THE CORTLANDT COMPLEX

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Trips 3-A, 3-B and 3E.

Introduction

The Cortlandt complex is a funnel-like mass of basic igneous rocks (mostly orthopyroxene gabbro or norite) outcropping in roughly oval shape principally in Cortlandt township south of Peekskill (Plate 13). That it is younger than the Inwood marble and Manhattan schists, which it intrudes, is known. But the age of these formations is itself a controversial matter, although they are certainly not younger than early Paleozoic.

The Cortlandt complex has attracted the attention of geologists for many years because of its unusually interesting petrologic and structural problems and because of the economic and mineralogic importance of its emery ores. A brief review of the history of investigation of the Cortlandt complex is a good illustrative example of how a geologic problem may be studied by the application of different methods, each contributing its part to a final picture.

Historical Summary

James Dana, in 1880, was the first to study the rocks as a whole and to recognize their genetic relationships to each other. It is to him that we owe the name Cortlandt series. Because of certain contact phenomena and locally pronounced banding he erroneously classified the rocks as metasediments. This hypothesis was abandoned by him in 1884 when additional field evidence led to the recognition of the true igneous nature of the complex.

G. H. Williams (1884 to 1888) published the results of very detailed petrologic work. Several species each of peridotite, norite, gabbro, diorite and mica diorite-all intimately related by transition - are described. Williams considered the more basic types to have been intruded first, followed by successive intrusions of more and more acidic magma. Unfortunately, Williams studies did not cover the entire outcrop area of the Cortlandt intrusive.

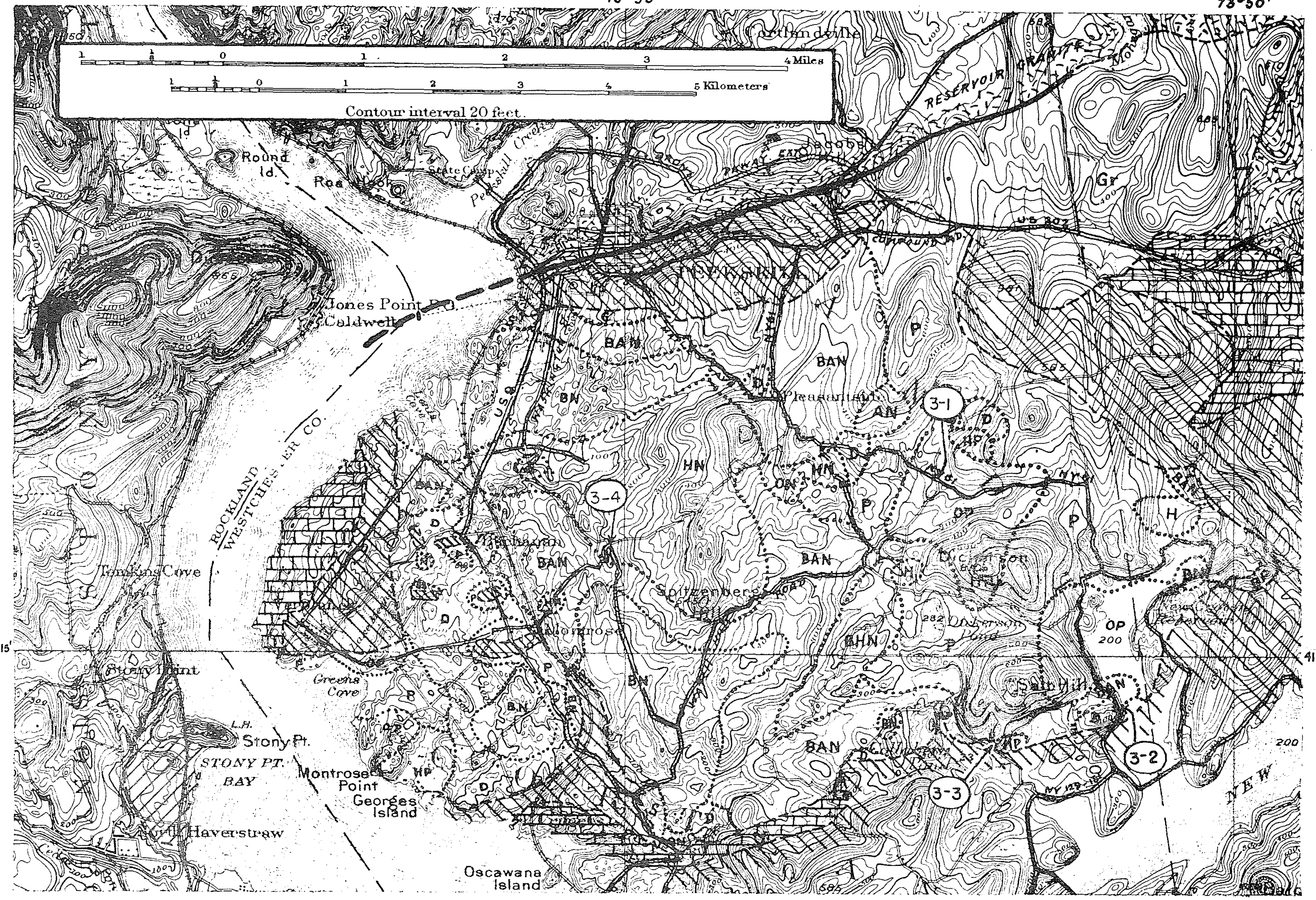
Berkey (1907) was the first to map the complete boundaries of the pluton and the first to suggest the possibility of a genetic relationship between certain granites outcropping immediately to the northeast (Peekskill granite) and the Cortlandt series proper. Such a relationship was not confirmed by Butler (1936, p. 542).

An important contribution was made by Rogers (1911) after intensive study of the entire area. The Cortlandt intrusive was divided into a large number of closely related types. Included among them were gabbro, several varieties of norite, peridotite, diorite, hornblendite and various species of pyroxenite (Plate 4). He had great difficulty in explaining their mutual relationships and magmatic history, although he believed the basic intrusions were followed by more acid magma.

New light was shed on the problem with the publication of Balk's (1927) classic structural study. Balk systematically mapped the dip and strike of

MAP OF THE CORTLANDT SERIES

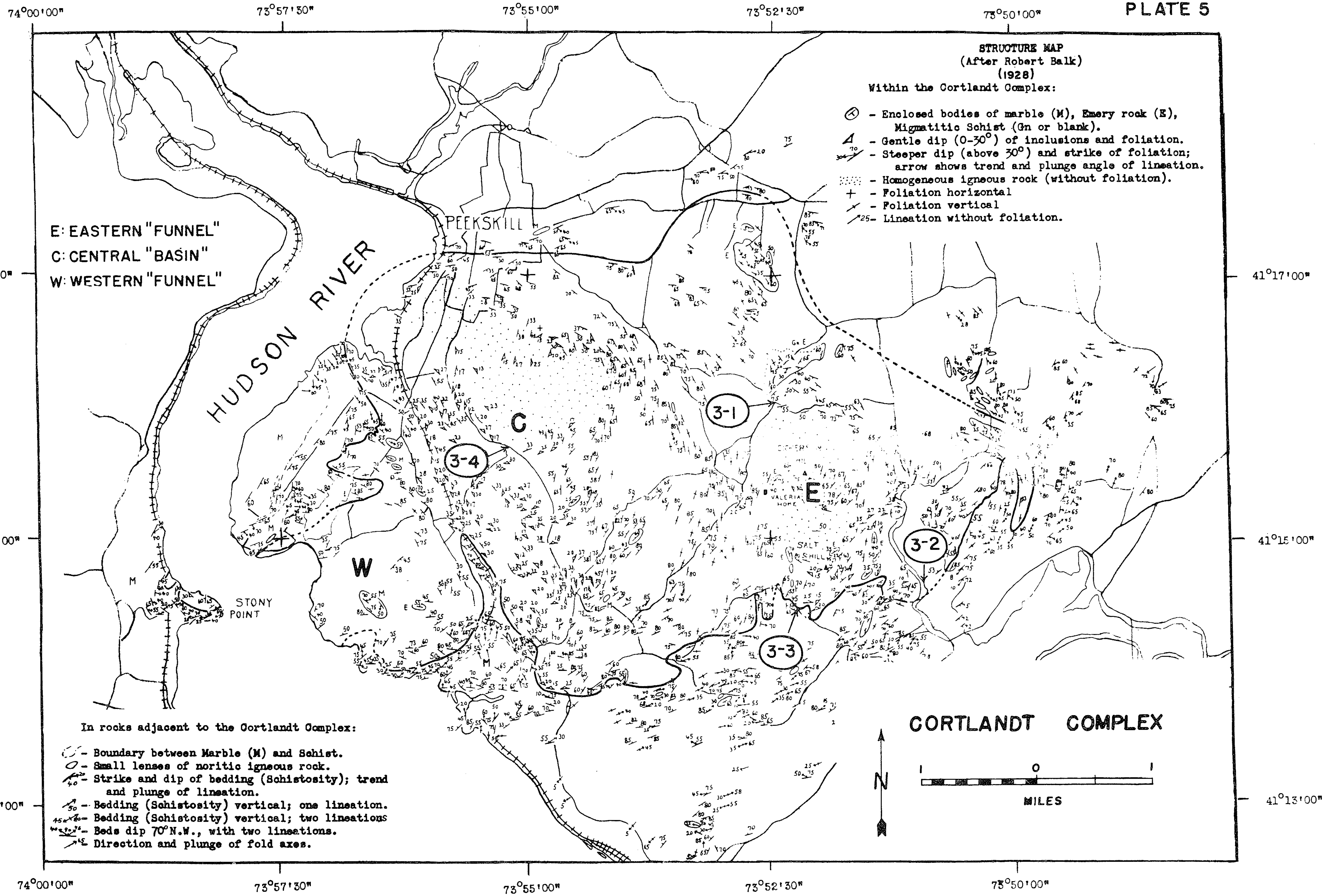
PLATE 4



AFTER G.S. ROGERS (1910)

Symbol	Rock
Gr	GRANITE
S	SYENITE
SS	SODALITE SYENITE
D	DIORITE
G	GABBRO
H	HORNBLENDITE
P	PYROXENITE
HP	HNB. PYROXENITE
OP	OLIV. PYROXENITE
BP	BIOT. PERIDOTITE
BN	BIOTITE NORITE
AN	AUGITE NORITE
BAN	BIOT. AUG. NORITE
HN	HNB. NORITE
BHN	BIOT. HNB. NORITE
ON	OLIVINE NORITE
QN	QUARTZ NORITE
▧	MANHATTAN SCHIST
▦	INWOOD LIMESTONE
▨	FORDHAM GNEISS

PLATE 5



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the banding, which is nearly always present (but not always prominent) in the Cortlandt complex (Plate 5). The bands are alternately light and dark, reflecting changes in mineral composition, although differences in grain size are sometimes more important distinguishing features than composition (Shand, 1942, p. 414).

Balk's map shows two oval areas within which the banding dips towards structureless focal "lows". At the first (Dickerson Hill; E of Plate 5) dips are steep on three sides but flatten to the south. The second and largest, running southeast from Peekskill (C of Plate 5), is asymmetric having steep dips on the east side but shallower dips to the west. On the southwest side of this second low a long reentrant seems to mark off a third area to the west (W of Plate 5). This is also suggested by a reentrant along the western Cortlandt-Manhattan contact.

On the basis of structure, Balk pictured the complex as the upper part of a funnel shaped magma chamber in which masses of early crystallized rock, rich in olivine, pyroxene or hornblende, floated upward. Around these "knots" wrapped the banding and schlieren, which he measured. Balk estimated the depth of the synclinal lows at from 3000 to 5000 feet with the funnel as a whole reaching depths of 3.75 to 6.8 miles.

Impressed by the complete lack of correlation between Rogers' petrologic and Balk's structural maps, Shand (1942) was led to a complete reexamination of the petrology of the Cortlandt complex. Noting the probability of Balk's structural funnels being channels by which the magma ascended and appreciating the strong evidence of all the main rock types belonging to a single period of intrusion, he became convinced there ought to be a rude concentric outcropping of different rock types around the funnels. Roger's map failed to show any such outcrop pattern.

In evaluating Rogers' work, Shand criticized the subjective character of his rock classification with its arbitrary boundaries. It is difficult, for example, to draw the line between biotite-hornblende norite and hornblende-biotite norite. In addition, Rogers failed to recognize the importance of compositional changes related to banding. Thus one outcrop can contain two or three different rock types. Finally it is remarked that Rogers made too few thin sections and relied too much on hand specimen identification.

In place of Rogers' "species petrology", Shand (1942) proposed "phase petrology". He defined critical phase to mean "... any phase which is restricted either to a particular part of the eruptive complex or to a particular period in the cooling history of the magma, and which may in consequence yield information about the chemical and physical changes that accompanied the freezing of the system" (p. 415). The most important phase is hornblende. This occurs in two forms (1) primary and (2) as a poikilitic replacement surrounding inclusions of plagioclase and pyroxene in norite. The first is confined to marginal zones (Plate 6) whereas the second coincides with Balk's central funnel (C of Plate 5) southeast of Peekskill.

Another critical phase is that of olivine in pyroxenite. This phase outcrops in a large eastern area and a smaller western area generally agreeing with Balk's eastern (Dickerson Hill) and western funnels. Each of these areas is surrounded by pyroxene without olivine. Although Shand questions the independence of the Dickerson Hill funnel, there seems to be no doubt as to the existence of a large, general Cortlandt complex funnel.

In discussing the history of crystallization of the magma, Shand concludes the the norite and pyroxenite were part of the same magma, but that the pyroxenite and peridotite were formed by the settling of crystals from the norite magma He postulates that the higher parts of the pluton, now eroded away, contained a greater proportion of norite. The steeply dipping, parallel bands are accounted for by subsidence of the partially differentiated mixture of crystals and liquid in the center of the funnel. The poikilitic hornblende was then formed by steam rising through the central funnel from hot, deeper portions of the magma chamber. This was in turn followed by local introduction of pegmatite and granite veins bringing crystallization to a close.

Woollard and Steenland (1948) conducted a gravimetric and magnetic survey of the area. Keeping in mind that such data are always open to several interpretations, it can be said that the gravity readings show anomalies roughly coinciding with the eastern and western peridotite-pyroxenite masses (Plate 7). Depths arrived at by assuming the masses to be funnels compare favorably with those of Balk. The central area, however, cannot be deeper than 1300 to 1800 feet. The magnetic readings show anomalies on the margins of the intrusive reflecting contact metamorphic, disseminated magnetite in emery ore. It is interesting to note that 3 of the prominent magnetic "highs" (Plate 8) fall within the present surface boundaries of the complex. This would suggest that the contact surfaces of the intrusive are, indeed, sloping inward in the form of a large funnel.

Bucher (1948) tried to weld all the facts into one interpretation (Insert on Plate 5). He concludes that the pluton must have become involved in the folding of the surrounding rocks while still quite fluid. In support of this concept are: the general presence of bent plagioclase twin lamellae, folding and faulting of marginal dikes, the general turbulence of the Cortlandt banding and the close accordance between this banding and the foliation in the Manhattan schist country rock. Also noted is the general parallelism of trend of the long axis of the Cortlandt complex with the regional fold trend (N 55° E). The liquid magma mushroomed around earlier crystallized viscous masses of olivine-pyroxene, wedging in between surrounding layers of country rock to form flange-like margins.

It seems well to remember that plagioclase crystals can be bent by jostling as they float upward during magmatic differentiation and that flow banding and schlieren are ordinarily expected to be roughly parallel to the contacts with the country rock. Also ascending plutons often accommodate themselves to surrounding wall rocks and can even cause marginal thrusting and folding as well as metamorphism during emplacement. It is possible to believe that the Cortlandt pluton may have been intruded after the main period of metamorphism but before all orogenic forces had subsided.

Genesis of the Emery

The genesis of the emery ores, which have been quarried for many years in the Cortlandt locality, is an interesting mineralogical problem. Quoting Friedman (1956, p. 7), "Emery is essentially an aggregate of corundum and magnetite, but many emery bodies also contain abundant spinel, while ilmenite is likewise common. Among the accessory minerals may be mentioned hematite, hoegbomite, pyrite, sillimanite, cordierite, andalusite, staurolite and garnet."

Emery is used as a commercial abrasive. Two types are recognized: (1) spinel bearing or black emery (no longer mined) and (2) gray or cordierite-sillimanite-sapphirine emery, now the only type quarried in Cortlandt township.

Through the years several theories have been proposed to account for the origin of the emery. A detailed discussion is not attempted here.

Rogers (1911) offered a theory of absorption of the Manhattan schist by Cortlandt magma with resultant aluminous segregations. He cited experiments in artificial production of corundum by Morozewicz.

Gillson and Kania (1930) gave deuteric contact metamorphism as the reason for emery formation. The gaseous or liquid emanations welled up through the already solid border of the igneous mass and into the schist. In support of this are: (1) emery and associated rocks contain common contact minerals, (2) emery occurs only with endomorphosed igneous rocks, and (3) quartz and corundum occur in the same rocks when they should have combined to form aluminum silicates, if absorption of schist had taken place.

A modification of the theory was made by Butler (1936). Contact metamorphism took place during the early liquid-magmatic stage of the basic Cortlandt intrusion. The emery was formed by emanations travelling in advance of the main magma into the country rock. He points out that emery deposits in norite are mineralized xenoliths engulfed by the magma. The emery was formed before solidification of the endomorphosed norite because norite cross-cuts emery lenses and encloses emery fragments.

Friedman (1956), after an exhaustive study of the entire problem of emery formation both in the United States and abroad, came to the conclusion that the spinel emery is a result of reaction between granitic emanations and pyroxene-rich basic rocks. Hornblende and biotite are formed and Fe, Mg and Al ions are released as a byproduct to form the emery. The emery occurs as irregular lenticular bodies replacing the basic rock. The ions that pass into the adjoining schists combine with silica to form a zoned hornfels and contact aureole. The influence of granitic material is evidenced by structural relations between the basic rocks and emery deposits, by typical mineral suites and by characteristic metasomatic changes in the basic rocks normally ascribed to granites.

In the case of the Cortlandt complex, such granitic emanations would come from the Peekskill granite outcropping to the northeast. This is the same granite that was thought to be an acidic differentiate of the Cortlandt series by Berkey and Rogers.

References

Balk, R. (1927) Die Primaere Struktur des Noritmassivs von Peekskill am Hudson, noerdlich New York. Neues Jahrb. Beilageband 57

Berkey, C. P. (1907) Structural and stratigraphic features of the basal gneisses of the Highlands, N. Y. State. Mus. Bull. 107

Bucher, W.H. (1948) Petrology and flow structure of the Cortlandt norite in Geol. Soc. Amer. 61 Ann. Meeting Guidebook of Excursions pp 33-38

Butler, J. W. (1936) Origin of the emery deposits near Peekskill, N. Y. Am. Mineralogist v. 21, pp 537-544

Dana, J. D. (1880) On the geological relations of the limestone belts of Westchester Co., N. Y., Am. Jour.. Sci., 3d Serv, v. 20, pp 194-220

------- -- (1881) Origin of the rocks of the Cortlandt series, ibid., v. 22, pp 103-119

------ -- (1884) Note on the Cortlandt and Stony Point hornblendic and augitic rocks, ibid., v. 28, pp 384-386

Friedman, G. M. (1956) The origin of the spinel-emery deposits with particular reference to those of the Cortlandt complex, N. Y. N. Y. State Mus. Bull. 351

Gillson, J. L and Kania, J. E. A. (1930) Genesis of the emery deposits near Peekskill, N. Y., Econ. Geol. v. 25, pp 506-527

Rogers, G. S. (1911) Geology of the Cortlandt series and its emery deposits, N. Y. Acad. Sci. Annals, v. 21, pp 11-86

Shand, S. J. (1942) Phase petrology of the Cortlandt complex, N. Y. Bull. Geol. Soc. Amer. v. 53, pp 409-428

Steenland, N. C. (1948) in Geol. Soc. Amer., 61st Annual Meeting, Guidebook of Excursions, pp 39-42 Petrology and flow structure of the Cortlandt complex

Williams, G. H. (1884) On the paramorphism of pyroxene to hornblende in rocks, Am. Jour. Sci. 3d Serv. v. 28 pp 259-268

------- -- (1886) The peridotites of the Cortlandt series on the Hudson River near Peekskill, N. Y. ibid. v. 31 pp 26-31

(Also additional papers on the Cortlandt series in 1887 and 1888, Am. Jour. Sci. vol. 33 and 35)

THE CORTLANDT COMPLEX

Trips 3-A, 3-B, and 3-E

Route Description

Mileage	
0	Shustin's Locust Manor (headquarters) - right (S) on Locust Ave.
.2	right (W) on US-6
.45	pass under Bear Mt. Parkway
.7	left (S) on Conklin Ave.
1.0	right on US-202 (Crompound Rd.)
2.0	sharp left (up-hill) on Arch St. and continuing on Boulevard
2.35	right on Riverview Ave.
2.5	cross Longview Ave. Pause: View of southeastern gateway of the Hudson gorge - on west side of River (from left to right): Dunderberg, West Mtn. and Bear Mtn. (with tower).
2.6	left on Maple Ave. heading southeast
3.20	hill at right with outcrops of Cortlandt complex augite norite
3.6) 3.7)	norite outcrops along both sides of road
5.3	intersection with Furnace Dock Road STOP No. 3-1 Olivine pyroxenite near northwest margin of "Eastern Funnel" (E on Plates 4 to 8) and "Olivine Region" (Plate 6). Typical spheroidal weathering similar to that of olivine zone in the Palisades. Dickerson Hill (center of "funnel") to the southeast. Banding mapped by Balk (Plate 5) is difficult to distinguish in this exposure. Discussion of structural and petrologic features of the Cortlandt complex.
5.3	continue (E) on Maple Ave.
6.5	end of Maple Ave.; right (S) on Croton Ave. - DRIVE CAREFULLY - steep hill down to Croton Reservoir
7.2	sharp right turn along reservoir following Croton Ave. - do not drive straight ahead on Baptist Church Rd.
7.6) 8.0)	Outcrops of pyroxenite at right (E)
8.4 to 8.55	STOP No. 3-2 Old quarry dumps on both sides of road. Collect samples of pyroxenite (with and without olivine) and augite norite. Note indistinct banding and quartz-pegmatite veins cutting pyroxenite and norite.
8.55	continue on Croton Ave. (S) along reservoir
8.65	Pause: Passing over contact of Cortlandt complex with Manhattan schist (country rock); schist outcrops on both sides of road. keep right after next curve in road

9.0 bear right (W) on NY-129 (Yorktown Rd.) - schist outcrops at right

9.55 right (N) on Mt. Airy Rd.

9.6 sharp right on Colabaugh Pond Rd. - Colabaugh Pond at left

10.1 STOP No. 3-3: Kingston Emery Quarry (operated by Colbate Emery Co., Peekskill, N.Y.) presently the only operating emery quarry in the Cortlandt complex. Note the following:

(1) In quarry, down near the working face, excellent rectangular jointing. Rocks are highly magnetic. South quarry wall shows crusts of quartz and calcite, and quartz veins in the pyroxenite.

(2) Walking up cut leading out of main excavation observe the pyroxenite grading into more banded augen schist which becomes a normal schist at the quarry entrance (Colabaugh Rd.). This zone of transition represents the Cortlandt complex - Manhattan Schist contact. The country rock shows evidence of having been mobilized by the Cortlandt pluton during intrusion. The contact effects are also well shown in the schist outcrops near the construction shacks. The quarry has only been in operation since 1942. The contact shown on Plates 4 to 8 is not quite accurate and should be shifted southwestward close to Colabaugh Pond Road.

(3) Emery ore (samples on dump at quarry entrance) is dark blue-gray with an occasional pinkish hue and massive. Quarrying operation has followed ore vein down-dip.

10.1 continue (W) on Colabaugh Pond Rd.

11.75 straight ahead (W) on Mt. Airy Rd.

12.1 sharp right (N) on Furnace Dock Rd.

12.4 left fork into Washington St.

13.0 intersection with Watch Hill Rd (blinker light) - continue straight (N) on Washington St.

14.6 intersection with Montrose Station Rd.

STOP No. 3-4:

Hornblende norite with poikilitic hornblende near western margin of central "basin" (C of Plates 4 to 8). Platy structure of hornblende crystals can be observed.

14.6 continue (N) on Washington St.

15.5 cross Welcher Av.

16.85 right (E) on South St. (traffic light) continuing on Division St.

17.0 left (N) on South Division St. proceeding to top of hill (monument)

17.35 left fork in front of monument into Highlands Ave.

17.9 right on approach road to Bear Mt. Pkway (ahead of underpass)

18.0 Pause: Poughquag quartzite (Cambro-Ordovician) in unconformable contact with Highlands gneisses (Pre-Cambrian) at right (S). Dips are nearly vertical.

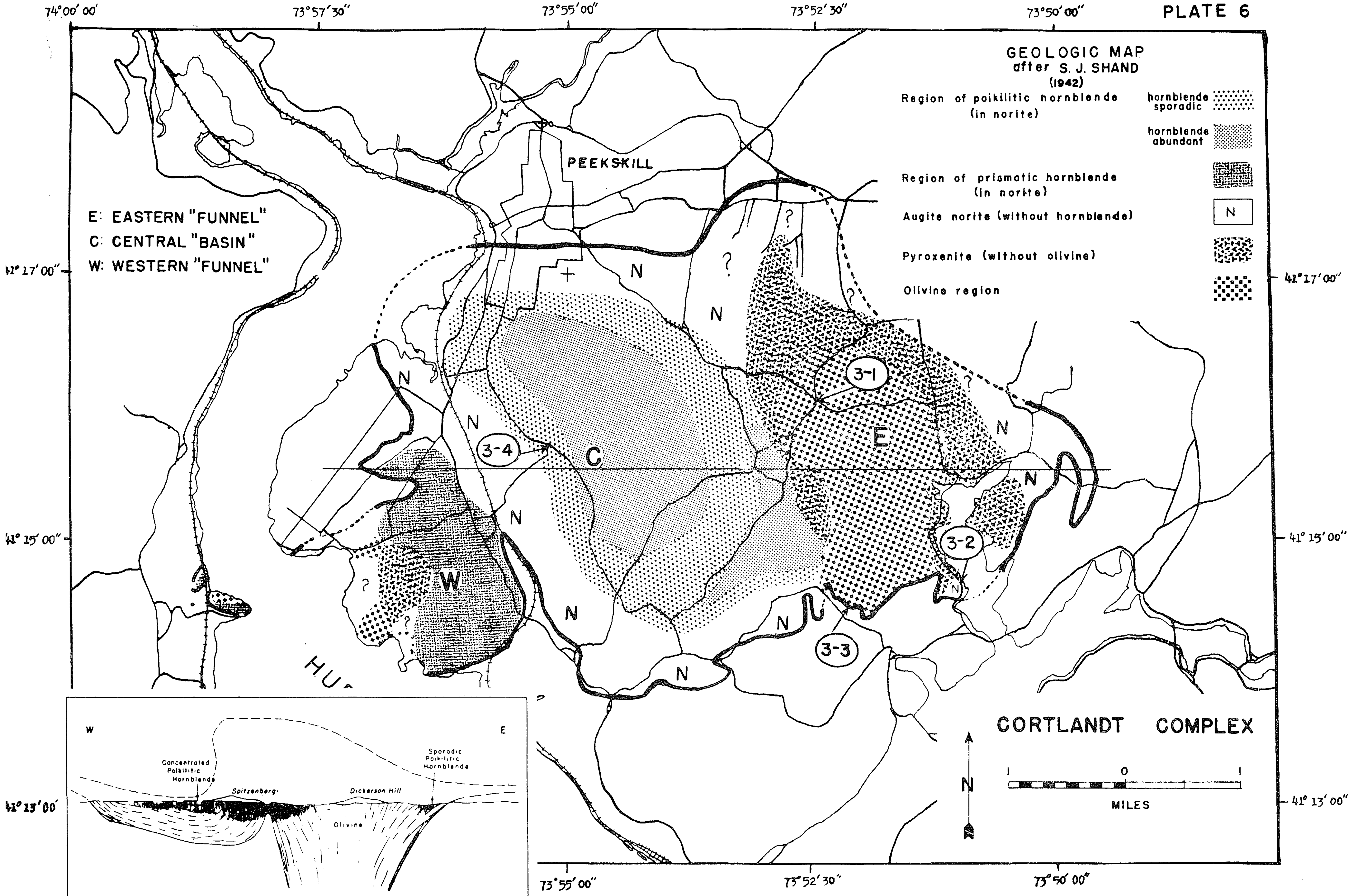
18.0 proceed (E) on Bear Mt. Pkway.

20.1 leave Parkway at US-6 exit (right) and then left (E) on US-6 passing under Parkway

20.25 left (N) on Locust Ave.

20.45 left into headquarters.

PLATE 6



A possible interpretation of the subsurface extension of the Cortlandt complex.

AFTER BUCHER (1948)

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PLATE 7

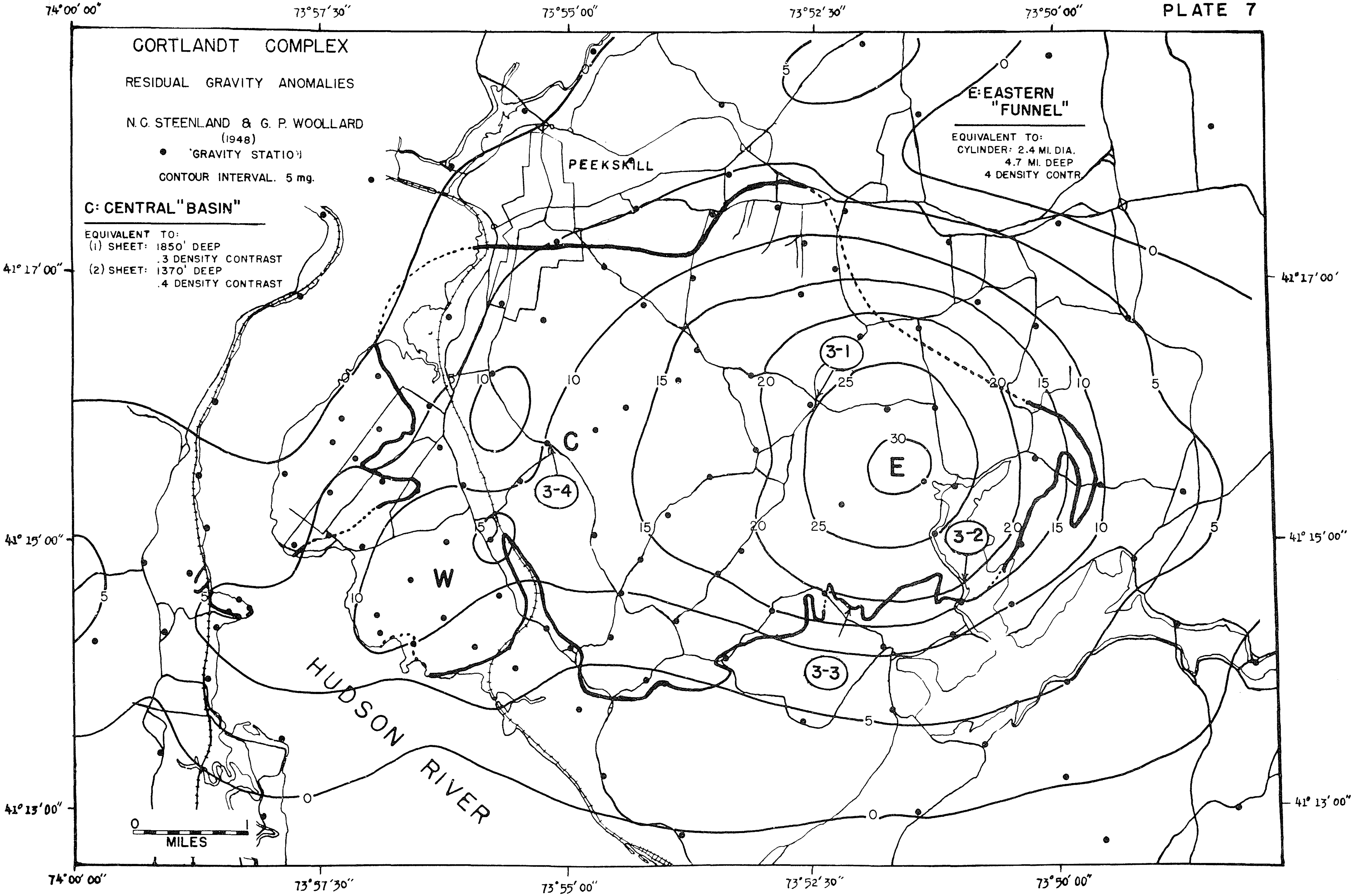

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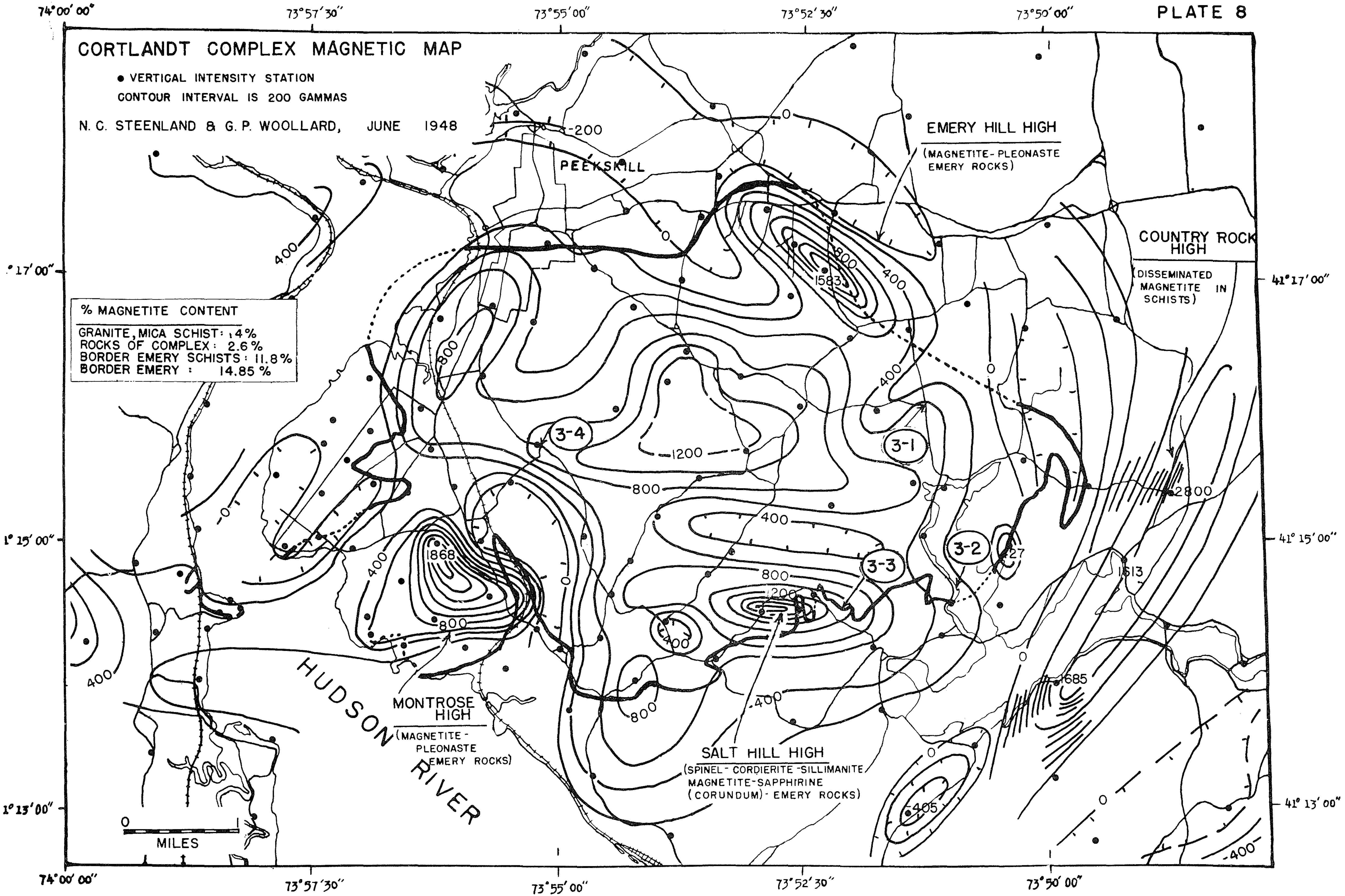
PLATE 8



CORTLANDT COMPLEX MAGNETIC MAP

● VERTICAL INTENSITY STATION

CONTOUR INTERVAL IS 200 GAMMAS

N. C. STEENLAND & G. P. WOOLLARD, JUNE 1948

% MAGNETITE CONTENT

GRANITE, MICA SCHIST: 1.4%
ROCKS OF COMPLEX: 2.6%
BORDER EMERY SCHISTS: 11.8%
BORDER EMERY: 14.85%

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