THE GEOLOGIC SETTING OF THE STERLING HILL ZINC-IRON-MANGANESE DEPOSIT

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The Sterling Hill mine is located on the west side of the Wallkill River Valley in the Borough of Ogdensburg, Sussex County, New Jersey. Ogdensburg, about fifty miles from New York City, may be reached by taking County Rte. 517 either south from its intersection with N.J. Rte. 23 in Franklin or north from the town of Sparta, about four miles distant.

The Sterling Hill deposit together with its now depleted companion at Franklin, 2½ miles to the north, are a pair of silicate-oxide ore bodies that are unique in all the world. The combination of ore and gangue minerals that comprise them is unknown elsewhere. Indeed, the mineral franklinite is not known to have been found outside of these two places.

Both bodies of ore are enclosed within the Franklin marble which is one of two bands of Precambrian metalimestones which strike northeasterly near the western border of the Reading Prong. The two marble bands, indistinguishable from one another, are separated by roughly 300 meters of heterogeneously mixed gneisses which comprise a unit aptly designated the "Miscellaneous gneiss" by Buddington and Baker (1970) but which is more commonly called the Cork Hill gneiss. All three bands dip southeasterly about 55° in the vicinity of the ore bodies.

The regional structural pattern is interpreted by Hague et al (1956) and Buddington and Baker (1970) as a group of northeast trending overturned isoclinal folds. Generally the folds plunge from 10° - 30° NE. Normal faulting predominates in the area with the faults dipping from about 70° to vertical and striking parallel with the predominantly NE trend of the Precambrian rocks. The contacts between the gneisses and the metalimestones are straight-to-broadly warped and reveal none of the complex folding seen within the marbles themselves.

The metalimestone is a medium-to-coarsely crystalline calcite marble characterized by bands of disseminated silicates (tremolite, phlogopite, chondrodite, etc.), pyrite, and graphite. The latter is ubiquitous in the metalimestones except where they are associated with the ores at Franklin and Ogdensburg and in halos around certain pegmatitic bodies. Inhomogeneities in grain size appear to be, at least in part, a function of mineral banding. Calcite grain diameters range from less than a centimeter to as much as sixty centimeters. In general, the sparsely mineralized calcite has a coarser texture than that which is heavily mineralized. It might be said that the calcite grain size varies inversely with the concentration of other minerals contained within it. It also appears that the calcite grains are flattened in planes parallel with the mineral banding of the marble.

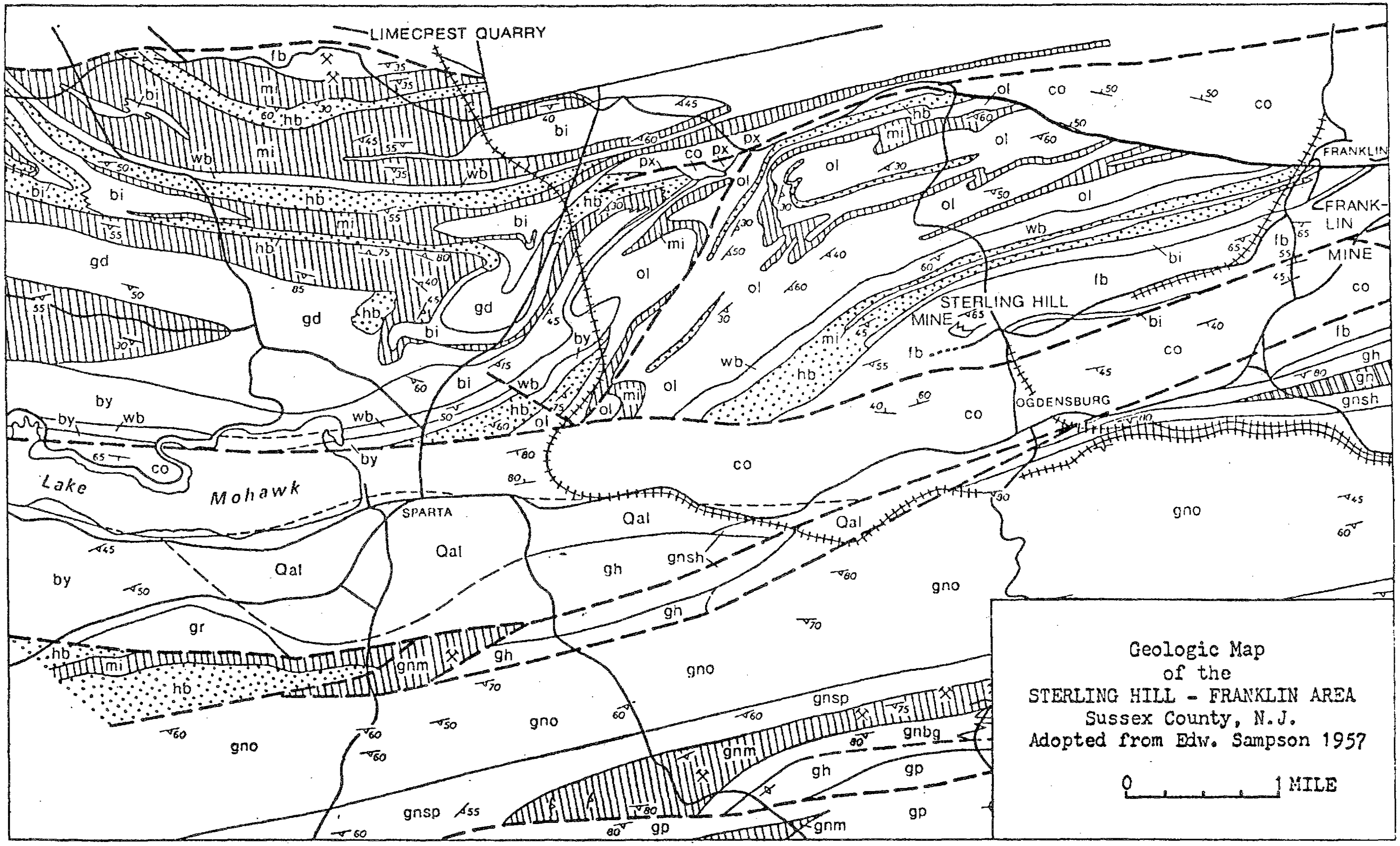
The contacts of the metalimestones with adjacent gneissic units are commonly characterizd by increasingly abundant coarse crystals of pyroxene, garnet, spinel, biotite, apatite and feldspar as the gneiss is approached. Grain diameters reach as much as 3-6 centimeters. Also common at the contacts are clots of white to pale yellow sphalerite. Dithizone analyses by the New Jersey Zinc Company of drill cores passing through marble into gneiss showed the presence of anomalously high traces of zinc at such contact.

A characteristic of the metalimestone belts is the presence within them of inclusions of "miscellaneous gneiss" which range from a few centimeters to many meters in diameter. They are not boudins but rather are fragments of gneiss which are far removed from the parent band. Were they isolated in an igneous rock rather than a marble they would be unquestionably called xenoliths.

Those xenolithoids which are composed of carbonate free amphilbolite, for example, typically have borders of randomly oriented 2.5-3 cm crystals of pyroxene, garnet, biotite and/or gahnite crystals. On the other hand, those fragments having some carbonate content generally have no obvious reaction rims.

Some xenolithoids are crossed by quartz filled fractures which terminate at the fragment boundaries. They clearly belong to the fragment and not to the enclosing marble.

The ore bodies at Franklin and Sterling Hill have afforded the best opportunities to study the metalimestone structure in some detail. The distinctive



Geologic Map
of the
STERLING HILL - FRANKLIN AREA
Sussex County, N.J.
Adopted from Edw. Sampson 1957

FIGURE 1

EXPLANATION

QUATERNARY

Qal	Alluvium and moraine

CAMBRIAN AND ORDOVICIAN

co	Cambro-Ordovician sediments

PRECAMBRIAN

gr	Granite
by	Byram gneiss
gd	Granodiorite gneiss
ol	Oligoclase gneiss--possibly the same as
gh	Hornblende granite with some alaskitic facies
gp	Pyroxene granite with local pyroxene syenitic facies

ROCKS OF UNCERTAIN ORIGIN

gm	Quartz-microcline granite-like gneiss
gno	Losee gneiss of type locality. Quartz oligoclase gneiss.

ORTHOGNEISS

gnsh / gnsp	gnsh Hornblende syenite gneiss gnsp Pyroxene syenite

METASEDIMENTARY AND METASOMATIC ROCKS

fb / wb	Marble. Franklin band. Wildcat band.
gnh	Hypersthene biotite quartz-oligoclase gneiss, in part with a very little accessory graphite
gnab	Mixed gneisses: quartz-bearing hornblende and pyroxene-plagioclase gneiss, biotite mafic gneisses, local interbeds of sillimanitic or garnetiferous quartz-microcline gneiss
gnp	Pyroxene quartz-plagioclase gneisses
gnbg	Biotite quartz-plagioclase and other gneisses
gne	Epidote-scapolite-quartz gneisses interlayered with pyroxenic and hornblendic quartz-microcline gneiss
mi	Microcline gneiss
gnm	Quartz-potash feldspar gneisses, in part seamed with pegmatite. Host to magnetite mineralization.
am	Amphibolite
hb	Hornblende gneiss, including calcareous facies
bi	Biotite gneiss
px	Pyroxene gneiss and related rocks, including calcareous facies

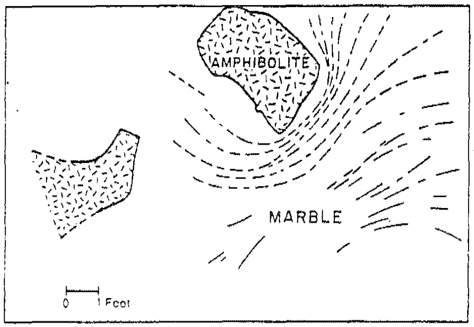


Figure 2

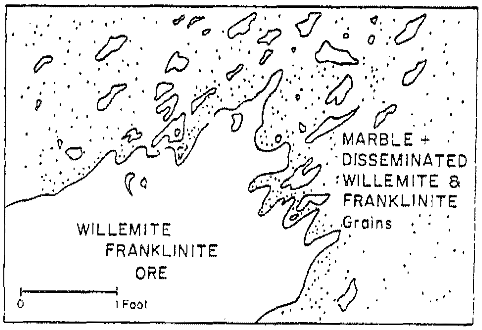


Figure 4

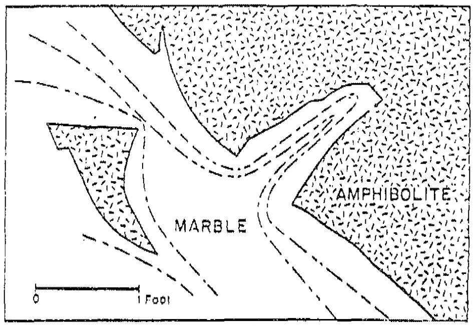


Figure 3

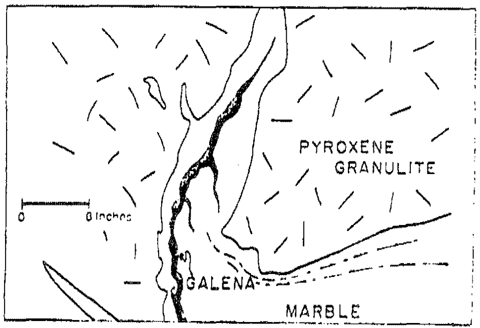


Figure 5

bands of willemite, franklinite, and zincite as well as those of more common calc-silicate minerals have made it possible to trace folding in the marble that would be otherwise obscure. A variety of textures, especially at Sterling Hill, reveal that ore and adjacent calc-silicates were originally carbonate free granulites. Certain distinctive graphite-phlogopite-chondrodite-pyrrhotite bands in the marble wall rock and a fluorite band at the contact between ore and marble as well as recognizable bands within the ore itself suggest that the ore was at one time stratiform.

Ore textures grade from massive granulose and gneissose to disseminated "pepper and salt". The appearance of the gradation suggests that the ore minerals as well as the adjacent calc-silicates were friable masses which became disaggregated within an extremely plastic or, in part, even fluid carbonate (fig. 4).

The shape of the ore body itself suggests a huge flow pattern influenced by a broken band of brittle gneiss fragments which it has engulfed. Where the sharply anglular gneiss blocks are near ore, the ore banding is bent around them. Where they are isolated in marble, the flow pattern is revealed by contorted silicate and graphite bands (fig. 2).

When the average density of the entire body (approximately 3.02) is considered together with the visual evidence for the plasticity of the enclosing marble (d = 2.75) it seems almost a certainty that the complex fold pattern of the ore body is due to its movement through the marble. The density contrast between ore and marble seems sufficient for gravity, in addition to tectonism, to have played an important part. It has therefore been proposed (Metsger, et al., 1967) that the ore body acquired its present shape as it sank through the limestone as an inverted diapir.

Marble "dikes" are common in the gneisses and granulites associated with the metalimestones. They were formed when the mobile carbonate flowed into fissures in the more brittle rocks (fig. 3). One such dike was observed in a pyroxene granulite fragment in the core of the Sterling ore body (fig. 5). The dike contained a vein of galena which occupied a fracture in the marble. The lead age of the galena, manifestly of more recent origin than the surrounding rock, was 1100 x 10^6 years.

From observations, chiefly in the Sterling Hill mine, it appears that the Precambrian history of the metalimestones and of the enclosed zinc, iron, magnanese ores was somewhat as follows.

1. Deposition of a series of limestones and siliceous sediments and volcanics beneath the sea. Within the carbonate horizon at least one metal rich bed was deposited.

2. The sedimentary series was folded and then—

3. forced to a depth where sillimanite grade metamorphic conditions prevailed. During this stage the granulites and gneisses were formed

from the siliceous and volcanic units. The metal rich horizon was metamorphosed to a granulose silicate and oxide band and the calcareous units to marble.

4. The region continued to subside until ambient conditions prevailed in which the gneisses and the ore were essentially unmodified while the marble became extremely plastic or, perhaps, fluid. During this period, currents in the viscous carbonates tore relatively thin bands of gneiss apart and produced complexly contorted folds in the less fragible ore and calc-silicate zones. Because of the low viscosity of the enclosing carbonate, the more friable bands of ore and calc-silicates disaggregated to produce the "pepper and salt" texture so common in certain parts of the marble units.

5. The subsidence was arrested and the region uplifted. As a result, uniquely metamorphosed ore deposits folded in complex flow patterns have been preserved which otherwise would have been destroyed by absorption into the mantle.

At the close of the Precambrian the metalimestones were exposed at the surface. Zones of rubble breccia have been observed, in the Sterling Hill ore body and in drill cores, which may be genetically related to the erosion surface that existed at that time. The brecciated zones cross-cut the ore structure and are comprised of rock and ore fragments, often mixed, in a matrix of the lithified insoluble residues from the marble and ore. Fragments range from a few centimeters to as much as a meter in diameter. The dimensions of the zones are measured in tens of hundreds of feet, with the principal dimensions vertical.

In general the marbles are quite pure calcite. Dolomitization has taken place principally along fractures and joints related to faulting of Paleozoic or more recent age. Such dolomitized marble is recognizable in quarry walls as a buff coloration against the pure white to gray color of calcitic rock.

REFERENCES CITED

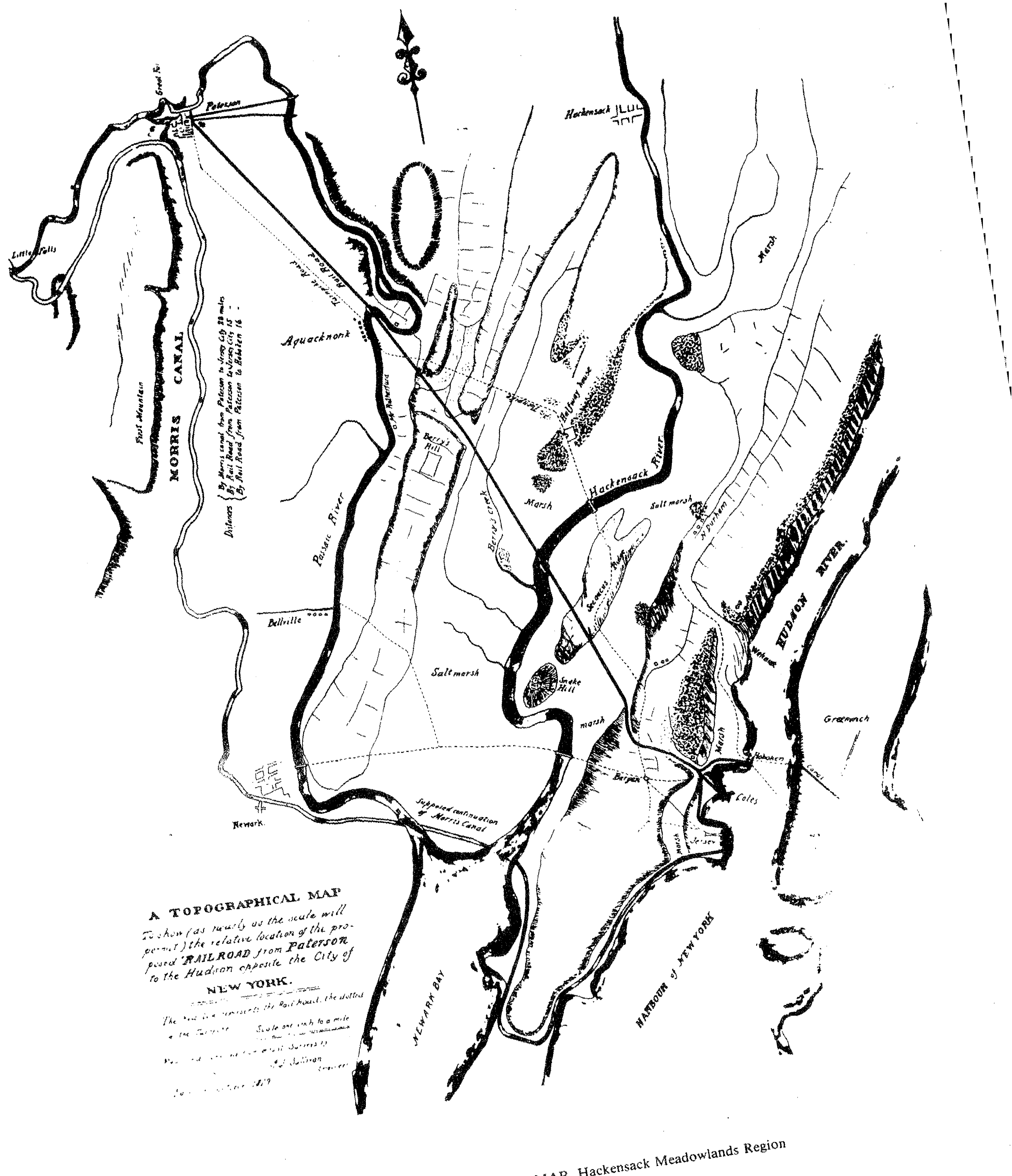
Hague, J.M., Baum, J.L., Herrmann, L.A., and Pickering, R.J. 1956, Geology and structure of the Franklin-Stering Area, New Jersey. Bull. G.S.A. Vol. 67, pp 435-474.

Buddington, A.F., and Baker, D.R., 1970, Geology and Magnetite Deposits of the Franklin and part of the Hamburg Quadrangle, N.J. USGS Prof Paper 638.

Metsger, R.W., Tennant, C.B., and Rodda, J.L., 1958, Geochemistry of the Sterling Hill Zinc Deposit, Sussex Co. N.J. Bull. G.S.A. v 69, pp 775-788.

Metsger, R.W., Skinner, B.J., and Barton, P.B., 1969, Structural Interpretation of the Sterling Hill Ore Body, Ogdensburg, N.J. (abs) Econ. Geol., v 64 p 833.

Frondel, C. and Baum, J.L., 1974, Structure and Mineralogy of the Franklin Zinc-iron-manganese deposit, New Jersey. Econ. Geol. v 69, pp 157-180.



TOPOGRAPHICAL MAP, Hackensack Meadowlands Region
1829
by I.L. Sullivan