scattered mineral deposits. Since the rocks that remain were the roots of two extensive orogenies, they were in close association under conditions of very high temperature and pressure for such a period of time that they have lost any distinctive features that might have been expected to appear in the region of contacts. Instead the rocks grade back and forth very gradually forming extremely irregular bodies which bear little, if any, relationship to the normal structural and lithologic differences that usually enable one to differentiate between sedimentary and igneous rocks. As a result it is futile to attempt to draw any definite dividing lines between the various lithologies in the area.

These relationships are further complicated by a fault or series of faults occurring in a north-south direction through the middle of Highfield Ridge, which apparently displace the sediments southward on the northeast end of The Ridge, at the same time changing the strike locally about 30 degrees. This structure is mainly determined by the very dislocated nature of the lithology and is not directly verifiable.

We believe that our investigations have shown the existence of as yet undiscovered mineral deposits in The Highfield Ridge Area. To support this conclusion there is: first, the evidence, found both by the authors and others, of extensive disseminated mineralization throughout the rocks of the region; second, the lack of low geochemical background anywhere except the southernmost salt marshes; third, the numerous small concentrations which have been mined from colonial times up to the present; and fourth, the results of geological investigation which shows the existence of scattered patches of highly metamorphosed, ancient sediments in association with the Andover granite.

The reason that mining in the area has not been attended by more success is probably the very nature of the mineral deposits. It is characteristic of this type of mineral deposit, Lead-Silver Veins of the Galena-Siderite-Tetrahedrite Group, that the ore is spotty and the ore shoots are discontinuous and irregular. Each mining operation was concerned with one ore shoot. This is well borne out by The Chipman Mine. From 1875 to 1880 mining was carried on in continuous ore, undoubtedly a single ore shoot, and the mine was shut down when this ran out. During the period 1919 to 1921 mining was carried on in one ore shoot less than 100 feet north of the old one and in another less than 100 feet south to the old one.

We feel that little further progress can be made in determining the actual structure by direct surface observation. Further studies can only be accomplished by detailed petrographic studies of the various lithologies accompanied, if possible, by core sampling. Complete determination of the structure would involve at least another year of detailed study, and even so it is most unlikely that the structure could be finally determined due to the irregularity and complexity of the contacts.

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APPENDIX

GEOCHEMICAL FIELD METHOD

As originally outlined by Huff this method was designed for the semi-quantitative determination of metal in samples collected in the field and brought to a field laboratory. It was necessary to extract the total metal by digesting the sample with nitric acid. Bloom[31] revised the method to make it possible to run the sample on location without resort to a field laboratory.

Bloom's method replaces extraction by nitric acid with extraction by cold ammonium citrate solution. The cold citrate extracts less than 10% of the total metal; however, although this is not sufficient to detect small variations in background, it detects valuable anomalies quite well. Actually the contrast between background and anomaly is magnified, as the following example illustrates.

Example:
Unit values in parts per million of zinc

	Background	Anomaly	Normal	Anomalous
Extractable (by cold citrate)	1	20	1	21
Not Extractable	75	80	75	155
Total extractable by hot nitric acid			76	176

31. Bloom, Harold, "A Field Method for the Determination of Ammonium-Citrate-Soluble Heavy Metals in Soils and Alluvium as a Guide to Ore, Econ. Geology, Vol. 50, pp 533-541, 1955.

These figures show how the contrast is increased by the cold citrate method. To be specific the contrast ratio for the cold citrate method is 20:1 as compared to only 2.3:1 for the hot nitric method.

Equipment

The following equipment is necessary for each man sampling in the field.

1 Volumetric scoop, about 0.2g.
1 Spatula or penknife
6 Pyrex culture tube 16 x 150 mm., marked at 3, 4, 5, 7, 9, 13, 18 ml., with tight plastic stopper.
1 Pyrex culture tube, 16 x 150 mm., marked at 10 ml.
2 8 oz. polyethylene wash bottles, marked at 100 ml.
2 8 oz. polyethylene screw-top bottles, marked at 100 ml.
2 32 oz. polyethylene screw-top bottles
1 Roll aluminum foil

In addition the base camp must have the necessary equipment to make up the reagents, such as separatory funnels, a pyrex still or water demineralizer and large graduates.

Reagents

The following reagents are necessary for each man in the field.

6 vials containing 0.01g dithizone crystals
10 lbs. pre-tested metal-free toluene
1 lb. pre-tested metal-free carbontetrachloride
5 liters citrate extractant (Field Solution A)

The base camp makes up and stocks reserves of the above reagents.

Preparation of Field Solutions

All containers must be washed with field solution **A** and dithizone before being used.

1. Stock Dithizone Solution

   Add less than 100 ml. of carbontetrachloride to 8 oz. screw-top bottle; add contents of one vial of dithizone and shake; rinse vial thoroughly with carbontetrachloride and fill bottle to 100 ml. mark; shake and allow to stand for one hour before using.

2. Field Dithizone Solution

   Add less than 100 ml. of toluene to 8 oz. screw-top bottle; measure 10 ml. of stock dithizone solution into marked culture tube and add to bottle; fill bottle to 100 ml. mark and shake; pour solution into wash bottle for use, and cover wash bottle with aluminum foil to prevent oxidation of solution by sunlight.

The above procedure yields a field solution of 0.001% dithizone; stronger or weaker solutions may be obtained by proportional variation of the amount of stock solution used in each 100 ml. batch of field solution.

Procedure

Before each sample is taken, the culture tube should be washed by repeated shakings of small amounts of field solution A and dithizone about 1 ml each, until the dithizone remains green. After the tube is washed, measure out one scoopful of sample taken from under the humus and tap into the culture tube. Add solution A to the 3 ml mark washing the tube down at the same time so that there will be no grit to interfere with the fit of the cap. Add field dithizone solution to the 4 ml mark; cap the tube tightly; and shake briskly for 15 seconds. After the dithizone solution has collected at the surface note the color. If it is green record 0, if blue-green record ½, if blue record 1. If the dithizone phase is purple to red add dithizone to the 5 ml mark and shake briskly for 5 seconds; if the dithizone phase is now blue record 2, but if it is still purple to red repeat the procedure adding dithizone to the next mark until a blue end-point is reached. Record the total volume of dithizone solution added.

It is important to standardize the timing of the shaking as increasing or decreasing the shaking will give higher or lower values. Serious contamination is possible by inadvertant contact with the fingers or contaminated objects. Care should be taken not to touch the rim of a clean tube or the inside of the stopper, and all unexpectedly high values should be re-run.

Adjusting the pH of the field solution A makes it extractive to different metallic ions. The solution used in this work was adjusted to a pH of 8.5 to make the test sensitive to copper, lead and zinc.