TRIP B
SOME ASPECTS OF TURBIDITE SEDIMENTATION IN THE VICINITY OF TROY, NEW YORK

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INTRODUCTION

In the course of geologic field work in the vicinity of Troy, New York, much interest and controversy have been evolved locally on the subject of deep water flow sediments, generically called turbidites. Numerous and highly varied types of turbidites are exposed within the immediate environs of Troy. Complicating factors in field mapping are the Logan Line thrust fault and the sharp local folding both of which produce tectonic breccias and otherwise complicate the definition and identification of stratigraphic units.

The following section outlines the history of the concept of turbidite sedimentation and briefly describes the two main types of turbidites which are to be seen on this trip.

HISTORICAL REVIEW OF TURBIDITES

Since the beginning of this century there has been a growing interest in the apparently anomalous occurrences of "shallow water" coarse grained sands, conglomerates, and breccias in association with deep water sediments and faunas.

The papers on the Deepkill by Rudolph Ruedemann first showed the coarse grained and brecciated character of a significant part of these sediments (1901). Later he argued strongly for the pelagic and deep water environment of the pure graptolite faunas of the Normanskill, Deepkill and Schaghticoke (Ruedemann 1926) and (1934).

The work of Manley Natland (1933) demonstrated conclusively the presence of deep water assemblages of foraminifers in association with sands and conglomerates of the Pliocene of the Los Angeles Basin, California.

Archanguelsky and Strakov (1938) followed a correlative line of thought in the sterile deep basin of the Black Sea and concluded that recent sediment from large areas of the shelf south of the Crimea had become unstable due to earthquake shocks and had slid off into the deeper parts of the basin. Archanguelsky (1927) also noted the presence of a layer of sand between two layers of abyssal deposits and commented that "This fact is extremely strange and suggests an idea of some very rapid catastrophic changes in conditions attending the transportation of the material". (p. 280)

Daly (1936) postulated that submarine canyons had been cut by mud-laden submarine streams during periods of glaciation when sea level, and hence base level were lowered.

FIGURE 1.

STRATIGRAPHIC SECTION
TROY AREA

ORDOVICIAN	Middle	SNAKE HILL	Gray shale with blocks of graywacke, limestone, chert, and black shale up to 600 ft. long.	Mega breccia
			Gray shale and subgraywacke.	Sub-graywacke
		NORMANS KILL	Alternating graywacke and shale. Cataclasite near thrust fault.	Graywacke
			Chert and shale.	
		DEEP-KILL	Chert, porcelanite, and flow bedded shale, brecciola.	Brecciola Black shale and Flow shale
	L.		Ribbon limestone with sedimentary boudinage, graptolitic black shale, thin bedded silt & occasional graded sandstone conglomerate and brecciola.	
CAMBRIAN	Upper	U€	Black clay shale, limestone, brecciola, calcareous sandstone.	
	Lower	TROY-SCHODACK	Black shale, limestone, brecciola, green shale.	
		METTAWEE	Purple and green shale.	
		BOMOSEEN	Massive grit	

Vertical scale - 1" = approx. 500'

Gould (1951) investigated subsurface currents in Lake Mead where heavy mud-laden flood water from the Colorado River flows below the clear water of Lake Mead with an initial velocity of 0.7 miles per hour, decreasing to 0.2 miles per hour 100 miles "downstream".

It remained for Keunen and Migliorini (1950) to demonstrate experimentally the process of turbidite deposition. They were able to illustrate further, by field observation in the Apennine Mountain arc, the competence of submarine currents to transport great masses of coarse clastics under water. Some of these sediment-laden currents appear to have originated as landslides on the upper continental slopes. As the mud and rock fall and slide down the steep slope, the flow incorporates an increasing amount of water, and gathers speed as it becomes less viscous. The carrying power of such a mud-laden stream of density 2.0 is theoretically 14,000 times the carrying power of pure water; experiments have demonstrated 9,000 times the power (Keunen lecture, 1950).

A flow of this type was triggered by earthquakes on November 18, 1929, from the Grand Banks (Heezen and Ewing, 1952). It flowed several hundred miles and snapped many transatlantic cables in its path. The greatest speed, calculated by the time of successively broken cables was 60 miles per hour. The speed was still 50 miles an hour 200 miles from the flow's source in 15,000 feet of water and on a comparatively gentle slope of 25 feet per mile. Where the bottom slope decreased to 4 feet to the mile, 400 miles from source, the flow was still moving 15 miles per hour.

Kuenen (1952) calculated the mass of this flow as being approximately 16 to 40 inches thick over an area of 100,000 square miles. This has been corroborated by Ericson, (1953) and Heezen, Ericson and Ewing (1954).

Other such flows are known in several places; for instance 30 miles south of Bermuda at a depth of 3 miles (Ericson, Ewing and Heezen, 1954), and at the mouth of the Magdelena River in Columbia (Heezen 1955). Extensive sedimentary studies have been made in the Black Sea and it has been found as noted above that south of the heavily faulted area adjacent to the Crimea, recent sediments have slid off of three quarters of the outer portion of the continental shelf. Studies in that area have emphasized the importance of faulting as a trigger action for such slides, and also the importance of a slippery layer to act as a skid plane. (Archanguelsky and Strakov, 1938).

Gentle currents similar to those in Lake Mead, but on a much greater scale, may be responsible for thin layers of sand and silt that are interbedded with deep-water clay over much of the abyssal plains of the North Atlantic. These sands have been studied by Ericson, Ewing, Wollin and Heezen (1961) in 230 cores. Ericson et al. noted that these sands never occur as patches on isolated highs but apparently do flow over low mounds that lie in the path of a flow. It is conceivable that flow after flow of sand could be brought into an area in such rapid succession that no abyssal clay would be deposited, resulting in a considerable thickness of laminated, fine-grained sand or silt.

It seems probable that these gentle currents may originate as submarine streams draining submarine deltas such as the delta in 14,000 feet of water at the mouth of the Hudson River Canyon; or they may be the fines from more

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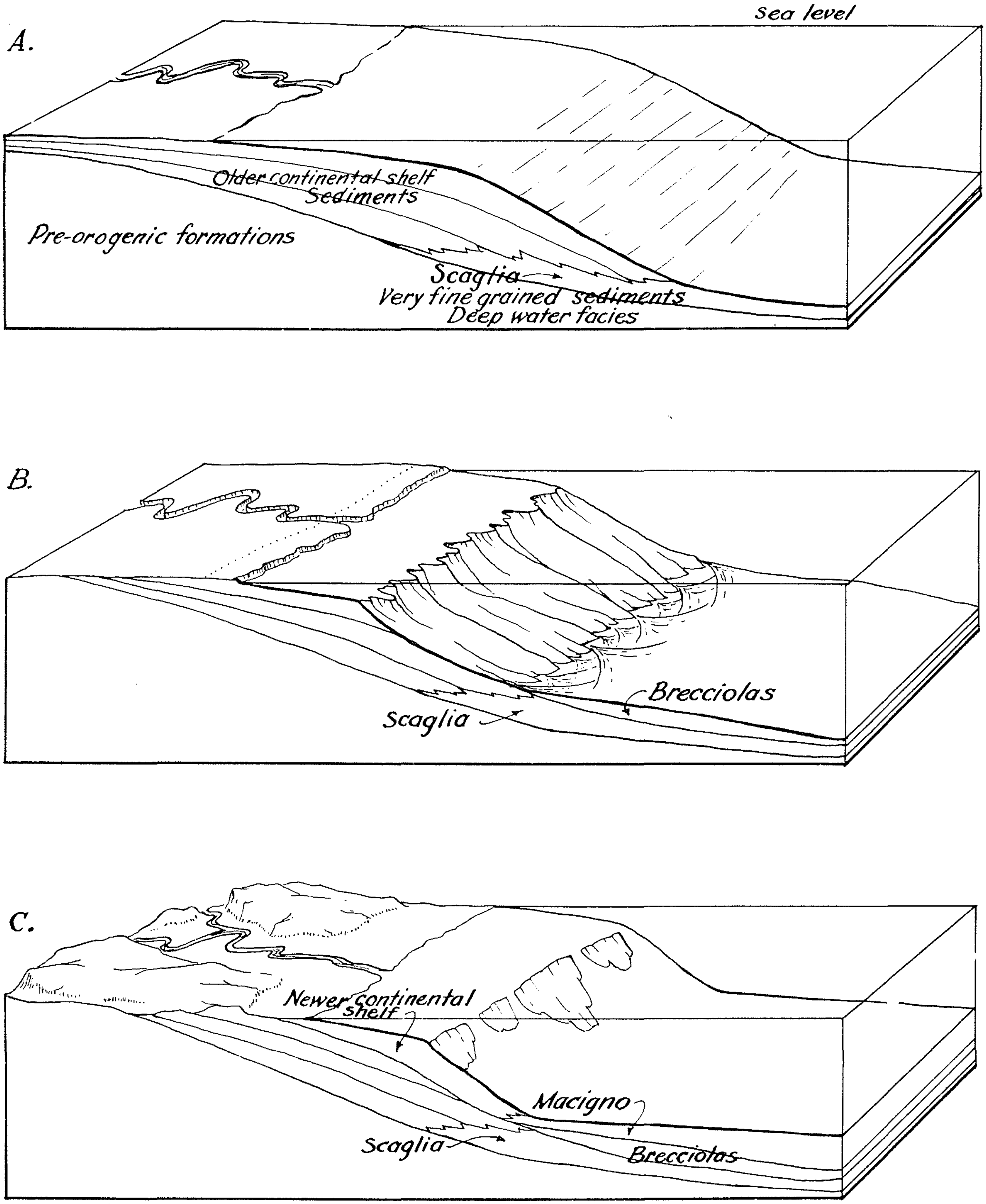

FIGURE 2.

HYPOTHETICAL DEPOSITION OF BRECCIOLAS AND MACIGNO
after Kuenen and Migliorini - Journal of Geology, March, 1950

EXPLANATION OF FIGURE 2
(after Kuenen and Migliorini)

"Block diagrams illustrating the sedimentation of the brecciolas and the macigno.....vertical scale is some twenty times the horizontal."

"Diagram "A" shows the phase immediately preceding the sedimentation of the brecciolas. No irregularities are shown along the base of the continental shelf, to avoid unduly complicating the drawing. The sea would be slowly retreating because of the growth of the continental terrace." [The scaglia appears to be the starved-basin deep-water equivalent of limestone-shelf deposits from which brecciolas were formed.]

"In "B" the littoral zone has been raised some 30 meters. This has brought about the erosion of the continental shelf by waves and of the slope by turbidity currents, and the deposition of breccíola fans at the foot of the slope.......Where the channels were closely spaced the individual fans would overlap laterally, whereas no brecciola would be deposited between widely spaced channels.......In the phase shown, the destruction of the terrace is well under way but has not yet reached its maximum."

"In "C" the mainland has been uplifted by orogenic deformation, and its rejuvenation is in progress.......the new continental terrace, which has already buried the submerged remains of the older one, is growing, a littoral plain is forming behind it, and the sea is retreating. Slumping along the unstable slope is bringing about the deposition of the macigno by turbidity currents."

"......In sections that have not been too disturbed tectonically, the contact between the brecciolas and the macigno is perfectly regular and concordant. In some places the two formations actually merge into each other by repeated alternations. But, notwithstanding this perfect sedimentary continuity, typical macigno sandstones always make a sudden first appearance in a brecciola and shale alternation. From this evidence the following deductions may be made: (1) At a given moment during the deposition of the brecciola formation there was a sudden influx of another type of sediment, consisting mainly of arenaceous material. The new type of sediment, which gave rise to the deposition of the macigno, obviously resulted from the erosion of a different source area than that from which the material of the underlying complex was drawn. (2) The conditions determining the sedimentation of the brecciola formation persisted for some time after the beginning of the macigno sedimentation. (3) The changeover to macigno sedimentation was not accompanied by any appreciable tectonic disturbance in the area of sedimentation."

"It should be remarked that the upper surface of the brecciola fans, which were deposited by swiftly moving suspensions, slopes out to sea and is uneven, whereas that of the macigno, which was deposited by a suspension that spread out on the bottom of the sea floor, is practically horizontal and even. Consequently, the brecciola formation thins out, whereas the macigno thickens in a seaward direction."

turbulent flows originating on the upper continental slopes; or, again, some of them may originate from the flood waters of rivers entering the ocean or large gulfs particularly in areas of locally narrowed continental shelves such as the Mississippi River.

Daly (1936) suggested that such mud-laden currents would be formed on a vast scale during glacial stages when wave base was lowered by lowering of sea level. Similar currents could be produced tectonically by uplift of the continental shelf with consequent lowering of wave base (Archanguelsky 1927). Occasional great storms might produce similar results without lowering of sea level or raising of the continental shelf. Such storms could produce bottom currents in a seaward direction to carry some of the storm-roiled sediment over the edge of the continental slope where it would form a turbidity current with resultant deposition on the lower slope or the abyssal plain (Kuenen and Migliorini, 1950) and (Rich 1950).

TYPES OF FLOWS

There is a tendency to classify turbidity currents into two groups, typified by the fast and slow flows described above. Actually there must be many kinds of flows in addition to the two types described. Also it seems probable that there are a wide variety of depositional types produced below wave base, comparable in variety perhaps to those produced above it.

Probably one of the best known types of turbidites are the brecciolas which were described from the Apennine Mountain arc by Migliorini in co-authorship with Kuenen (Kuenen and Migliorini, 1950). The name brecciola was applied to sedimentary "little breccias", in which the fragments are preponderantly limestone. It has been found that there are other "little breccias" in the Troy area, some of which are composed of sand in a sand matrix, lime fragments in a sand matrix, lime fragments in a dolomite matrix, lime fragments in a clay matrix, and clay fragments in a clay matrix. It seems reasonable to include these also in the brecciola facies of the turbidite clan.

TRIP STOPS AND DESCRIPTIONS OF EXPOSURES

The purpose of this trip is to examine deep water sedimentary rocks in the field. Of the many assemblages that there are of such rocks, two are particularly well developed in the Troy area. One of these is composed of brecciolas and associated rocks; the other is the group of rocks that make up the euxinic assemblage.

Schodack Brecciola Assemblage

Stop 2. See Figure 3. Four brecciolas are described which apparently belong to the Schodack (West Castleton) Formation. These are typically developed at the following locations: School 14, west edge of playing field at 13th St. and College Ave.; Sage Avenue, 250 feet west of 15th Street; R. P. I. Campus, east end of football field; and Troy High School, northwest corner of athletic field.

All four occurrences appear to be distinctive, and they are not noticeably lenticular like the brecciolas of the upper and lower Deepkill some of which lens out across the outcrop. The Sage Avenue brecciola occurs at four localities one-half mile apart, and is clearly recognizable at each locality. The Troy High School sequence of brecciolas occurs in two extensive outcrops, approximately 800 feet apart, at both of which it possesses the same distinguishing characteristics. All four brecciolas are sharply distinct from one another, except that all are ten to twenty feet thick without marked lenticularity. They differ in this respect from the Deepkill brecciolas, which are inches thick and sharply lenticular. The brecciolas described by Migliorini in the Apennines appear to be closer to the Deepkill variety than to those of the Schodack. The Grand Banks brecciola of 1929 was calculated to be 16 to 40 inches thick. By comparison, the Schodack brecciolas are unusually large, although not to be compared to the Rysedorph megabreccia facies of the Snake Hill (Middle Ordovician) (J. G. Elam, 1960 unpublished).

A. School 14 locality (North of College Age. along an extension of 13th Street at west edge of playground of School 14.)

One hundred feet of outcrop extends north-south, strikes N25E and dips 45° southeast with the top of the section to the southeast as judged by graded bedding. The south end of the outcrop is a pale, gray-green quartzite, poorly sorted and mostly fine grained.

The MATRIX is a brownish purple, fine grained sandstone or siltstone with frequent coarse, round, sand grains and some clay, much calcareous dust and small calcareous fragments, many blobs of clay varying from black to light gray, and also with frequent light gray calcareous granules.

The FRAGMENTS are coarse-grained, light-gray, massive, and fossilferous limestone varying in shape from irregular to round to tabular. Average size is 2"-5" with some longer dimensions up to 18". There are also a few large slabs the largest of which is two feet thick and eight feet long. The general orientation of fragments is subparallel to the boundaries of the main flow. Abundant small clay blobs about 2" across are also found, along with some dense light gray limestone fragments and a few sandy fragments. At the north end of the outcrop the ratio of pebbles to matrix is about 30:70 varying to 20:80 near the middle, and dropping to 10:90 at the south end of the brecciola outcrop. This indication of grading suggests the beds are right side up with the top to the south east.

Deepkill Euxinic Assemblage

Stop 1. The first stop will be at the type locality of the Deepkill, one-quarter mile east of Grant's Hollow, ten miles north of Troy on Route 40.

The upper Deepkill is separated from the lower by a covered interval of 800 feet, and its rocks comprise a different assemblage from the euxinic lower Deepkill. The upper Deepkill is a series of mud flows, clay-in-clay brecciolas, a few lime-in-clay brecciolas, porcelanites, and thin beds of chert. Near the bottom of the section there is a small amount of graptolitic black shale and dark gray limestone. This part of the Deepkill is mentioned because its proximity makes it available for those who may be more interested in spending a half-hour on this additional sedimentary type than in collecting graptolites and turbidites from the lower Deepkill.

Both the top and the bottom of the lower Deepkill are covered. The part of the section which is exposed is made up of black shale, gray shale, light gray thin bedded siltstones in banks one to four feet thick, and various types of brecciolas and graded beds.

This assemblage appears to be produced by two sets of factors. First, the underlying euxinic chemical environment dominated by H_2S affects Eh much more than pH (Krumbein and Garrels 1952). This permits the accumulation of lime mud at one time and sapropelitic black mud at another depending on alternating chemical controls that are related to tectonic activity on the basin margin. An example is the Black Sea where the lime muds overly sapropelitic ooze (black organic shale) and the two are separated by a thin layer of terrigenous sand (Archanguelsky 1927). The second set of factors are those which produce turbidites of various kinds, brecciolas and graded beds of one kind or another depending on the speed of flows from the upper parts of continental slopes triggered by faulting or by overloading of metastable shelves. More gentle currents from continental shelves would bring a steadier supply of sand and silt to build the banks of thin bedded siltstones.

When turbidity flows were in action and diluted the euxinic environment, then lime muds or organic ooze would not be present as pure rock types, but when the flows died down the euxinic deposits would form the dominant rock type with alternation from lime to mud to organic ooze, and with an occasional turbidite flowing into the depositional area from one side of the basin or the other.

The faunal evidence as analyzed by Ruedeman fits well with the postulated euxinic environment. The predominant fossils are graptolites which are thought to be pelagic or pseudopelagic (i.e. living attached to seaweed). Other fossils are rare and are thin shelled chitinous forms which appear to be well adapted to a pseudopelagic environment. Other bottom dwelling types are wanting in the shales, silts, and calcilutites.

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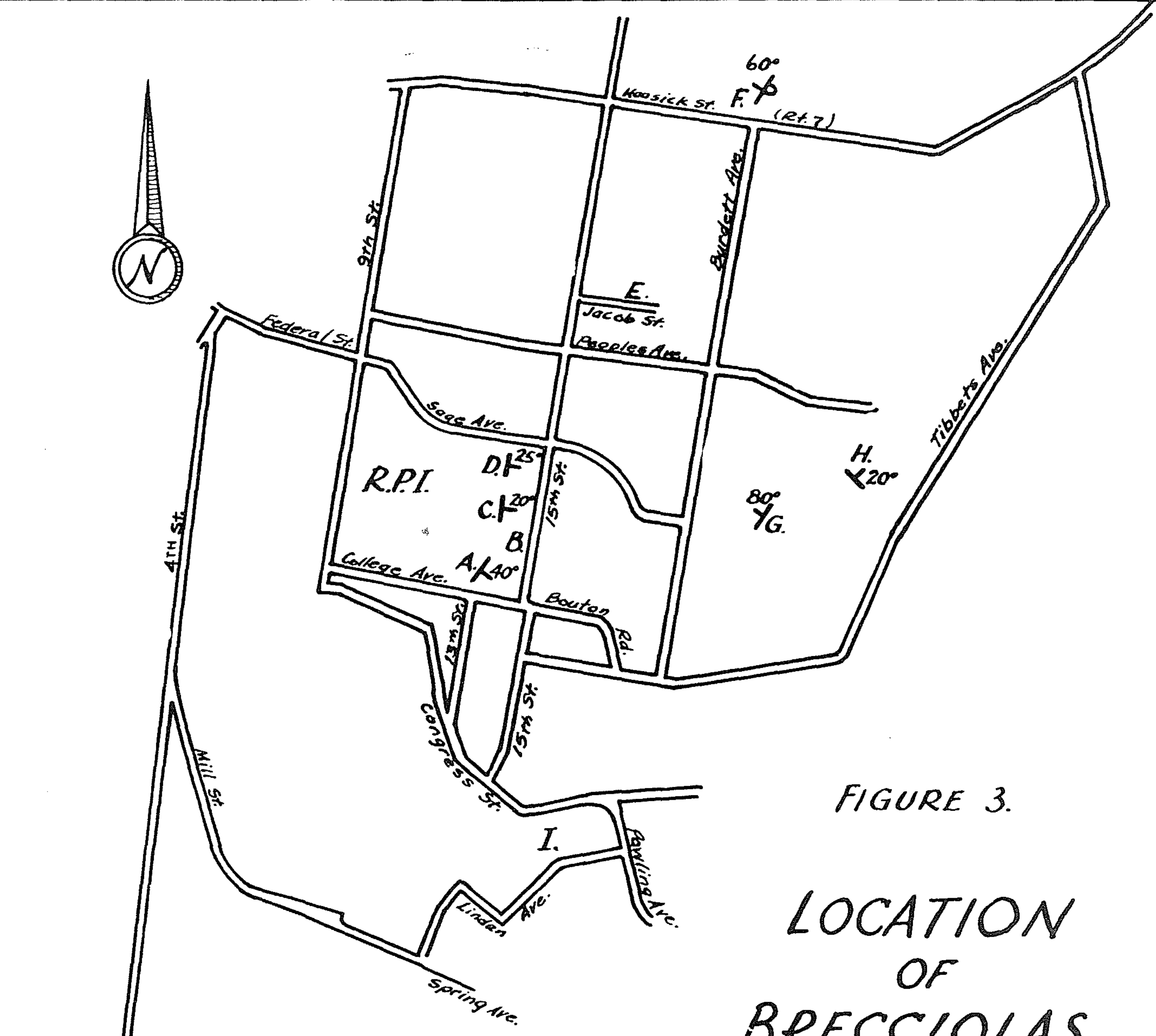

FIGURE 3.

LOCATION OF BRECCIOLAS

A. School 14, College Ave. and 13th Street.
B. Sage Ave. brecciola, 15th St. occurrence.
C. Campus brecciola at east side of playing field.
D. Sage Ave., 250 ft. west of 15th Street.
E. Brecciola north side of Beman Park.
F. Dunn Garden Apartments, Hoosick St. and Burdett Ave.
G. Troy High School playing field.
H. Between Rensselaerwyck and Troy High School playing field.

B. Sage Avenue locality - 15th Street occurrence.

The outcrop is buried beneath the buildings along 15th Street in the vicinity of the 15th Street Lounge. Large boulders 4' by 6' were blasted from an old quarry wall and moved by bulldozer to their present location between the South Parking Lot and the tennis courts. There is one predominant type (TYPE 1) of rock, which makes up about 90% of the boulders and there are several subsidiary types.

TYPE 1. FRAGMENTS: About 80% of the fragments are coarse grained, fossiliferous, light gray, limestone, averaging 4" to 6" in size, irregular to subspherical in shape, with no linear distribution, and with no noticeable grading. Since the occurrence is a pile of boulders there are no observable stratigraphic relationships. Minor constituents are small fragments of light gray, dense limestone and sandstone of which the former is more abundant.

MATRIX is a brown-weathering dolomite mud with numerous medium-to coarse, rounded sand grains. About 20 to 50% of the matrix is composed of light gray, dense, calcilutite fragments averaging $\frac{1}{4}$" in diameter. These give the matrix the appearance of a pebble conglomerate.

The relative abundance of matrix and fragments is variable from boulder to boulder but the general average is about 60% fragments, not counting the $\frac{1}{4}$" calcilutite fragments that appear to make up a considerable part of the conglomeratic matrix.

SPECIAL FEATURES OF TYPE 1. The coarse grained fossiliferous limestone fragments with brown weathering dolomite cement are closely similar to the outcrops on Sage Avenue, 250 feet west of 15th Street (Location D) where the bed is well exposed along a joint face. It also outcrops in Beman Park near Samaritan Hospital at the west edge of the parking lot. This was one of S. W. Ford's fossil localities (1876). Walcott also collected Lower Cambrian fossils (Elliplocephala asaphoides zone) from the calcarenite fragments at the Beman Park locality. The calcarenites in the boulders at the 15th Street occurrence of the Sage Avenue brecciola probably are as good a locality for collecting fossils from this zone as we will see on this trip.

Similar features of matrix fragments are seen in the upper brecciola at Hoosick Street and Burdett Avenue (section buried), now represented by boulders in the rubble pile to the west of the Dunn Garden Apartments. These three occurrences appear to lie on strike and are probably correlatable.

C. R. P. I. Campus locality (12' brecciola outcropping on R. P. I. campus east of football field)

The general dip of 20° to the east places this brecciola beneath the "Sage Avenue brecciola". It is underlain by greenish-gray clay with interbeds of dolomitic, fine-grained sandstone two to three inches thick and six to ten feet apart. The brecciola is overlain by greenish-gray shale with thinly interbedded siltstone or very fine grained sandstone. The interval from the top of the "campus brecciola" to the base of the "Sage Avenue brecciola" appears to be 15 to 30 feet, with the latter being the younger of the two.

MATRIX is dark gray, flow-streaked mudstone. No evidence is seen of stratigraphic differentiation, graded bedding, or direction of flow.

FRAGMENTS are predominantly (80%) coarse grained light gray, fossiliferous limestone, ranging in size from 2" to 1½ feet, irregular in shape and with no preferred orientation. There are a few small fragments of dense light gray limestone, about one per cent by volume. Medium grained, rounded sandstone makes up about 20% of the fragments with irregular distribution and no preferred orientation.

FRAGMENTS & MATRIX: Relative percentage of fragments to matrix is 40:60 to 50:50. Evidence of scour is seen in the presence of green clay blobs in the lower part of the flow. Load casts are also present in the form of green clay injected into the base of the brecciola.

STRATIGRAPHIC CORRELATION: This brecciola is lithologically closely similar to the lower brecciola at Dunn Garden Apartments (Hoosick & Burdett). It also falls in the same succession of beds and is thought to be stratigraphically equivalent.

G. Troy High School playing field. (Sequence at the east end of the track and playing field north of Troy High School on Burdett Avenue.)

Strike of these beds is N15E, dip is 75 west; top of the stratigraphic section is to the west. The brecciola sequence is made up of three members with eleven submembers. It is overlain by thin bedded, fine grained sand and shale with a possible thickness of 200 feet. The brecciola sequence is underlain by brown weathering green claystone with dark gray wispy interbeds, having a possible thickness of 300 feet. The thickness of the brecciola sequence is approximately 90 feet. The Troy High School outcrop is the most extensive and gives the best picture of both the brecciola and the beds associated with it.

Brecciola Sequence (in descending order)

Bed 3b; Mostly covered but with occasional patchy outcrops of dense, light gray limestone fragments in a dark gray clay matrix. A large outcrop that is probably stratigraphically equivalent occurs at the southeast corner of Burdett Avenue and West Peoples Drive. This outcrop has a ratio of fragments to matrix of about 15:85; the fragments are uniformly light gray, dense limestone, 2" to 3" thick, 8" long, and randomly oriented. The matrix is uniform dark gray claystone.

3a: Thin bedded light gray dense limestone, interbedded with thin beds of dark gray shale. Unit is regularly bedded but slightly disturbed, giving the appearance of layers being slightly pulled apart in sedimentary boudinage. This occurrence, which is 2 feet thick and over 8 feet long, may be a large mass that slid or flowed some distance without turbulence, or it may have slid only a few inches or feet, but enough to cause the disturbance noted. Similarly bedded limestone in a similar stratigraphic position occurs about 500 feet to the east across the High School playing field.

Bed 2e. Three feet of tan weathering green claystone with numerous black wispy streaks that show flow bedding.

2d. One and one half feet of light gray, dense limestone fragments in a dark gray matrix with 10:90 ratio; fragments are 2 by 6 inches and randomly oriented.

2c. Two and one half feet of tan weathering green claystone.

2b. One foot of green clay blobs (1" to 2") in maroon weathering clay matrix; ratio 20:80.

2a. Seven feet of green clay with black wispy interbeds and one interbed of coquina one inch thick with worm borings, giving supporting evidence of top and bottom.

Bed 1d. Four feet of light gray dense limestone and black shale fragments in a rusty, medium-grained, rounded sand matrix with a 20:80 ratio. Fragments and trains of fragments are subparallel to the margins of the flow. A small percentage of the limestone fragments are granular and fossiliferous. A few others are light brown and well-bedded. Average size of limestone fragments is 3 by 6 inches.

1c. One foot thick, similar to above but with sand and clay matrix 50:50, and showing an increase in the percentage of limestone fragments to matrix, to about 40:60.

1b. Black shale boulder one foot thick and eight feet long, oriented parallel to the margins of the brecciola.

1a. Brecciola bed five feet thick; ratio of limestone fragments to clay matrix is 80:20. Orientation of fragments is sub-parallel to the boundaries of the brecciola. The limestone fragments are mostly dense light gray limestone, granular fossiliferous light gray limestone, and light brown well-bedded limestone in a ratio of 60:20:20. The matrix is dark gray clay.

SYNOPSIS OF MAIN BRECCIOLA MASS (Beds 1a-1d)

GRADED BEDDING. The sand matrix shows incipient grading above bed 1c which is mixed sand and shale. The main mass of the flow 1a-1d shows marked increase in the abundance of limestone fragments downard through the flow.

OTHER CRITERIA OF TOP AND BOTTOM.

Worm borings: as noted under 1a.

Scour: the basal portion of 1a shows many wispy blobs of green clay that appear to have been scoured from the underlying green clay beds while they were unconsolidated.

STRATIGRAPHIC DIFFERENTIATION.

MATRIX: The sand and clay matrices appear to be well differentiated stratigraphically.

FRAGMENTS: The fragments are less well differentiated than the matrix but they do show a notable differentiation from the top to bottom. Toward the top of the bed, the limestone pebbles are mostly calcilututes while at the base the pebbles contain about 10% of calcarenites. The pebble-to-matrix ratio is perhaps 20:80 toward the top, increasing to 80:20 toward the base. At the top of the main brecciola the matrix is nearly pure sand; this changes gradationally downward to sandy clay and to nearly pure in clay in the base of the flow.

Correlation of separate outcrops on the west and east sides of the athletic field is satisfactory. On the west side the units are oriented from top on the west to bottom on the east; on the east side the orientation of the same sequence has the top on the east and bottom on the west. In spite of this structural complication the correlation of the various brecciola units can be made in some detail.

NOTES ON TRIP B

REFERENCES

Archanguelsky, A. D., 1927, On the Black Sea sediments and their importance for the study of sedimentary rocks; Bull. Societe des Naturalistes des Moscow N.S. Vol. 25, Section Geologique, Vol. 25, pp. 199-289. English Summary pp. 264-289.

Archanguelsky, A.D. and N. Strakov, 1938, Brief outline of the history of the Black Sea; Academie Nauk U.S.S.R. Moscow. English Summary 202-226, Bibliography

Daly, R.A., 1936, Origin of submarine "canyons"; Am. Jour. Sci. 5th Ser., Vol. 31, pp. 401-420.

Elam, J. G., 1960, Geology of Troy South and East Greenbush quadrangles, New York: Ph.D. dissertation, Rensselaer Polytechnic Institute

Ericson, D.B., 1953, Further evidence for turbidity currents from the 1929 Grand Banks earthquake; Geol. Soc. Amer. Spec. Paper 62 pp. 205-219.

Ericson, D.B., Ewing, Maurice, Wollin, Goesta, and Heezen, B. C. Atlantic Deep Sea sediment cores; Geol. Soc. Amer. Bull. Vol. 72, No. 2 1961 pp. 193-285.

Gould, H. R., 1951, Some quantitative aspects of Lake Mead turbidity currents; Soc. Econ. Paleontologist and Mineralogists Spec. Pub. 2, pp. 34-52.

Heezen, B. C., 1955, Turbidity currents from the Magdelena River, Columbia; Geol. Soc. Amer. Bull. v. 66, p. 1572

Heezen, B. C., Ericson, D.B., and Ewing, Maurice, 1954, Further evidence for a turbidity current following the 1929 Grand Banks earthquake; Deep-Sea Research, Vol. 1, pp. 193-202.

Heezen, B.C., Ewing, Maurice, 1952, Turbidity currents and submarine slumps, and the 1929 Grand Banks earthquake; Am. Jour. Sci., Vol. 250, pp. 849-873.

Krumbein, Wm. C., and Garrells, R.M., 1952, Origin and classification of chemical sediments in terms of pH and oxidation-reduction potentials; Jour. Geol. Vol. 60, No. 1

Kuenen, P. H., 1950, Turbidity currents of high density; 19th Internat. Geol. Congress Rept. pt. 8, pp. 44-52.

Kuenen, P. H., 1951, Properties of turbidity currents of high density; Soc. Econ. Pal.&Min. Special Pub. No. 2, pp. 14-33

Kuenen, P. H.,1952, Estimated size of the Grand Banks turbidity current; Am. Jour. Sci. Vol. 250 pp. 874-884.

Kuenen, P. H.,1953, Significant features of graded bedding; Bull. Am. Assoc. Petroleum Geologists. (In Press).

Kuenen, P. H., 1953, Graded bedding with observations on Lower Paleozoic rocks of Britain; K. Akad. Wetensch. Nederlandsch. Verhandl. (in press).

Kuenen, P. H., & Migliorini, C. I., 1950, Turbidity currents as a cause of graded bedding; Jour. Geol. Vol. 58, No. 2, 1950 pp. 99-127.

Natland, Manley L., The temperature and depth distribution of some recent and fossil foraminifera in the southern California region; Bull. Scripps Inst. Oceanography, Vol. 3 #10, 1933, pp. 225-230. Plate and cross section of Halls Canyon showing silt, sand and gravel associated with deep water foraminifera in beds of Lower Pleistocene to Middle Pleocene age.

Natland, M.L. and Kuenen, P. H., 1951, Sedimentary history of the Ventura basin, California and the action of turbidity currents; Soc. Econ. Paleontologists and Mineralogists Spec. Pub. 2, pp. 76-107.

Rich, J. L., 1950, Flow markings, groovings, and intrastratal crumplings as criteria for recognition of slope deposits, with illustrations from Silurian rocks of Wales: Am. Assoc. Petroleum Geologists Bull., Vol. 34, pp. 717-74.

Ruedemann, Rudolph, 1901, The graptolite (Levis) facies of the Beekmantown formation in Rensselaer County, N.Y.; New York State Museum, Report of the State Paleontologist Bull. 52, Paleontology 6, pp. 546-575.

Ruedemann, Rudolph, 1926, Faunal facies difference of the Utica and Lorraine shales; N. Y. State Museum Bull. 267, pp. 61-77.

Ruedemann, Rudolph, 1934, Paleozoic plankton of North America, Mem. 2, Geol. Soc. Amer. p. 8.