1969

Stratigraphy and economic geology of uranium-bearing sediments in the Poison Spider District, Natrona County, Wyoming

Carlos Enrique Reijenstein d'Acierno

Recommended Citation

Reijenstein d'Acierno, Carlos Enrique, "Stratigraphy and economic geology of uranium-bearing sediments in the Poison Spider District, Natrona County, Wyoming" (1969). *Masters Theses*. 5436.
https://scholarsmine.mst.edu/masters_theses/5436

STRATIGRAPHY AND ECONOMIC GEOLOGY OF URANIUM-BEARING SEDIMENTS IN THE POISON SPIDER DISTRICT NATRONA COUNTY, WYOMING

BY

CARLOS ENRIQUE REIJENSTEIN d'ACIERNO, 1943

440

A

THESIS

submitted to the faculty of

THE UNIVERSITY OF MISSOURI-ROLLA

in partial fulfillment of the requirements for the

Degree of

MASTER OF SCIENCE IN GEOLOGY

Rolla, Missouri

1969

Approved by

A C Spreng (advisor) Geza Kisvarsanyi

G. E. Vaughn, Jr.

ABSTRACT

Geologic, stratigraphic, and mineralogic characteristics of the Eocene Wind River and Oligocene White River Formations were determined for the southern portion of the Poison Spider District, Natrona County, Wyoming.

Sieve analysis and heavy mineral techniques were used to recognize stratigraphic units, determine their environment of deposition, obtain a better knowledge of the grain size distribution, and to identify a possible source area for the sediments. Particular emphasis was concentrated on the evaluation and interpretation of the available geophysical data (gamma ray and resistivity logs), and geological information which have led to the establishment of several relationships between the local geology and the uraniferous mineralization.

This mineralization is present in close association with carbonaceous material enclosed in the coarse, unconsolidated, arkosic sediments of the Wind River Formation. The uranium deposits are most likely epigenetic, with the carbonaceous material acting as one of the major precipitants of the uranyl ion from the mineralized ground water solutions. The uranium is believed to have been concentrated and brought to the area by meteoric waters which derived the metal from terrigenous sediments resulting from disintegration of Precambrian rocks (Granite Mountains), and/or Tertiary tuffaceous sediments (White River and Arikaree Formations). The mineralization found in the Wind River Formation has no economic value at present, due to its low grade character.

Structural and tectonic features in Pliocene(?) time is believed to have reversed the direction of the mineralized ground water flow coming to the area. This drainage change not only prevented the mineralization from reaching the Poison Spider area, but may also have caused leaching of some pre-existing uranium within the Wind River Formation.

ACKNOWLEDGEMENTS

The writer wishes to express his sincere appreciation to Dr. Alfred C. Spreng, Professor of Geology at the University of Missouri at Rolla, as advisor for the thesis and his guidance, helpful suggestions and discussions. He also supervised the initial writing of the manuscript.

Unqualified gratitude goes to the V. H. McNutt Foundation for financial support of the laboratory work, and to Petro-Nuclear, Ltd., for permitting the writer to develop his thesis project while employed for the company. A special note of thanks to Dr. Spenst M. Hansen, Manager of Mining Operations, for his assistance in supplying information of the studied area.

TABLE OF CONTENTS

LIST OF FIGURES AND PLATES

LIST OF PLATES

Frontispiece. Drilling rig in operation, Poison Spider Area, Wyoming.

Chapter I

INTRODUCTION

A. Location and Extent of Area

This study was made in the Poison Spider District, located in central Wyoming west of Casper, Wyoming (Fig. 1). The area is located in the northwest corner of the McCleary Reservoir 7.5 minute quadrangle, Natrona County, Wyoming. The quadrangle is bounded by parallels 42°45' and 42°37'30" North latitude, and by meridians 106°52'30" and 107°00' West longitude. In 1951 the quadrangle was topographically mapped by the United States Geological Survey. This thesis mainly concerns section 24, T. 32 N., R. 85 W.; and sections 30, 31 and 32, T. 32 N., R. 84 W., an area of about 3 square miles (Fig. 2).

The district is named after the stream, located about 6 miles to the north, which drains the area.

B. Geography

The Rattlesnake Range is the dominant topographic feature; it divides the regional drainage into two systems of northward and southward flowing streams. There are no perennial streams in the area covered by this report. Henderson Creek, section 36, T. 32 N., R. 85 W. (Figure 2), which heads in the southern slope of the Rattlesnake Hills, is fed by several springs along its course, hence this stream flows throughout the early part of the summer.

A few springs occur on the northern slope of the Rattlesnake Range; however, the cumulative flow from these springs is not sufficient

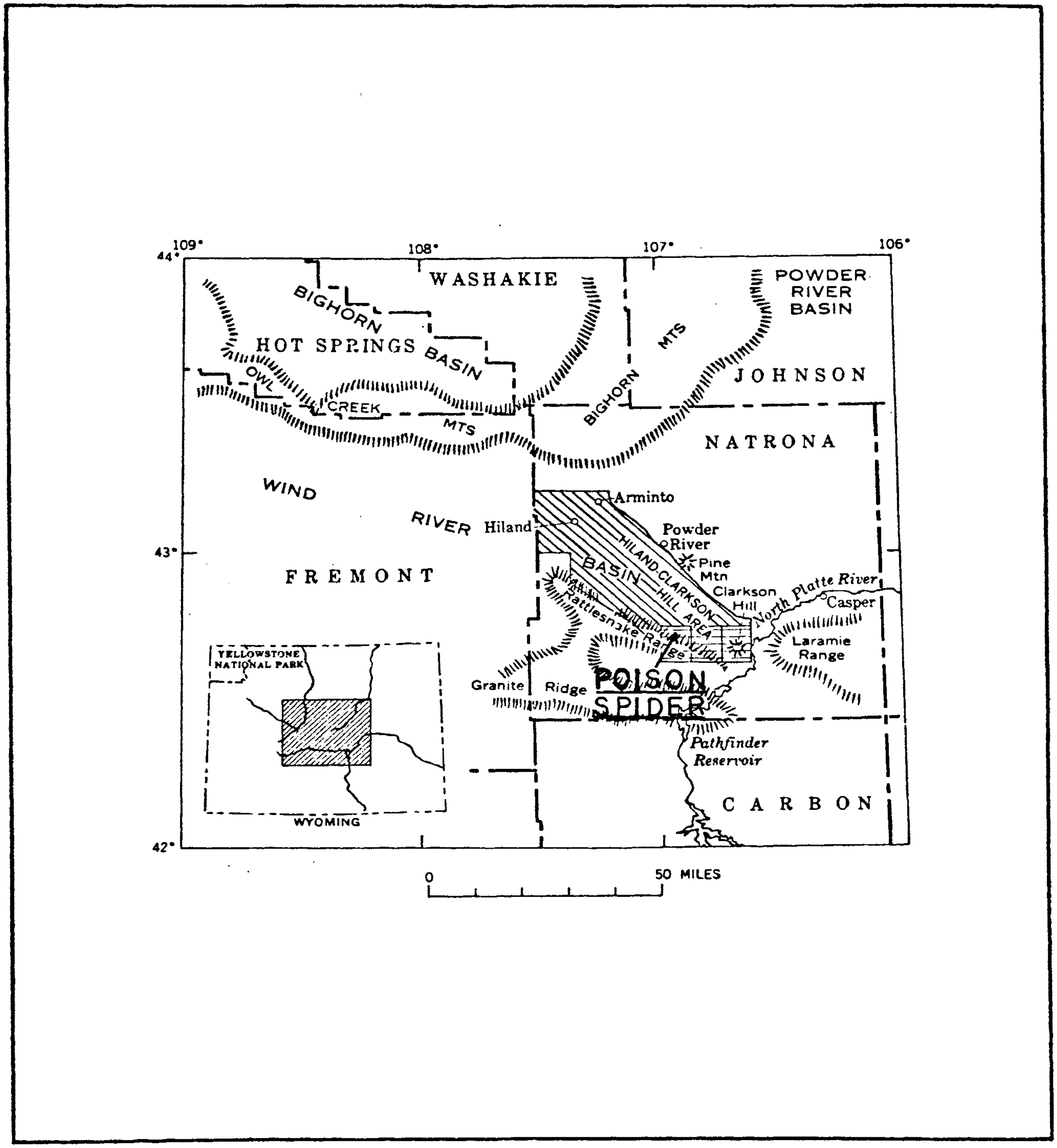


Figure 1. Index Map showing the location of the Poison Spider District, Natrona County, Wyoming (from Rich, 1962).

to maintain a constant flow of water in any stream.

Earthen dams have been built along many of these water courses to store water for cattle during the summer months.

The altitude in the mapped area ranges from less than 6,600 feet to about 7,251 feet above sea level at a high point on the Rattlesnake Range called Grieves. Westward from Grieves and outside the mapped area, the Rattlesnake Hills rise to about 7,340 feet on top of Horse Heaven, a high mesa in sections 26 and 27, T. 32 N., R. 85 W. The Rattlesnake Range represents in the Poison Spider area, both a drainage divide and a natural boundary between two types of topography. To the north the region is highly dissected with a pattern of finger-shaped parallel terraces, whereas toward the south it is relatively flat and undissected land.

C. Climate

The climate in most of the Poison Spider area is arid, although it is semiarid along the crest and slopes of the Rattlesnake Range. Heavy snows and considerable periods of subzero temperatures are characteristic of most winters. There are neither precipitation nor temperature recording stations within the area; however, the average temperature at Casper is 48°F and at Pathfinder Reservoir, about 10 miles south of the area, it is 45.6°F. The average annual precipitation of the area ranges from 6.8 inches at Arminto to 14.15 inches at Casper. More than half the annual precipitation falls during the months of April, May, June, and July.

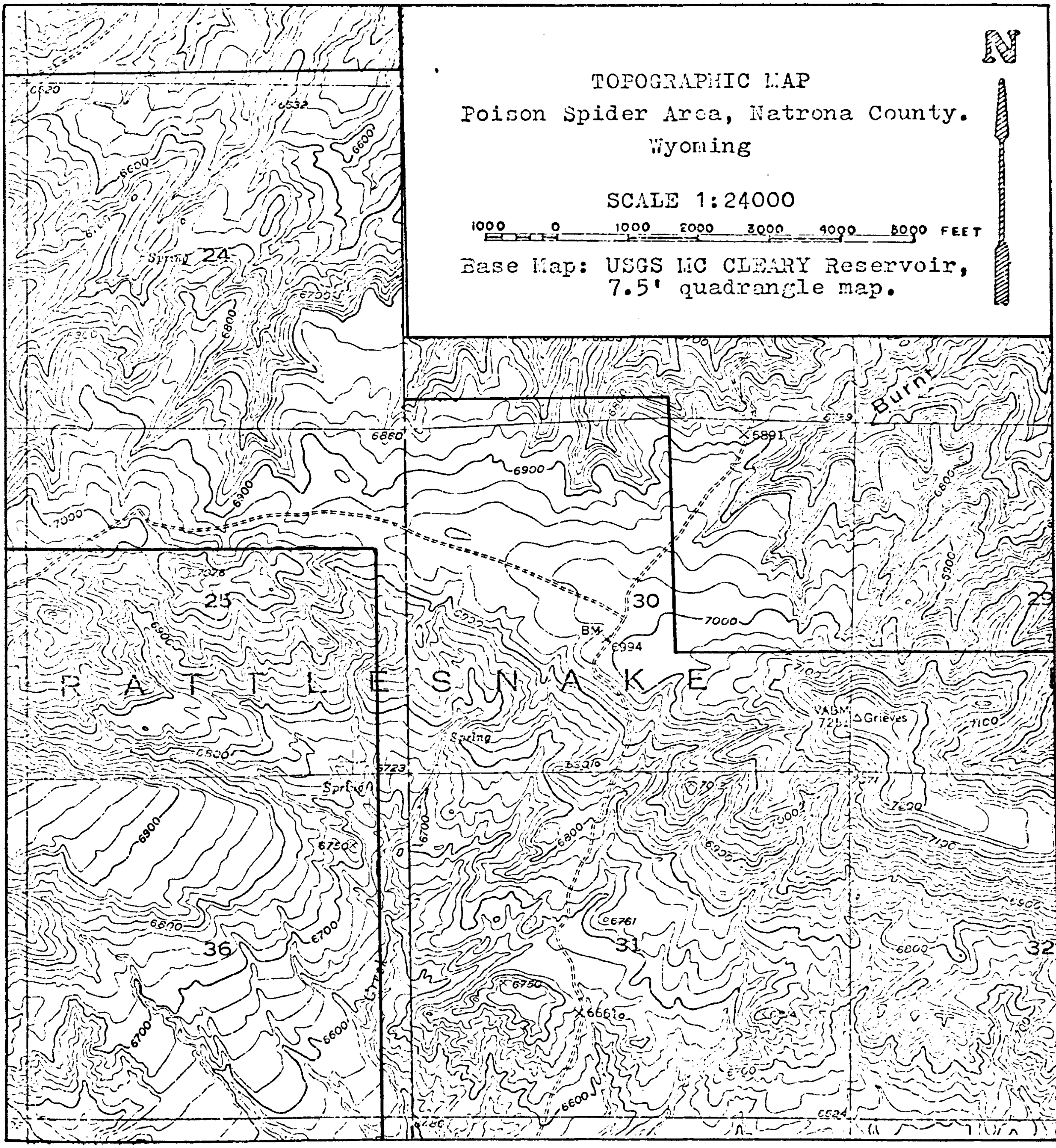


Figure 2. Map showing the location of the thesis project in the Poison Spider Area, Natrona County, Wyoming.

D. Cultural Development and Accessibility

Casper, with a population close to 50,000 inhabitants, is the largest settlement of the region, and is about 64 miles east of the Poison Spider District. The city of Casper, served by the Chicago, Burlington and Quincy Railroads, and Continental Trailways Bus Line, is connected with other principal towns by a well-maintained net of highways. An oiled road from Casper, the Poison Spider road, provides the northern access to the district; and Wyoming State Route 220 provides an almost all-weather southern access, through the Diamond Ring Ranch property.

E. Field and Laboratory Investigations

The field work for this thesis was accomplished while working as a geologist for Petro-Nuclear Ltd., during the months of June, July, and August and part of September, 1968. The Poison Spider project was one of the several intensive uranium exploration programs of the Company in the sedimentary basins of Wyoming. Most of this exploratory work involved examination and study of cuttings, nine measured bulldozer trenches and a moderately large open pit. Outcrops are almost nonexistent in the studied area.

A logging truck, two bulldozers and three drilling rigs were utilized on the Petro-Nuclear Poison Spider property. The policy of the Company was to drill to a maximum depth of 200 feet on the topographic highs, and to a lesser footage toward the ravines. The diameter of the bits used were 4 1/2, 4 3/4, and 5 8/10 inches. Only five drill holes in the entire summer operation were in the depth range of 400-600 feet, all of them placed over the outcropping White River Formation in the southern part of the area.

All the geologic information was recorded on a United States Geological Survey base map of a scale 1:24,000 and on Plates and Figures enclosed in this report. Outcrop and trenched section measurements were made by means of Brunton compass and hand level. True elevations were provided by a topographic crew operating for the Petro-Nuclear Company or were taken from the aforementioned topographic map.

The laboratory investigation (September 1968 - February 1969) was mainly concerned with the detailed correlation of cutting samples in the areas of higher radioactive anomalies, detailed study of the measured stratigraphic sections, sieve analysis of the sediments, binocular and petrographic microscopic examinations, and heavy mineral determination for 59 samples of the Wind River Formation, 2 of the White River Formation (lower member) and 1 sample from the terrace deposits. Gamma and resistivity logs from 34 drill holes were utilized to obtain better lithologic and stratigraphic control over the uranium-bearing sediments, both in the vertical and horizontal directions.

F. Purpose and Scope of the Investigation

The presence of radioactive anomalies in the Poison Spider District suggested that a detailed study of the lithology and environment of deposition of the Wind River Formation might yield useful information regarding the occurrence and stratigraphic distribution of the uranium-bearing sediments in the area. In the detailed study of this radioactive district, five major objectives were outlined:

1. To present, synthesize, evaluate, and interpret available geophysical and geological information of the mapped region in the Poison Spider area.
2. To determine the possible reason or reasons which caused the mineralization to take place.
3. To offer a reasonable theory of genesis for this type of uranium deposit.
4. To determine the possible relationships between the local geology and the occurrence of the mineralization.
5. To point out probable geological guides that might prove useful in future exploration programs.

G. Previous Work

No detailed study of the geology of the thesis area has been published; however, the area has been included in some published general geologic reports of very large areas of central Wyoming. Ernest Rich (1962, p. 451) gives a summary of them.

Rich's work (1962) in the Hiland-Clarkson Hill area, is the only one which includes the geology of the thesis area; this report also contains a geologic map scale 1:31,680. The map was produced to determine both the general geologic relations of the different rock units, and the areas which seem most favorable for the accumulation of uranium. Rich also outlines the general structure, the tectonic history and the economic geology of the Hiland-Clarkson Hill area.

Chapter II

REGIONAL GEOLOGIC SETTING OF THE WIND RIVER BASIN

Introduction

The Poison Spider District lies in the central-southern part of Natrona County, Wyoming, and represents part of the southern edge on the eastern third of the Wind River structural basin. The Wind River Basin is located in central Wyoming lying almost entirely in Fremont County with a finger-like extension toward the southeast into the Natrona County (Fig. 3). It is bounded on the north by the Owl Creek and Big Horn Mountains, on the southwest by the Wind River Mountains, and on the south by the Sweetwater Uplift and the Granite Mountains. Most of the Wind River Basin, which occupies almost 10,000 square miles, lies at an altitude of about 5,500 feet with the surrounding mountains rising to more than 13,000 feet above sea level.

The axis of the basin trends NW-SE in the eastern and westernmost thirds, swinging to a more east-west trend in the middle third.

Geologic History - Summary

The Wind River Basin was part of the stable shelf region that lay east of the Cordilleran Geosyncline during Paleozoic and much of the Mesozoic times. Deposition in the neighboring Cordilleran Geosyncline began in Precambrian time and continued, although interrupted by intervals of erosion, until near to the close of the Cretaceous Period when the Tertiary basins of Wyoming began to

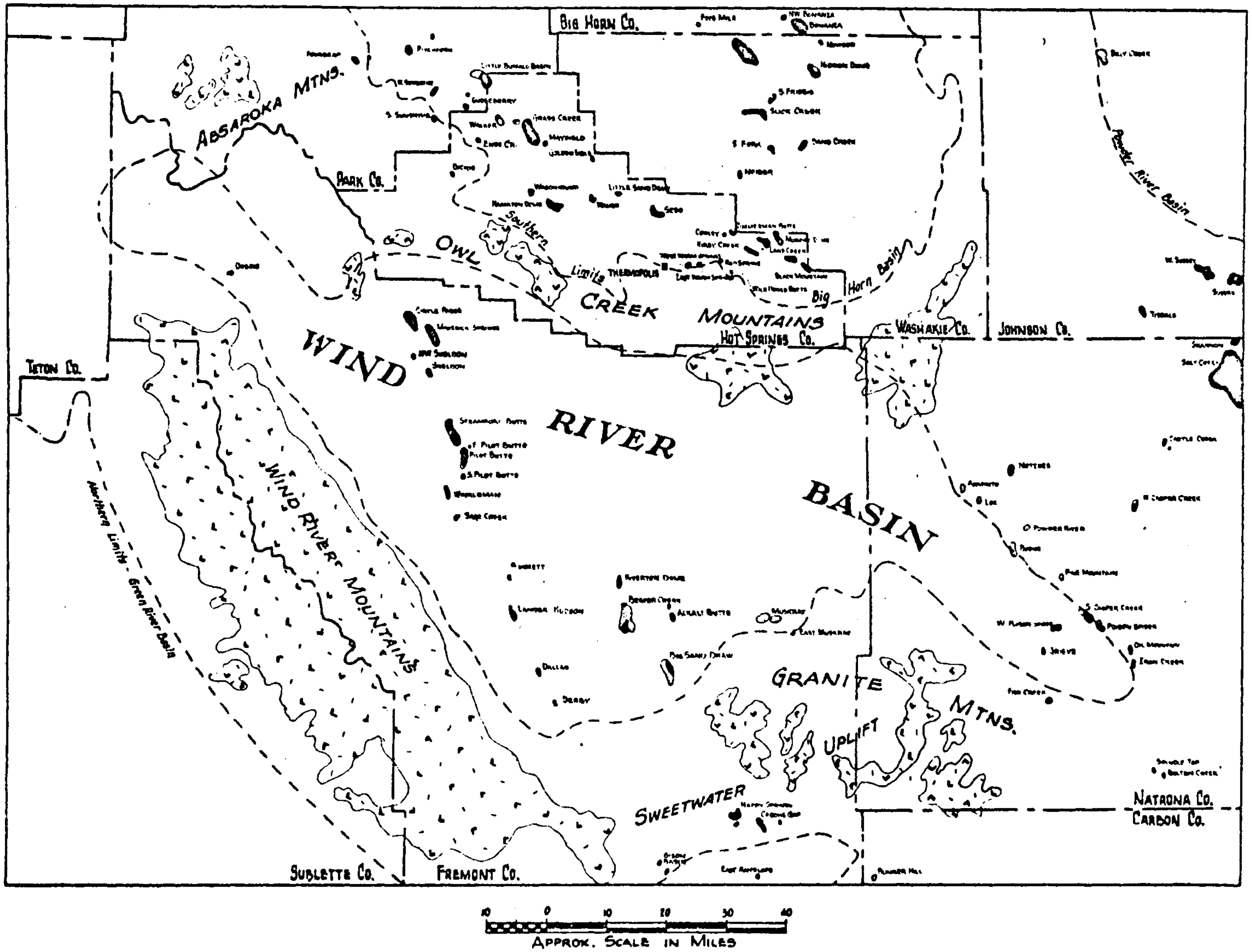


Fig. 3—Oil and gas fields, Wind River Basin and vicinity, Wyoming. (From Thompson, 1958).

form as a result of the Laramide Orogeny. The first consequences of the Laramide Orogeny are reflected in the withdrawal of the sea, accompanied in the early Tertiary time by the beginning of continental deposition and intense folding and faulting.

Stratigraphy

A. General Features

The geologic column in the Wind River Basin ranges from Precambrian to Holocene. Precambrian to Quaternary rocks are exposed along the margins of the basin, and early Eocene rocks (Wind River Formation), resting unconformably on older rocks, fill the central part of the basin.

According to Thompson (1958, p. 309),

> The total thickness of the sedimentary column, exclusive of the Tertiary rocks, in the Wind River Basin is about 17,000 feet in contrast to over 75,000 feet in the geosyncline area along the western margin of the state.
>
> Paleozoic rocks in the Wind River Basin are represented by all systems except the Silurian. These systems are thicker in the western part of the Basin (about 3,500 feet), and even here they represent only a small part of Paleozoic time. The Basin was emergent during most of the Paleozoic and only the strongest advances of the seas left sediment in the area. Mesozoic rocks in the Basin are about four times as thick as the Paleozoic rocks but they also represent only portions of the systems. In general, eastward-spreading epicontinental seas invaded the area during Triassic and Jurassic time. In Late Jurassic time and early Cretaceous time there was complete withdrawal of the seas from the area. During Cretaceous time there was both transgression and regression of the seas and much confusion exists in classification of some of these rocks.

Tertiary rocks in the basin may locally be as much as 15,000 feet thick. They are continental in origin and are thickest near the axis of the basin on the north side.

The Tertiary rocks also cover almost 75 percent of the basin area and represents over half its total volume.

B. Precambrian Rocks

The Precambrian rocks (granites, schists and gneisses) are exposed in the core of the Granite Mountains, Wind River Mountains, the Owl Creek Mountains and the Big Horn Mountains, almost entirely surrounding the basin (see Fig. 3).

C. Paleozoic Rocks

The Paleozoic rocks begin with the Upper Cambrian section which rests on the basement complex. Lithologically they are mainly represented by limestones, dolomites, shales and sandstones, with several hiatuses and unconformities. No Silurian rocks are known. The Paleozoic rocks originated entirely in marine environments.

D. Mesozoic Rocks

1. Triassic

The Mesozoic stratigraphic sequence starts with the marine Dinwoody Formation (siltstones, shales, and sandstones) 60 to 200 feet thick. Overlying this formation is a uniform re-bed sediment, the Chugwater Formation, deposited partly, on a shallow epicontinental sea spreading eastward from the Cordilleran geosyncline. It is about

1,000 to 1,200 feet thick and consists of three members; with the Red Peak at the base (red siltstone, shale, and some fine-grained sandstone in the upper part). Above the Red Peak is the Alcova limestone. Overlying the Alcova limestone is the uppermost member of the Chugwater Formation, the Popo Agie (bright orange claystone, limestone conglomerates, purple and red shale). The Chugwater is nearly devoid of fossils except for reptiles and plant remains.

2. Jurassic

During the lower and middle Jurassic marine or near shore marine conditions prevailed (Nugget, Gypsum Spring and Sundance Formations), giving way to fluviatile-flood plain deposits of the dinosaur-bearing Morrison Formation in Late Jurassic times.

The Nugget Sandstone, at the base of the Jurassic in the Wind River Basin, is a red to gray, massive sandstone, locally cross-bedded. In the southwestern part of the basin it is 500 feet thick but thins rapidly northward and eastward to a wedge edge.

Lying unconformably above the Nugget Sandstone is the Gypsum Spring Formation, up to 250 feet in thickness of red siltstone, massive white gypsum, limestone, red shale, and dolomite. It is present in the western part of the Wind River Basin. It pinches out to the east and it is absent to the southeast.

The Sundance Formation, which overlies the Gypsum Spring Formation, is divided into the oolitic "lower Sundance" up to 350 feet thick in the northwest part of the basin thinning uniformly southward to about 75 feet in the southern part of the basin; and the glauconitic "upper Sundance", 100 to 200 feet thick and consists of limestones, shales, and limy sandstones.

The non-marine, dinosaur-bearing Morrison Formation consists of silty and poorly sorted sandstones, 100-200 feet thick in the basin.

3. Lower Cretaceous

The Lower Cretaceous sequence, lying above the Morrison Formation, starts with the Cloverly Group at base (Lakota, Fuson, and Dakota Formations). The Thermopolis Shale overlies the Cloverly Group.

The Muddy Sandstone Formation, which is present over most of the basin, ranges in thickness from a few inches to 150 feet along the western margin. It represents the uppermost lithology of the Lower Cretaceous.

4. Upper Cretaceous

According to Thompson (1958, p. 317), "The boundary between the Upper and Lower Cretaceous in the Wind River Basin appears to lie somewhere in the lower part of the Mowry Shale". This shale is typically silver-gray with interbedded bentonite. Fish scales are also characteristic of this formation. Above the Mowry lies the Frontier Formation, a sandstone with interbedded shale. A thick sequence of marine shales (4,000-5,000 feet), sandy toward the top, called the Cody Shale, was deposited above the Frontier Formation.

The Mesaverde Formation rests on the Cody Shale. It is a non-marine sequence of sandstones, thin shales and coal beds. The clastic Meeteetse Formation overlies the Mesaverde in the northern and eastern part of the Wind River Basin, while the yellow to white non-marine sandstones of the Lance Formation rests unconformably, in some places, over the Mesaverde or Meeteetse Formations.

E. Cenozoic Rocks

All Cenozoic sediments are continental in origin. As mentioned before, about 75 percent of the basin area is covered by Tertiary rocks which account for half the sedimentary volume. The oldest Tertiary formation is the Paleocene Fort Union, lying unconformably over the Cretaceous rocks. Regarding its thickness, it can be said that along the southern margin of the basin it ranges from a few feet to a few hundred feet. Along the northern portions outcropping sections are as much as 6,000 feet thick, and farther east, subsurface data seem to indicate still thicker sections. The lithology consists of sandstones, conglomerates, shales and thin coals. Fossil leaves are locally abundant.

Unconformably overlying the Fort Union is the Wind River Formation (Wasatch) of Lower Eocene age. Like the Fort Union it is also thickest on the northern portion of the basin along the structural basin. The lithology is mainly composed of claystones and sandstones and in some places it has been divided into two members on the basis of vertebrate fossils.

A sequence of middle and upper Eocene rocks, in some places, overlies the Wind River Formation. They are greenish to gray volcanic-rich rocks present on the west, north, and south sides of the basin.

The Oligocene White River Formation (tuffaceous silts, fine-grained sandstones) and Miocene rocks are present mainly along the south side of the basin, with some possible lithologic equivalent in the northwest and northern edges of the Wind River Basin.

The remainder of the geologic column includes some Pliocene(?) rocks and Quaternary deposits.

The Wind River Formation (Eocene) and the White River Formation (Oligocene) will be specifically considered, mainly in the Hiland-Clarkson Hill area (Fig. 1), because they represent the stratigraphic column in the area covered by this thesis.

1. Wind River Formation

a. History of Stratigraphic Terms

According to Rich (1962, p. 486),

> The first use of the name Wind River was apparently by Hayden (1861), who referred the strata overlying the Fort Union Formation to the deposits in the Wind River Valley. In Hayden's report of 1869, he refers to the 'Wind River Deposits' and also used the word 'formation' in connection with these strata. Since that time the Wind River has been considered by most authors to be a formation. No type area, other than the Wind River Basin was designated by Hayden.

Regarding the same lithology, Soister (1968, p. A8) notes that

> Endlich (1878, 1879) used the term 'Wasatch Group' for the present Wind River and Wagon Bed Formations at the foot of the Beaver Divide Escarpment in the south-western part of the basin and in the Muskrat Basin.

> In terming these rocks 'Wasatch', Endlich was undoubtedly influenced by his previous work south of the 43d parallel where typical Wasatch strata occur. He made no mention of their relation to the 'Wind River deposits' of Hayden, although the beds in the southwestern part of the basin which he mapped as Wasatch probably were included in Hayden's 'Wind River deposits'.

Later workers divided the Wind River Formation into faunal and lithologic units in several locations within the Wind River Basin.

Different basis for the definition of these units and lack of stratigraphic equivalence between the different localities studied have been the capital reasons for the varied present Wind River terminology.

The nomenclatural problem undoubtedly is a reflection of the sedimentary and environmental conditions prevailing during the deposition of this formation: sediment source areas and depositional environment varied from place to place within the basin, making the sediments develop "local" characteristics difficult to recognize over a major part of the basin. Some of the workers, as mentioned by Rich (1962, p. 486), have subdivided the Wind River Formation differently in the following areas:

Badwater Area: - In the Badwater area, lying to the north of the Hiland-Clarkson Hill area Sinclair and Granger in 1911 divided the Wind River Formation into two members, the "Lysite" (below), and the "Lost Cabin" (above), based on faunal and lithologic evidences.

<u>Gas Hills Area</u>: - In Gas Hills area, which is contiguous with the Hiland-Clarkson area on the west, Zeller and others in 1956 divided the Wind River Formation into a lower fine-grained facies and an upper coarse-grained facies.

Rich (1962, p. 486) also records,

> The lower fine-grained facies of Zeller may be lithologically and temporarilly equivalent to the Lysite and Lost Cabin members in the Badwater area. The upper coarse-grained facies of Zeller is limited in distribution to a relatively narrow outcrop band along the southern margin of the Wind River Basin and apparently has no lithologic or genetic equivalent in the Badwater area.

Rich (1962) in his geologic work concerning the Hiland-Clarkson Hill area (in the eastern third of the Wind River Basin) adopts Zeller's terminology as being more suitable for that region, and he states (p. 486),

> The lower fine-grained facies is exposed from the western boundary of the area [referring to Clarkson Hill area] as far as Poison Spider Creek, T. 33 N., Rs. 83-85 W.; eastward from Poison Spider Creek the upper coarse-grained facies is exposed.

b. Lithology of the Wind River Formation in the Hiland-Clarkson Hill Area

<u>Lower Fine-Grained Facies</u>: - The basal contact with the Paleocene Fort Union Formation is marked by an angular unconformity ranging from 5° to 45°. Two units were recognized by Rich (1962) within the lower fine-grained facies of the Wind River Formation: a lower variegated sequence and an upper drab greenish-gray sequence. The basal section of the variegated sequence is nearly everywhere a medium-grained to conglomeratic yellowish-gray sandstone, 1 to 3 feet thick. Overlying this basal sandstone, and completing the

whole variegated sequence, is a poorly bedded red, purplish-red, greenish gray to gray siltstone interbedded with lenticular light-gray to yellowish-gray channel-filling sandstone. The sandstones, in general, are progressively more arkosic toward the east, and almost everywhere with small fragments and pebbles of Mesozoic and Paleozoic rocks.

The variegated sequence grades upward into the drab greenish gray siltstone sequence, and seems to be the only persistant feature throughout the area to place the contact, although this change does not occur everywhere at the same stratigraphic horizon.

The general lithology of the drab greenish-gray sequence is mainly composed of intercalated siltstone, claystone, and lenticular arkosic sandstone beds.

The lower fine-grained facies appears to thicken basinward from the margins. Vertebrate fossils of early Eocene age were found in diverse localities but always in the lower variegated sequence of the lower fine-grained facies of the Wind River Formation. Fossils were not found in the drab greenish-gray unit. Finally, Rich (1962) mentioned that the variegated sequence mentioned above may be stratigraphically equivalent to the Lost Cabin member of the Wind River Formation in the Badwater area, however being doubtful for some localities.

<u>Upper Coarse-Grained Facies</u>: - Regarding this lithologic unit Rich (1962, p. 493) records,

> The upper coarse-grained facies of the Wind River Formation is exposed only north of the Rattlesnake Hills drainage divide in the eastern third of the mapped area. This facies rests with erosional unconformity on the lower

> fine-grained facies, and near Poison Spider Creek it fills channels cut into the upper surface of the lower fine-grained facies.

The lithology of this upper coarse-grained facies is composed of medium to coarse grained light-yellow-gray arkosic sandstone and granite pebble to cobble conglomerate with minor amounts of lenticular siltstone, claystone, and carbonaceous shale. A higher than background radioactivity is associated with the carbonaceous layers. The whole sequence is poorly consolidated with sudden vertical and horizontal lithologic changes.

Rich (1962, p. 495) also records,

> For the most part of the coarse-grained facies was truncated by erosion to form the present surface; however, in T. 31 N., R. 82 W., it is unconformably overlain by the basal conglomerate of the White River Formation. There, the contact is marked by an angular unconformity of about 30° and by a change upward from a coarse-grained arkosic sandstone to a coarse boulder and cobble conglomerate.

The maximum thickness recorded for this upper coarse-grained facies was about 900 feet in the Cities Service Oil Company well in T. 32 N., R. 85 W., along the southern margin of the basin (Hiland-Clarkson Hill area). It is not present on the northeastern edge of the basin and 50 feet of this section is recorded along the eastern margin.

On textural basis, roundness, and mineralogical composition Rich concludes that the possible source area for this unit is the Granite Mountains about 10 miles south of the studied area, although some sediments may have been derived from local sources along the margins of the basin.

Fossils were not found in the upper coarse-grained facies, therefore its age has to be determined by correlation with dated adjacent localities. In the Gas Hills area a similar facies is overlain by rocks of middle and late Eocene age and underlain by rocks of early Eocene age, and on this basis Rich has assigned to this unit an early Eocene age.

2. White River Formation

Rich (1962, p. 496) records that,

> From a study of the Tertiary rocks of the high-plains areas of Wyoming, Nebraska, and South Dakota, Meek and Hayden (1861) defined the strata overlying the rocks of Eocene age and named them the White River Group. The White River Group was further divided by Darton (1889, p. 736) into the Chadron and Brule Formations, in ascending order. Darton (1908, p. 463) extended the White River nomenclature into the area of this report [referring to the Hiland-Clarkson Hill area] and assigned the exposed Oligocene rocks to the Chadron Formation. In the Beaver Divide area the Oligocene rocks have been variously called the White River Group, White River Formation, Chadron, Chadron and lower Brule, Brule, or Oreodon beds (Wood, 1948, p. 39); however, as a result of recent stratigraphic studied in that area, Van Houten (1954) assigned these rocks to the White River Formation of Granger (1910). The Oligocene rocks in the Hiland-Clarkson Hill area are here referred as the White River Formation.

The White River exposures in the northern limit of the thesis area generally is defined, by the east-west trending north Granite Mountain fault zone. The basal White River Section in the area, rests unconformably on the underlying formations, either upper Cretaceous and older rocks, or over the Wind River Formation.

The lower 12 to 50 feet of the White River Formation are described, according to Rich (1962, p. 497-498) as,

> A massive to poorly bedded conglomerate containing granite boulders as much as 20 feet in diameter, rounded pebbles and cobbles of Paleozoic sandstone, brownish-gray quartzite, basic igneous rocks, and pale-green Precambrian quartzite; the matrix consists of coarse-grained arkosic sandstone....The rest of the White River Formation is characterized by light gray, pinkish gray, tan, and white tuffaceous siltstone and claystone interbedded with light to dark-gray tuff and conglomeratic sandstones. The individual beds are lenticular and can be traced only short distances along the strike. The upper 50 to 100 feet is predominantly white to light-gray tuff interbedded with pinkish-gray tuffaceous siltstone. The tuff beds are lenticular and range in thcikness from 0 to about 20 feet.

Carbonaceous beds are not abundant in the White River Formation.

Rich also mentions in his report the presence of Miocene rocks resting with an erosional unconformity on the White River Formation (cut and fill structures). The basal section of these "Miocene" rocks of Rich (1962, p. 503) has been determined to be of Oligocene age in recent studies. Norman M. Denson (written communication, 1968) informs that by heavy mineral studies and through inference from potassium-argon determinations the lower conglomeratic section of these rocks, as much as 800 feet thick, is of Oligocene age and not basal Miocene as previous workers have contended.

Both the basal conglomerate of the White River Formation and the upper coarse-grained facies of the Wind River Formation, are considered to be of orogenic origin derived from a sharply elevated land mass south or southwest of the Hiland-Clarkson Hill area.

The rest of the White River Formation is considered as being deposited on a flood plain which also received considerable amounts of ash material, as pyroclastic debris and washings from the uplands. The vertebrate fossils collected from the White River Formation indicates an early Oligocene age.

GENERAL STRUCTURE OF THE WIND RIVER BASIN

The roughly parallelogram-like shape of the structural Wind River Basin is interpreted by Thompson (1958) as a result of components of thrusting. He notes (p. 319),

> The Owl Creek Mountains were thrust southward over the basin for several miles. The Wind River Mountains responded by moving southwestward onto the Green River Basin. The southern portion of the Sweetwater Plateau moved southward. These components had much to do with the present shape of the basin.

The northern and western margins of the Wind River Basin are areas of complex folding and faulting; the northeastern side is also structurally defined by a line of faults and folds, and along the southern flank of the basin a series of northwestward trending en echelon anticlinal folds. One of them, the easternmost is the Rattlesnake Hill Anticline. The most intense faulting and folding is localized on the Rattlesnake Hills Anticline and along the northeastern margin of the basin. The general trend for most of the structural features is northwest-southeast, with some exceptions trending in the northeast-southwest direction.

Most of the folds in the basin are asymmetric, with the steep side on the southwest, and they are commonly underlain by east-dipping reverse or thrust faults.

Normal faulting is also mentioned to be present on most anticlines in the basin.

A. Folds

Outcrops of Mesozoic and Tertiary rocks along the margins of the basin are dipping basinward, outlining the broad asymmetrical

Wind River Basin Syncline. The upper Cretaceous rocks dip from 36° to 78° along the northeastern flank of the basin, and from 15° to 45° along the southwestern margin. The Paleocene Fort Union Formation also dips basinward but from 10° to 43° along the northeastern flank and from 5° to 10° along the southwestern border.

The Eocene Wind River Formation, which crops out in most of the basin area, also dips basinward along the margins from 5° to 20° but the formation lies almost horizontal near the axis of the basin.

B. Faults - Hiland-Clarkson Hill Area

In the southern part of the Hiland-Clarkson Hill area there is an east-west trending fault zone named North Granite Mountains Fault Zone. To the west and in the area of this thesis the fault zone is considered by Rich (1962) to be poorly exposed and many of the faults can be detected only as linear features on aerial photographs.

The faults dip northward at angles ranging from 60° to 85°. Rich (1962, p. 510), also records,

> The displacement of the Oligocene and Miocene rocks along the North Granite Mountain Fault Zone is thought to be the result of post-Miocene adjustment along a pre-existing fault zone. Geophysical data indicate that the displacement of the Wind River and older formations along the fault zone may be as much as 5,000 feet with the strata on the north side of the fault dropped relative to those on the south side. On the other hand, surface data indicate that the post-Wind River strata along the fault zone are displaced about 175 feet and the strata on the south side of the fault are dropped relative to those on the north side. Thus, the relative displacement of the Oligocene and Miocene rocks is in the reverse direction and of considerable less magnitude than that in the Wind River and older formations....

...The first episode of movement along the North Granite Mountain Fault Zone may have taken place during middle and late Eocene time. This episode of faulting is dated by the relations of the Wind River Formation to the fault zone and to the overlying formation.

Chapter III

STRATIGRAPHY

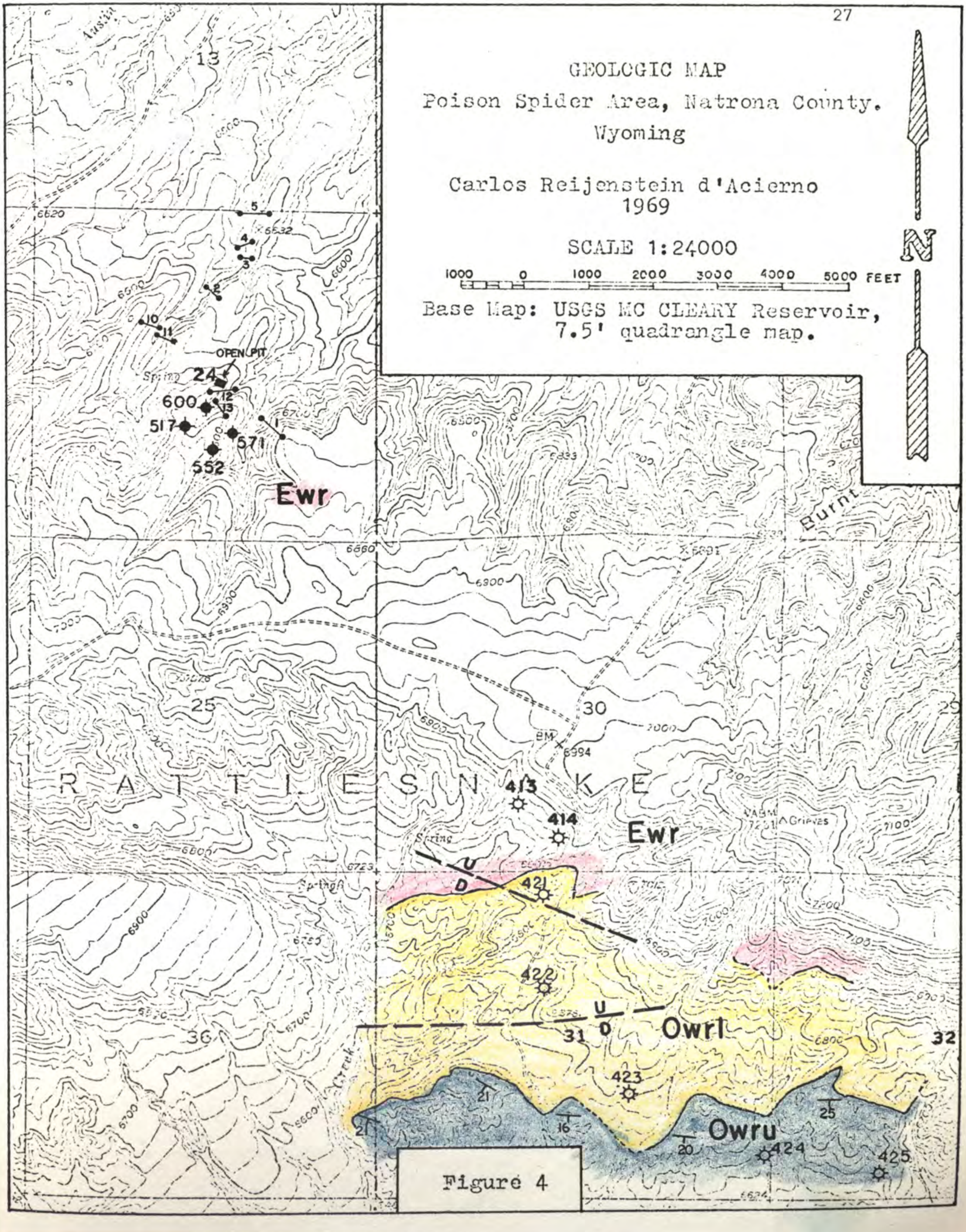
A. General Statement

The regional geology was described in the preceding chapter. The present chapter deals with the details of local geology investigated in the Poison Spider area. The exposed rocks, in this portion of the Wind River Basin, range in age from Eocene to Recent, being entirely of continental origin. The oldest Tertiary formation is the Eocene Wind River, which is well exposed in more than fifty percent of the area investigated (Fig. 4). It crops out all over the northern and central portions to about half a mile downslope on the south side of the Rattlesnake Range. The lithology is predominantly clastic, coarse grained arkosic sand in most cases. The Oligocene rocks are represented by the lower and upper members of the White River Formation, exposed from the southern slope of the Rattlesnake Range toward the south. No more rocks of Tertiary age are present within the mapped area.

Quaternary gravel deposits caps at least three terraces north of the Rattlesnake Range, and consist mainly of granitic and quartzitic pebbles and cobbles.

B. Stratigraphic Contacts

In sections 31 and 32, T. 32 N., R. 84 W., south of the Rattlesnake Range, three stratigraphic discontinuities are found, each showing a sharp lithologic change. From south to north, the



GEOLOGIC MAP
Poison Spider Area, Natrona County.
Wyoming

Carlos Reijenstein d'Acierno
1969

SCALE 1:24000
1000 0 1000 2000 3000 4000 5000 FEET

Base Map: USGS MC CLEARY Reservoir, 7.5' quadrangle map.

Figure 4

LEGEND

	<u>WHITE RIVER FORMATION</u>	OLIGOCENE
Owru	Upper member Conglomerate at base, sandstones, and siltstones	
Owrl	Lower member Sandy siltstone with conglomeratic sandstone intercalations	
	<u>WIND RIVER FORMATION</u>	EOCENE
Ewr	Gravel, gravelly sand, sand, both with clay-silt intercalations	
•⟍• 13	Stratigraphic Section	
⊤ 21	Strike and Dip	
◆	500 Series of Drill Holes. Only corner drill holes shown	
☼	Holes (400 Series)	
▰	Open Pit	
— U/D —	High-angle fault -D, downthrown side; U, upthrown side-	

Figure 4

predominant lithologies of the formations are:

White River Formation, upper member:

Sandy conglomerate at base, siltstones and sandstones upward, grayish white in color.

White River Formation, lower member:

Grayish white calcareous sandy silt, minor amount of conglomeratic sandstone to fine conglomerate.

Wind River Formation:

Pale yellowish orange sand, medium-coarse to gravelly, clay intercalations.

The White River (lower member) - Wind River contact can be clearly delineated in the field along the northwest corner of section 31. From there toward the east it remains covered by Recent sediments, but on the west side of section 32 appears again (Fig. 5-A) but covered toward the east. The lower member of the White River Formation lies in a relative topographic low, between the Rattlesnake Range at the north (Wind River Fm.), and a trend of topographic highs at the south (basal conglomerate of the upper member)(Figures 5-B and 6). The lower-upper member contact trends approximately east-west and is located along the central-south portions of sections 31 and 32. The topographic highs were produced by the differential erosion of the resistant conglomerates, and the more readily eroded sandy silt of the White River Formation. The lower-upper member contact is very irregular since the basal conglomerate of the upper member represents channel deposits over the underlying White River sediments. Channeling structures are very evident in the outcrops and individual beds cannot be traced for long distances.

Figure 5-A. Photograph showing the Wind River-White River contact, southern slope of the Rattlesnake Range, section 32, T. 32 N., R. 84 W.

Figure 5-B. Photograph showing cross-bedding in the basal conglomeratic deposits of the upper member of the White River Formation, section 32, T. 32 N., R. 84 W.

A

B

Figure 6. Regional view of the Rattlesnake Range (at left) and its southern slope taken from Horse Heaven (sections 26-27, T. 32 N., R. 85 W.) toward the east-southeast. Triangulation Station Grieves, located in SW 1/4, section 29, T. 32 N., R. 84 W., is indicated by the letter "G". The rocks in the ravines (foreground) belong to the Wind River Formation which show an apparent dip of more than 10° southward.

The lower member of the White River Formation forms topographic lows (L), while the upper member forms small hogbacks (U).


G
L
U

Along parts of this conglomeratic beds were taken the only reliable data for strike and dip for the section south of Rattlesnake Range. The strike is approximately east-west with an average dip of 20° toward the south.

C. Wind River Formation

1. Name

The first use of the name Wind River was apparently made by Meek and Hayden in 1861, to define the strata overlying the Fort Union Formation in the Wind River Valley. The nomenclatural history of the formation is summarized in Chapter II. Usage of the name in this thesis is in accordance with the definition by the United States Geological Survey.

2. Distribution

The Wind River Formation is the most widely distributed rock unit in the Poison Spider and thesis area. It is the only formation exposed on the crest and north of the Rattlesnake Range.

3. Lithology

Rich (1962) recognized an upper coarse-grained facies and a lower fine-grained facies for the Wind River Formation in the Hiland-Clarkson Hill Area (Fig. 1). In the thesis area only the upper coarse-grained facies is present both on surface and subsurface. The average lithology consists of medium-coarse grained sand to gravelly sand (arkosic and micaceous) with clay beds and clay lenses, and minor amounts of carbonaceous-rich intercalations. A complete and detailed analysis of the lithology based on cutting examination and study of stratigraphic section samples, is given in Chapters 4 and 5. As the Wind River sediments are poorly indurated, they are described in this text as unconsolidated materials.

4. Thickness

The thickness of the Wind River Formation in the thesis area was impossible to measure since the underlying Paleocene Fort Union Formation is not exposed, and all the wells drilled as much as 200 feet deep remained entirely within the Wind River sediments.

Rich (1962) mentions that a maximum thickness of 900 feet was determined for the upper coarse-grained facies sediments in the Cities Service Oil Company well in T. 32 N., R. 85 W., close to the thesis area.

5. Stratigraphic Relations

The Wind River Formation is the basal Eocene unit in the Wind River Basin and, according to the consulted literature, overlies the Paleocene Fort Union Formation with a marked angular unconformity. This relationship could not be observed in the thesis area because the Fort Union is not exposed. For the most part of the coarse-grained facies was truncated by erosion to form the present surface. However, in sections 31 and 32, T. 32 N., R. 84 W., it is unconformably overlain by the basal section of the White River Formation.

6. Age

The lithologic section of the Wind River Formation in the thesis area, belongs to the so-called upper coarse-grained facies (Rich, 1962). The same author correlated this unit in the Hiland-Clarkson Hill area with a lithologically and stratigraphically similar early Eocene facies of the Gas Hills area.

As no fossils were found, the upper coarse-grained facies of the Wind River Formation is considered, based on the above-mentioned correlation, of Early Eocene age.

7. Provenance

The section discussing the possible source area for the sediments of the Wind River Formation is placed at the end of Chapter 7.

D. White River Formation

1. Name

The name White River was originally used by Meek and Hayden in 1861 to define the strata overlying the rocks of Eocene age of the High Plains of Wyoming, Nebraska, and South Dakota. The nomenclatural history of the formation is summarized in Chapter II. Usage of the name in the thesis is partially in accordance with its definition by the United States Geological Survey (Rich, 1962). Two members are recognized for the White River Formation in this thesis work. The lower one is equivalent to that lithology considered as "White River Formation" by Rich (1962) for the same area. The upper member of the White River Formation in this thesis is equivalent to the basal section of the rocks considered "Miocene" by Rich (1962) in the same area.

2. Distribution

The White River Formation is confined in the thesis area to a narrow belt of outcrops about 1 mile wide, on the southern slope of the Rattlesnake Range.

3. Lithology

The White River Formation has been divided into two members: the lower member and upper member. The lower member is a carbonate rich tuffaceous siltstone with conglomeratic sandstone to conglomerate intercalations. The upper member is coarser grained, conglomeratic at the base with sandstones and siltstones upward, both grayish-white in color. A more detailed lithologic description is given in the following pages where the members are treated individually.

4. Thickness and Stratigraphic Relations

The maximum original thickness of the White River Formation cannot be determined because of the following reasons:

1) An erosional contact separates the lower and upper members of the White River Formation.
2) The lower member overlies the Wind River Formation with a fault or erosional contact.

3) The upper member of the White River Formation is overlain with an erosional contact by the early Miocene Arikaree Formation, half a mile south of the thesis area (Denson, 1968, written communication).
4) One of the several branches of the North Granite Mountain Fault Zone affects the outcropping White River Formation and underlying formations in the thesis area (Rich, 1962; Denson, 1968, written communication), almost parallel to the strike of the beds.

Any estimation of the minimum thickness of the White River Formation in the thesis area seems to be highly speculative. The general dip of the sediments is not constant, although some reliable values were obtained, they have local value and cannot be extrapolated to the rest of the section. Moreover, the sediments discussed were disturbed by the North Granite Mountains Fault (Rich, 1962) which has increasingly complicated the general scheme.

5. Age

No fossils were found in the White River Formation of the thesis area. Rich (1962) reported that vertebrates collected from about 20 feet above the base to within 100 feet of the top, in the Hiland-Clarkson Hill area, gave an early Oligocene (Chadron) age for the "White River Formation" (lower member of the White River in this work). Also, potassium-argon age determinations gave an Oligocene age (Denson, 1968, written communication), for the upper member of the White River Formation.

6. Topographic Expression

The White River crops out all over the southern slope of the Rattlesnake Range. The easily eroded lower member of the White River Formation lies in a relative topographic low, between the Rattlesnake Hills at the north (Wind River Formation), and a series of low hogbacks at the south (Basal conglomerate of the upper member).

a. White River Formation - Lower member

1) Name and Correlation

The lithologic unit recognized in this thesis as lower member of the White River Formation is equivalent to the "White River Formation" of Rich (1962) for the same area.

2) Distribution

The lower member of the White River Formation is exposed in a narrow east-west strip, on the southern slope of the Rattlesnake Range, along sections 31 and 32, T. 32 N., R. 84 W.

3) Lithology

The lower member of the White River Formation cropping out in the thesis area, is composed of a very uniform light gray, pinkish gray and white sandy siltstone with minor intercalations of conglomeratic sandstone.

The basal conglomerate of this lower member, as described by Rich (1962, p. 497) does not appear at the Wind River-White River contact of the thesis area, therefore it is assumed that this coarsest unit was not deposited along this local region.

Petrographic studies were made on samples taken from the uppermost part of the lower member of the White River Formation: one thin section was studied to determine the general mineralogical composition, and two slides were studied for heavy mineral determinations. Moreover, a sieve and pipette analysis were run for the same sample for which a thin section was prepared.

A thin section of the lower member of the White River Formation taken from section 31, T. 32 N., R. 84 W. is a tuffaceous calcareous sandy silt. The grain size distribution of this sample, a sandy silt, is shown as a histogram and cumulative curve in Figure 7. Its general grain size distribution is:

sand size	36.0%
silt size	63.6%
clay size	0.3%

The minerals present in the above sample are:

Quartz and plagioclase.....	45%
Calcite....................	40%
Heavy Minerals.............	10%
Microcline.................	5%

Almost all the grains, with the exception of the heavy minerals are very angular with low sphericity. In the thin section a few microcrystalline partially isotropic grains were observed which could be interpreted as partially crystallized vitreous material of volcanic origin.

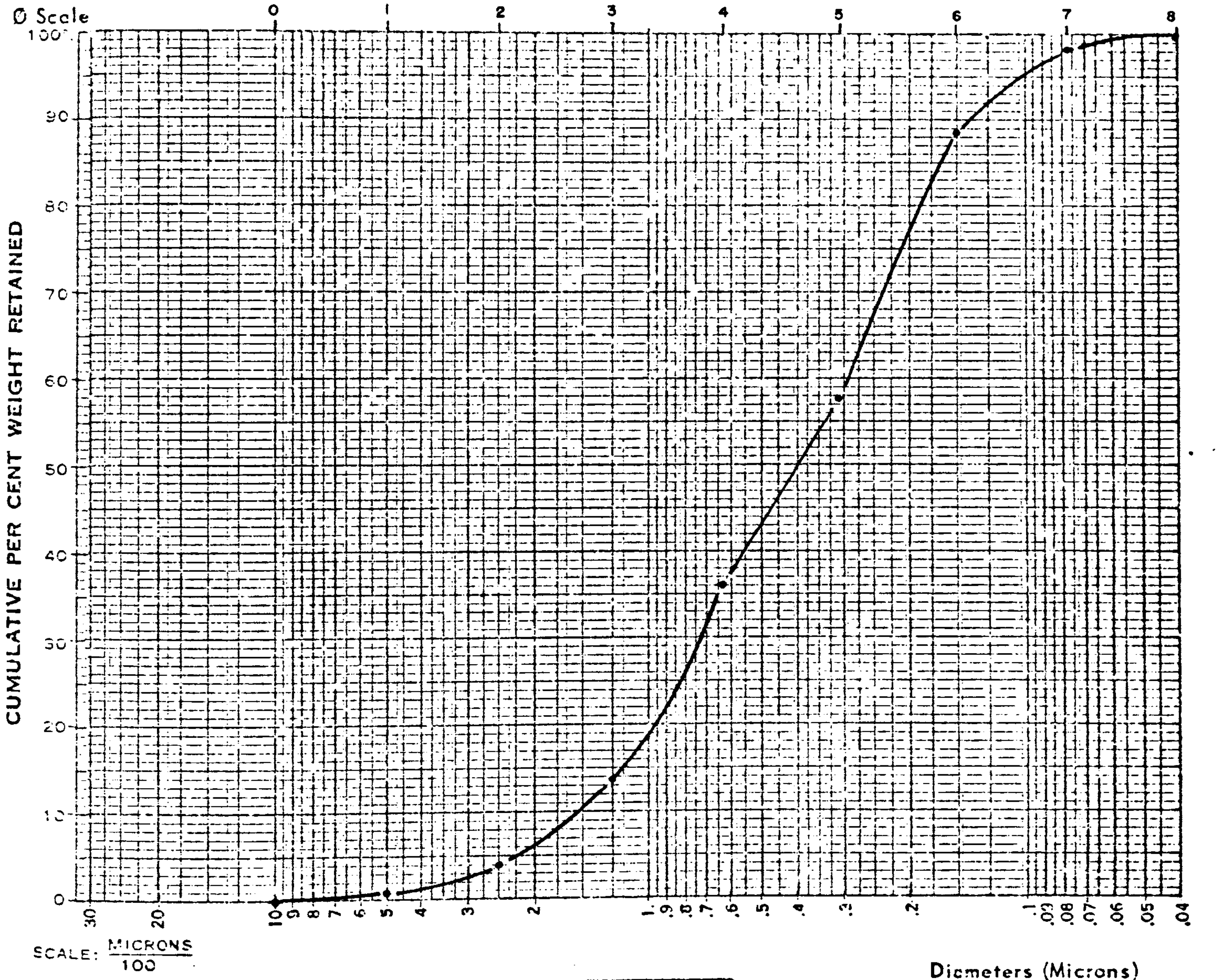
Two slides were prepared for the study of the heavy minerals. As shown graphically in Figure 17, the following heavy mineral suite was determined for the lower member of the White River Formation.

WHITE RIVER Fm.

Sandy Silt

Sample No.________________

Screen Analysis



Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
1	0	0.03	0.0	0.03	0.0
1/2	1	0.47	0.8	0.50	0.8
1/4	2	1.88	3.1	2.38	4.0
1/8	3	5.85	9.7	8.23	13.7
1/16	4	13.45	22.4	21.68	36.0
1/32	5	13.01	21.6	34.69	57.7
1/64	6	18.65	31.0	53.34	88.7
1/128	7	5.68	9.4	59.02	98.1
1/256	8	0.95	1.6	59.97	99.7
	9	0.16	0.3	60.13	100.0
	TOTAL	60.13	99.9		

1% = 450
50% = 40
Modal Class (Ø Scale) = (5,6)

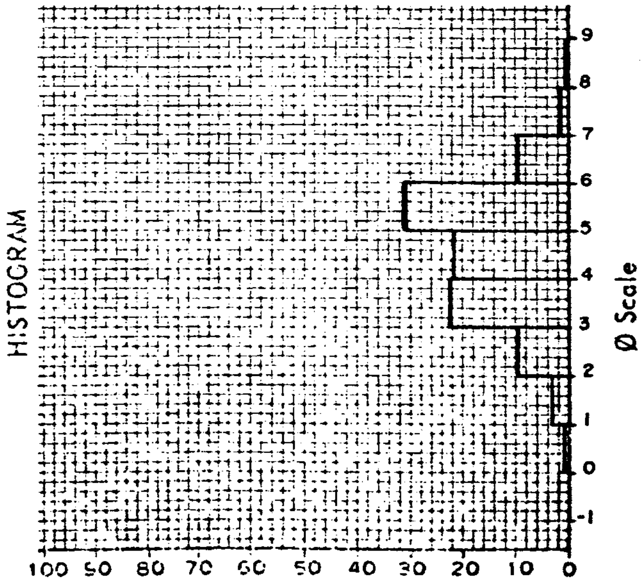


Figure 7

The opaque minerals ilmenite, magnetite, and leucoxene (very few), constitute 5 percent of the total. The non-opaque minerals consist mainly of hornblende (75 percent), garnet-zircon (10 percent), augite-hypersthene (5 percent), and a group of heavy minerals (5 percent) in which sillimanite and rutile are present.

The hornblende consists of three mineralogic varieties, blue to blue green hornblende 40 percent; green brown hornblende 25 percent; and red brown hornblende 10 percent, which makes the total of 75 percent, of hornblende present in the heavy mineral slides. The minerals are subangular to well rounded with a sphericity ranging from low to high.

4) Age

As mentioned before, this lower member of the White River Formation is equivalent to the "White River Formation" of Rich (1962) in the same area. Rich has determined an early Oligocene (Chadron) age for the lithology in question, based on vertebrate fossils collected in some place within the Hiland-Clarkson Hill area. The fossiliferous material was present from about 20 feet above the base to within 100 feet of the top of this lower member.

5) Stratigraphic Relations

The lower member of the White River Formation (Early Oligocene) overlies unconformably the Wind River Formation. The contact, possibly of erosional character, can be inferred in the field along the northwest corner of section 31, T. 32 N., R. 84 W. from there toward the east it remains covered by Recent sediments.

In the west side of section 32, T. 32 N., R. 85 W., it appears again, sharply defined at a possible fault contact (Fig. 5-A).

The lower member, along the central-southern part of sections 31 and 32, T. 32 N., R. 84 W., is unconformably overlain by the basal conglomerate of the upper member.

6) Provenance

The tuffaceous character of the sediments, the predominant silt size, the marked angularity of the particles of different size, the predominantly volcanic heavy mineral suite, etc. may suggest frequent and prolonged ash contribution in the White River Formation, as pyroclastic and transported elements. Some authors have suggested that volcanic vents in the Yellowstone-Absaroka region in the northwest corner of Wyoming, have contributed the pyroclastic debris. The coarser conglomeratic sandstones intercalations suggest a local provenance, due to the different rock types present; the wide size range, and the angular character, implying short transportation.

b. White River Formation - Upper member

The upper member of the White River Formation was not studied in detail for this thesis, and only the general characteristics will be given.

1) Name and Correlation

The upper member of the White River Formation in this thesis is equivalent to the basal section of the rocks considered

Miocene by Rich (1962) in the same area (Denson, 1968, written communication).

2) Distribution

The upper member is exposed along a narrow east-west trending belt about half a mile wide, lying on the southern part of sections 31 and 32, T. 32 N., R. 85 W.; and on the northern area of sections 5 and 6, T. 31 N., R. 84 W.

3) Lithology

The upper member of the White River Formation is composed of a coarse conglomeratic basal section becoming finer upward. The basal section, in some places thicker than 270 feet, is made up of alternating light gray tuffaceous sandy silt and lenticular sandy conglomerate. The conglomeratic beds contain fragments of quartz and feldspar as much as 2 to 3 inches in diameter; angular to subrounded pebbles of basic igneous rocks, granite, quartzite, metamorphic rocks, etc. as much as one foot in diameter. Overlying the basal beds is a white to light gray sandstone-siltstone sequence.

4) Stratigraphic Relations

The upper member rests with erosional unconformity on the lower member of the White River Formation. The upper member fills broad channels cut into the lower one (Fig. 5-B). One of the few places within the thesis area, where reliable information of strike and dip can be taken is along the outcropping basal section of the upper member. The general strike is nearly east-west with an average dip of 20° to the south.

Most of the upper section of the upper member dips toward the south out of the thesis area. In the central-northern portion of sections 5 and 6, T. 31 N., R. 84 W., there is an erosional contact with the Miocene Arikaree Formation (Denson, 1968, written communication).

5) Age

The age of the upper member of the White River Formation was dated by heavy mineral studies and through inference from potassium-argon determinations. By means of these studies an Oligocene age was determined and not basal Miocene as previous workers have contended (Denson, 1968, written communication).

6) Provenance

The variety of rocks and range of sizes making the bulk of the basal conglomerate suggests that the headwaters of the streams were actively eroding different rock types in different parts of a local source area.

E. Quaternary Sediments - Terrace Gravel Deposits

Gravel caps at least three terraces north of the Rattlesnake Range, in the Poison Spider area, overlying the truncated Wind River Formation (not shown on map, Fig. 4). On the measured stratigraphic sections of the Wind River Formation the capping gravel deposits range from 0 to more than 26 feet in thickness and consist mainly of granitic and quartzitic pebbles and cobbles, with some shale pebbles. The matrix, very abundant, is composed of a very coarse micaceous sand to silt grain size. All are poorly sorted and unconsolidated. The largest particles show not very often, percussion marks.

The upper surface of the terraces are relatively flat, sloping with a very small angle toward the north, and slightly tilted toward the east-northeast.

1. Heavy Minerals

Only one sample was taken for laboratory heavy mineral studies from the gravel deposits. It corresponds to the lowermost section of gravel capping the Wind River stratigraphic section number 2 (Plate 2). A sieve analysis was also made for the same sample (See Fig. 8) which shows 55.9 percent of gravel-sized material, 41.2 percent sand, and 3.0 percent silt-clay material.

The following heavy minerals were identified (Fig. 17):

Opaque Minerals (10% of total)

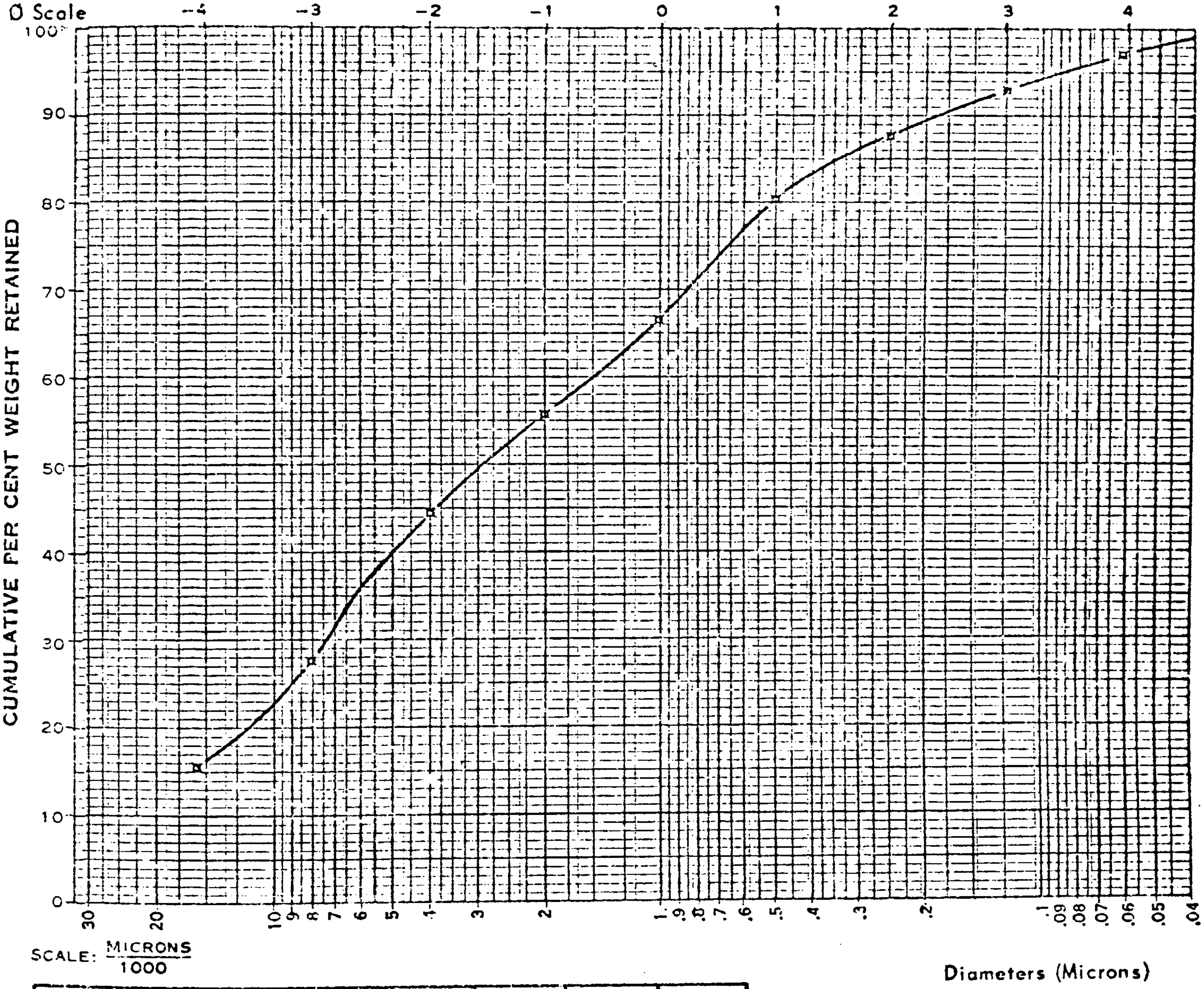
Magnetite
Ilmenite

Non-opaque Minerals (90% of total)

Hornblende
Augite
Garnet
Hypersthene
Zircon
Andalusite
Apatite

Hornblende (60 percent) is present in three varieties; green to blue green (most abundant), green brown, and red brown (scarce);

Sample No. S 2-1 **Screen Analysis** Sandy Gravel



Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4	12.22	15.6	12.22	15.6
8	-3	9.49	12.1	21.71	27.7
4	-2	13.50	17.2	35.21	44.8
2	-1	8.61	11.0	43.82	55.8
1.00	0.00	8.40	10.7	52.22	66.5
(1/2) 0.5	1.00	10.83	13.8	63.05	80.3
(1/4) 0.250	2.00	5.96	7.6	69.01	87.9
(1/8) 0.125	3.00	4.00	5.1	73.01	93.0
(1/16) 0.062	4.00	3.13	4.0	76.14	97.0
Pan		2.36	3.0	78.50	100.0
	TOTAL	78.50	100.1		
	Loss				

1% =
50% = 2,850
Modal Class (Ø Scale) = (−3,−2) (−5,−4)

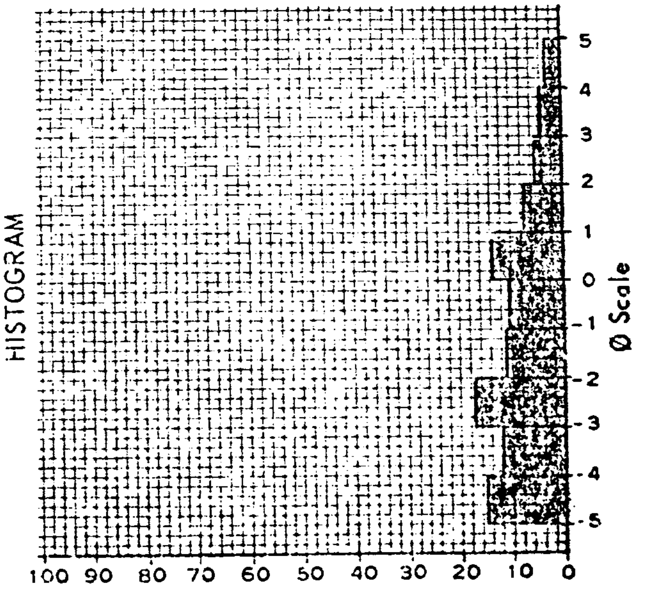


Figure 8

augite, garnet and hypersthene constitutes 25 percent of the mineralogical sample; and a group of heavy minerals, zircon, andalusite, apatite, etc. represent the rest of the heavy minerals (5 percent).

Almost all the minerals are rounded to well-rounded, with variable sphericity. The high roundness values for the heavy minerals of this deposit is in striking contrast compared to the Wind River-White River heavy mineral suite.

2. Provenance

The granitic pebbles and cobbles of these deposits are assumed to be derived from the Granite Mountains. Quartzitic pebbles and cobbles and clay pebbles are derived from Paleozoic and Mesozoic rocks of the area. The heavy mineral suite seems to indicate the contribution of Tertiary lithologies as source area for the finer elements of the gravel deposits.

Chapter IV

LITHOLOGIC DESCRIPTION OF THE STRATIGRAPHIC SECTIONS WIND RIVER FORMATION

A. Introduction

Stratigraphic sections 1, 2, 3, 4, 5, 10, 11, 12, 13 and the Open Pit, which shall be the basis of study in the following pages, have been made along bulldozer cuts in the Wind River Formation in Poison Spider Area. The location and elevation of each section is shown in Figure 4 and Plates 1 and 2.

Each section is always tabulated with the youngest bed at the top; the beds sampled for sieve analysis show the percentages of gravel, sand and mud (silt + clay), respectively. A sand is considered gravelly with more than 5% of gravel-size material; and muddy (silt + clay) when it has over 15% of silt-clay material. The radiometric reading for every bed (with the exception of section 1) is recorded. The reading was taken with a Precision Radiation Instruments, Inc., Scintillator, Model 111B, DeLuxe. These values appear within parenthesis at the end of every lithologic description; they are also stratigraphically tabulated on Plates 1 and 2. All the readings have been made, without exception, on the 0.25 scale of the Scintillator, and they are given in the radiation unit milliroentgens per hour (MR/HR).

The stratigraphic section in the Open Pit is the only one where there are available both scintillator readings and chemical analysis (% U_3O_8) for the same lithologic sample. The paper chromatographic method was used for the determination of the uranium in the samples. This method of uranium analyses is effective between the uranium concentration of 4 parts per million and about 0.14 percent U_3O_8 upper limit.

Almost every one of the sections described is capped by a sandy gravel which is considered a fluvial terrace deposit. These capping gravels are included in the description of the sections.

B. Open Pit

The open pit, constructed in 1968 in the Poison Spider area, is located exactly in the center of the section 24, T. 32 N., R. 85 W. It is the most interesting stratigraphic section available, since the 70-foot excavation allows one to see clearly the whole stratigraphic section, the characteristics of the mineralized zone in the area, and its thickness and lithology (Plate 1).

Both scintillator readings and U_3O_8 content (from chemical analysis) are available for samples from the mineralized zone downward.

The radioactive background in the open pit (to be taken in account for the scintillator readings) ranges between 0.07 and 0.032 MR/HR. This wide range in radioactive background radiation will account for the discrepancies between the chemical analysis and the scintillator values obtained, since an increase in the scintillator readings may not correspond with a higher value of U_3O_8 percentage as determined by chemical analysis. The scintillator readings for the other stratigraphic sections (1 to 5, 10 to 13) have a more constant radioactive background due to the fact that these sections are exposed only along shallow trenches, and eliminate the abnormal mass effect of a reading in a deep pit or trench.

There have also been run two semi-quantitative spectrographic analysis, one for the mineralized zone (carbonaceous silt-clay) and the other one for the underlying muddy sand.

OPEN PIT

		THICKNESS (feet)
	TOP	
a.	Sand, dark yellowish orange, fine, muddy, discontinuous intercalations of a dusky red clay, rich in calcium carbonate.........	4.0
	Sample 1: 0.4-81.1-18.5. Muddy sand, fine.	
b.	Clay, pale olive with discontinuous layers of yellowish orange color, silty, increasing in sand content downward. Calcium carbonate concentration in the uppermost foot. (0.040)..................................	4.5
c.	Sand, pale yellowish olive, fine, muddy, muscovite-rich (particles several millimeters in diameter) and with angular quartz up to 4 mm across (0.035)............	1.3
	Sample 3: 0.2-78.8-21.0 Muddy sand, fine	
d.	Sand, yellowish gray, with a gradational change in grain size from medium to coarse at the top, to coarse and very coarse gravelly sand and sandy gravel at the base. Arkosic and muscovite-rich. At the very base the average grain size is about 1 centimeter, with larger particles of granitic rocks reaching 6 inches across. (0.035)(0.045).............................	16.5
	Sample 4 (top): 2.9-92.1-4.9 Sand, medium to coarse Sample 5 (lower middle): 27.3-67.5-5.3 Gravelly sand, coarse to very coarse.	

e. Clay, pale olive, very silty with sandy silt bands of dark yellowish orange in color (0.085)....................................... 0.7
Chemical Analysis: $U_3O_8 = 0.0007\%$

f. Silt-clay, moderate brown, sandy, carbonaceous with abundant plant remains. The contact is gradational to the underlying unit. Thickness variable. (0.105)................ 1.5

This is the bed with highest mineralization found in the area. Semi-quantitative spectrographic analyses values are reported in parts per million, except where noted otherwise, to the nearest number in the series 1, 1.5, 2, 3, 5, 7, etc.

Na	1%	Ag	<5	Co	<15	La	<150	Sb	<200	V	50
K	3%	B	<70	Cr	150	Mn	70	Sc	<20	W	<1000
Ca	3000	Ba	500	Cu	70	Mo	<15	Sr	70	Y	30
Mg	3000	Be	<7	Ga	20	Ni	15	Sn	<15	Zr	300
Fe	2%	Bi	<10	Pb	50	Nb	<200	Ti	3000	Zn	<500
										Pt-Pd	0.1
										Au	<0.02

Chemical Analysis U_3O_8		Scintillator Counter Reading (MR/HR)
Top	0.059%	0.105
Middle	0.036%	
Bottom	0.016%	

g. Sand, dark yellowish orange, muddy, very silty. Carbonaceous intercalations no thicker than 3 mm (0.110).................. 2.0

Sample 8: 0.0-73.3-26.6. Muddy sand, fine.

Semi-quantitative spectrographic analyses. Values are reported in parts per million, except where noted otherwise, to the nearest number in the series 1, 1.5, 2, 3, 5, 7, etc.

Na	1%	Ag	<5	Co	<15	La	<150	Sb	<200	V	50
K	2%	B	<70	Cr	100	Mn	70	Sc	<20	W	<1000
Ca	3000	Ba	500	Cu	30	Mo	<15	Sr	50	Y	<30
Mg	2000	Be	<7	Ga	15	Ni	15	Sn	<15	Zr	300
Fe	3%	Bi	<10	Pb	30	Nb	<200	Ti	2000	Zn	<500
										Pt-Pd	0.05
										Au	0.02

	Chemical Analysis U_3O_8%	Scintillator Counter Reading (MR/HR)
Top	0.016	0.110
1 foot below	0.024	

h. Sand, dusky yellow, medium to coarse, with a very thin layer of pebble to cobble gravel at the base (a few inches thick). The whole bed is channel filling, quite variable in thickness with wavy contacts due to cut and fill structures. (0.045).... 4.0

Sample 9: 4.2-86.2-9.6. Sand, medium to coarse.
Chemical Analysis U_3O_8 = 0.0007%

i. Sand, grayish green, medium grained at top, becoming finer downward and very rich in silt-clay content. (0.035)(0.047)(0.038) (0.050)....................................21.0

Sample 10 (top): 1.6-87.5-10.7. Sand, medium
Sample 12 (bottom): 0.0-50.2-49.7. Muddy sand, fine.
Chemical Analysis (from top to bottom) U_3O_8 = 0.028% top, 0.0015, 0.005, <0.005, 0.0010, 0.005.

j. Sand, pale yellowish orange, fine, muddy, very thin gravelly sand with granitic pebbles at the base (0.070)(0.087).................... 3.5

Sample 13: 0.0-66.6-33.4. Muddy sand, fine.
Chemical Analysis U_3O_8 <0.0005%

k. Sand, light gray, coarse, gravelly, increasing in size downward. Conglomeratic sandstone with pyrite cemented at base in lens. (0.2 to 0.3 foot thick and 2 feet long). (0.085).................................... 9.5

Sample 14: 12.6-81.6-5.9. Gravelly sand, coarse.
Chemical Analysis: U_3O_8 = 0.0007; 0.0025

TOTAL THICKNESS..........68.5 feet

C. Stratigraphic Section #1

Thickness (feet)

TOP

a. Gravel, sandy, locally very sandy. Sizes of coarser particles vary from more than 1 inch to 14 inches. Their composition is mainly quartzite with percussion marks, granite, and light green shale pebbles. At the very base, lithology changes to a gravelly sand............................ 16.75

Sample 1 (bottom): 16.7-74.6-8.7 Gravelly sand, coarse

b. Sand, pale yellowish orange, coarse at top and becoming gradually gravelly downward.... 5.25

Sample 2a (top): 0.3-90.2-9.5 Sand, coarse

Sample 2b (bottom): 13.6-81.8-4.6 Gravelly sand, coarse

c. Sand, pale yellowish orange, coarse to very coarse, gravelly, the largest particles are several inches in diameter. A few shale pebbles are present in this unit............ 12.95

Sample 3: 39.5-53.7-6.6 Gravelly sand, coarse to very coarse.

d. Clay, gray, orange and purple in parts, silty and locally sandy..................... 10.50

e. Sand, pale yellowish white, medium-grained..... 8.40

Sample 5: 0.7-93.4-5.9 Sand, medium-grained.

f. Sand, pale yellowish white, coarse to very coarse, gravelly and some gray clay intercalations................................. 18.1

Sample 6 (middle); 18.8-75.6-5.5 Gravelly sand, coarse to very coarse.

g. Sand, dark yellowish orange, coarse-grained, with gravel particles as large as 4 mm; more clayey and gravelly at the base. Iron oxide abundant........................ 15.71

Sample 7 (middle): 0.8-94.1-5.1 Sand, coarse grained.

h. Sand, medium grained, gravelly, clayey at top, and with frequent clay intercalations....... 13.65

Sample 8 (middle): 12.9-75.5-11.7 Gravelly sand, medium grained.

i. Clay-silt, yellowish brown, with sand content increasing downward where it becomes a sandy silt-clay material.................... 8.60

Sample 9 (bottom): 0.0-82.2-17.9 Muddy sand.

j. Clay-silt, yellowish brown, sandy, gravelly toward the base............................ 31.50

TOTAL THICKNESS...........141.41 feet

D. Stratigraphic Section #2

Thickness (feet)

TOP

a. Gravel, mainly pebbles and some cobbles of granite and quartzite, sandy, medium to poor roundness. The size decreases toward the base, where sample 1 was taken. (0.025)............................ 10.5

Sample 1 (bottom): 55.9-41.2-3.0 Sandy gravel, pebble size.

b. Sand, pale yellowish orange, fine at top, increasing in size downward. (0.020)....... 12.35

Sample 2 (middle): 3.5-90.9-5.7 Sand, medium, to very coarse.

c. Sand, pale yellowish orange, silty at top, increasing in size downward. (0.030)(0.033) 6.8

Sample 3: 3.0-89.7-7.2 Sand, medium to coarse.

d. Sand, pale yellowish orange, coarse to very coarse, gravelly. Granite particles abundant. (0.035).......................... 5.75

Sample 4: 15.6-80.4-3.9 Gravelly sand, coarse to very coarse.

e. Silt-clay, grayish pale green, with dark yellowish orange spots, sandy. At the base there are some light gray sandstone pebbles (0.035)(0.030)...................... 9.50

f. Sand, pale to dark yellowish orange, medium to coarse. (0.025)........................... 5.25

Sample 6: 1.3-84.3-14.4 Sand, medium to coarse.

g. Silt, pale to dark yellowish orange, sandy. At the base there are pebbles (1.5 feet) of a well-indurated sandstone. (0.030) (0.022)(0.023)............................. 11.50

h. Sand, medium to coarse; the grain size decreases toward the base. (0.020)(0.024).. 8.40

Sample 8: 0.8-90.5-8.7 Sand, medium to coarse.

i. Sand, yellowish orange, medium to coarse. (0.020).................................... 10.50

Sample 9: 2.9-84.2-12.8 Sand, medium to coarse.

j. Sand, medium to coarse. (0.022)............... 5.25
Sample 10: 2.5-90.6-6.9

TOTAL THICKNESS........... 85.80 feet

E. Stratigraphic Section #3

Thickness (feet)

TOP

a. Gravel, with some particles larger than 2 feet, mainly of granite and quartzite. (0.030).................................... 7.25

b. Sand, dark yellowish orange, medium to coarse. (0.030)........................... 3.25

Sample 1: 1.4-91.8-6.7 Sand, medium to coarse.

c. Clay, silty with sand intercalations (0.025)... 4.25

d. Sand, pale to dark yellowish orange, fine to medium. Some thin clay intercalations. (0.050)................................... 5.25

Sample 2: 0.1-85.5-14.5 Sand, fine to medium.

e. Clay, grayish green with dark yellowish orange spots, silty and locally sandy. At the base of this bed there are clastic particles of a whitish gray sandstone, well-indurated, similar to that found at the bottom of a sandy silt clay, at the 66.15 foot horizon in Stratigraphic Section #2. (0.033) (0.028)(0.027)............................. 34.35

f. Sand, gravelly and silty, some particles larger than 5 inches. (0.026).............. 3.25

g. Sand, medium to coarse, gravelly. (0.021)..... 21.0

Sample 5: 7.4-81.2-11.1 Gravelly sand, medium to coarse.

TOTAL THICKNESS........... 78.60 feet

F. Stratigraphic Section #4

Thickness (feet)

TOP

a. Gravel, mostly pebble size, sandy. (0.020).... 5.25

b. Sand, pale to dark yellowish orange, medium to coarse, decreasing in size toward the base. (0.020)(0.024)...................... 16.75

Sample 1: 0.3-93.8-6.0 Sand, medium to coarse

c. Clay, grayish white with dark yellowish orange spots, silty and locally sandy. (0.021)(0.025)................................ 20.0

d. Sand, pale yellowish orange, fine-medium grained at top with clay-silt intercalations. Downward the grain size increases becoming a gravelly sand, coarse to very coarse. (0.021)(0.030)(0.025)......................... 25.25

Sample 3 (top): 0.0-89.4-10.6 Sand, fine to medium.
Sample 4 (bottom): 24.8-72.4-2.8 Gravelly sand, coarse to very coarse

e. Clay. (0.025)(0.022)........................... 0.25

f. Sand, medium to coarse at top, becoming gravelly downward. (0.026).................. 5.25

Sample 5: 5.3-89.3-5.4 Gravelly sand, medium to coarse grained.

TOTAL THICKNESS........... 72.75 feet

G. Stratigraphic Section #5

Thickness (feet)

TOP

a. Gravel with particles larger than 1.5 feet, sandy, Poor roundness. (0.021).............. 14.75

b. Sand, pale to dark yellowish orange; gravelly sand decreasing in size downward. (0.029)... 8.80

Sample 1 (bottom): 1.3-89.9-8.7 Sand, medium to coarse.

c. Clay, light grayish green, silty and partly sandy. (0.032)............................. 2.95

d. Sand, dark yellowish orange, medium to coarse, with some clay intercalations. (0.029) (0.039).................................... 10.50

Sample 2: 3.7-85.4-10.7 Sand, medium to coarse.

e. Clay, grayish green, silty and locally sandy. (0.029)(0.024)............................. 10.50

f. Sand, dark yellowish orange, gravelly and muddy. (0.032)(0.030)...................... 5.25

Sample 3: 6.5-78.3-15.1 Gravelly, muddy sand.

g. Covered. (0.024)............................. 15.75

h. Sand, very dark yellowish orange, coarse. (0.049)(0.050)............................. 8.50

Sample 4: 4.0-90.7-5.3 Sand, coarse

i. Sand, dark yellowish orange, medium to coarse. (0.042)........................... 7.30

Sample 5: 0.0-88.8-11.2 Sand, medium to coarse.

j. Sand, dark yellowish orange, gravelly with abundant pebbles. (0.033).................. 1.00

k. Sand, dark yellowish orange, fine to medium grained. (0.050).......................... 10.50

Sample 6: 1.4-84.7-13.9 Sand, fine to medium.

TOTAL THICKNESS........... 95.80 feet

H. Stratigraphic Section #10

Thickness (feet)

TOP

a. Gravel, contains particles up to 2.5 feet in size, sandy, moderate middle to poor rounding. Downward it decreases in size to the underlying texture. (0.026)......... 12.50

b. Sand, pale yellowish orange, medium to very coarse, gravelly. (0.031).................. 6.25

Sample 1: 20.9-77.5-1.6 Gravelly sand, medium to very coarse.

c. Sand, dark yellowish orange; gravelly at top, decreasing in size downward. (0.050)(0.058). 11.95

Sample 2 (top): 2.5-91.0-6.4 Sand, medium to coarse.
Sample 3 (bottom): 0.8-92.7-6.5 Sand, medium to coarse.

d. Silt, pale yellowish orange, sandy. (0.055) (0.052)(0.050)............................. 6.70

e. Sand, pale to dark yellowish orange, medium to very coarse, gravelly. (0.046)(0.060)(0.054) (0.071).................................... 15.75

Sample 5: 13.9-82.4-3.8 Gravelly sand, medium to very coarse.

f. Clay-silt, pale to dark yellowish orange, sandy. (0.058)(0.042)...................... 7.75

TOTAL THICKNESS........... 60.90 feet

I. Stratigraphic Section #11

Thickness (feet)

TOP

a. Gravel, sandy; particles more than 2 feet in diameter with medium to poor roundness...... 26.25

b. Sand, dark yellowish orange, medium to very coarse, gravelly. The coarsest constituents mostly in the pebble size, with medium to poor roundness. (0.040)(0.048)............. 9.5

Sample 1: 7.5-83.7-8.8 Gravelly sand, medium to very coarse.

c. Sand, grayish white, medium to very coarse, gravelly. (0.059)......................... 5.25

Sample 2: 6.4-85.1-8.4 Gravelly sand, medium to very coarse.

d. Silt, pale yellowish orange, sandy. (0.060)... 1.5

e. Sand, medium to coarse. The grain size increases toward the base. (0.062)(0.067) (0.058)...................................... 13.15

Sample 4: 3.3-86.9-9.8 Sand, medium to coarse.

f. Silt, becoming clay downward, pale yellowish orange to brownish, sandy. (0.055)(0.042) (0.044)(0.047).............................. 13.50

TOTAL THICKNESS........... 69.15 feet

J. Stratigraphic Section #12

Thickness (feet)

TOP

a. Gravel, sandy, with some particles larger than 6 inches.............................. 1.0

b. Sand, pale yellowish orange, ranging from gravelly at the top to medium coarse sand at bottom. There is a 10 inch yellowish gray clay intercalation, 7.8 feet below the upper contact. (0.030)................ 21.85

Sample 1 (top): 14.1-77.0-8.7 Gravelly sand, medium to very coarse.
Sample 2 (middle): 2.1-88.2-9.7 Sand, coarse.
Sample 3 (bottom): 0.8-89.7-9.4 Sand, medium to coarse.

c. Clay, yellowish green with irregular-shaped zones of reddish violet and purple colors. (0.046).......................... 2.75

d. Sand, pale yellowish orange, medium to coarse, increasing in size toward the base. (0.029).................................. 1.95

Sample 5: 0.5-90.0-9.5 Sand, medium to coarse.

e. Clay, yellowish green with thin irregular intercalations of reddish purple clay. (0.041).................................... 3.75

f. Sand, coarse at top, increasing in silt content downward. (0.035)(0.039)(0.034) (0.033)...................................... 13.85

Sample 6 (top): 1.4-86.2-12.3 Sand, coarse.
Sample 7 (middle): 1.3-84.0-14.7 Muddy sand, medium grained.
Sample 8 (bottom): 4.9-78.2-16.9 Muddy sand, fine to medium grained.

TOTAL THICKNESS........... 45.15 feet

K. Stratigraphic Section #13

Thickness (feet)

TOP

a. Gravel, sandy with particles as large as 1 foot, mainly of quartzite and granitic rocks, some of them highly altered. (0.020).................................... 5.3

b. Sand, pale yellowish orange, fine-medium at top, to gravelly sand at base, where the gravelly particles range from 4 mm to 4 inches. (0.031)(0.030).................. 13.85

Sample 1 (top): 0.3-87.7-12.1 Sand, fine to medium.
Sample 2 (bottom): 17.0-72.6-10.5 Gravelly sand, coarse.

c. Sand, grayish white, gravelly, with 4 inch purple clay intercalation. The clay content increases downward. (0.032)................ 2.05

Sample 3 (middle): 29.3-58.0-12.7 Gravelly sand, coarse to very-coarse grained.

d. Sand, grayish white, coarse to very coarse, gravelly. (0.028)........................ 6.0

Sample 4 (middle): 17.3-71.7-10.9 Gravelly sand, coarse to very coarse-grained.

e. Clay-silt, light grayish green, sandy and gravelly with particles as large as 5 mm. (0.033).................................... 1.0

f. Sand, grayish white, muddy at top and gravelly and muddy toward the base. Brownish clay intercalations are common. (0.033)(0.034)............................. 21.0

Sample 6 (top): 2.0-81.2-16.8 Muddy sand.
Sample 7 (bottom): 5.4-76.9-17.8 Gravelly muddy sand

TOTAL THICKNESS........... 49.20 feet

L. Stratigraphic Sections (Trenches) - Summary

1. General Lithology

The lithology is mainly sand, gravelly sand with some clay lenses, and clay beds and lenses. The color of the gravelly sand and sand is pale to dark yellowish orange and the clay is bluish green.

Both the sand and gravelly sand are arkosic in composition.

Almost every section is capped by a sandy gravel which corresponds to one of the several terrace deposits, developed in the Poison Spider area. Its composition is mainly quartzite and granitic rocks, some of them showing percussion marks typical of a fluvial piedmont transportation. The larger particles reach 2 or 3 feet in size and usually are quartzitic in composition. The roundness is poor to medium and the matrix is sand to fine gravel.

The thickness of the terrace deposit is variable, from 1 foot in section 12 to 26 feet in section 11.

2. Sections 10-11 - Open Pit - 12-13-1 (Plate 1)

In sections 10 and 11 the highest scintillator readings are associated with a dark yellowish orange gravelly sand with a radiometeric reading ranging from 0.046 to 0.071 MR/HR, and a greenish sandy clay with readings ranging from 0.052 to 0.060 MR/HR.

In the open pit excavated during the early summer of 1968, high readings were recorded around a carbonaceous layer 1.5 feet thick, very rich in plant remains (see Plate 1). The highest reading, from 0.085 to 0.11 with a background of 0.032, was recorded immediately below this layer in a sandy silt, pale to dark yellowish orange in color, also with thin carbonaceous intercalations.

In sections 12 and 13, the scintillator readings are low.

3. Correlation

Sections 10 and 11 show good correlation and demonstrate how a clay bed pinches out toward the southeast. In the line of sections of the open pit, sections 12, 13 and 1, it is possible to see that the irregularities in thickness and disposition of the beds reflect its fluvial character with its channelling structures.

4. Sections 11-10-2-3-4-5 (Plate 2)

A study of the 6 stratigraphic sections, 11-10-2-3-4-5, indicates a general and gentle apparent dip (about 2°) of the beds approximately toward the northeast.

All the sections are capped by a sandy gravel which, in this particular line of sections, corresponds to the same terrace deposit. The base of this terrace also agrees with the general dip of the underlying beds. Its composition is the same as already described for sections 1, 12, and 13, i.e., quartzitic and granitic particles 2 or 3 feet long. The highest readings with the scintillometer were recorded in sections 11 and 10 associated with a dark yellowish orange gravelly sand, and a sandy clay (0.046 to 0.071 MR/HR). In sections 2, 3, and 4, both clayey and sandy sediments show low readings (0.020 to 0.035) but in section 5, a dark yellowish gravelly sand shows readings from 0.042 to 0.05 MR/HR.

The general lithology is mainly gravelly sand and sandy clay silt. The relative proportion of clay to sand in every section is not constant due to the variation in the thicknesses of the different layers. From the lithologic correlations established, it is possible to see how the main clay bed of the sections appears to pinch out toward the southwest and northeast, reaching its maximum thickness near sections 3 and 4. The general shape of this clay bed is that corresponding to a lense elongated in the northeast-southwest direction. The presence of clay lenses in the Poison Spider area is a fact demonstrated also in the cuttings from the drill holes.

Chapter V

DRILL HOLES ON NORTH FLANK OF RATTLESNAKE RANGE

500 Series Drill Holes

A. Rotary Cuttings

Data from 32 of the 500-numbered series of drill holes (Fig. 9) located in section 24, T. 32 N., R. 85 W. were used to define the general lithology of the shallow subsurface portion of the Wind River Formation in this area. The drill holes were spaced at 100 foot intervals to have a close control over the trends and compositional characters of the lithology and the uranium-bearing sediments. They were drilled and logged during the summer season of 1968. An upper coarse-grained unit and a lower fine-grained unit are recognized. The boundary, based on cuttings examined and the resistivity curves, was placed arbitrarily at an increase of the resistivity value, very definite and present on almost any resistivity log of the 500 series of drill holes. The upper coarse-grained unit is characterized by being mostly a gravelly sand, with thin clay intercalations. The grain size decreases downward.

The lower fine-grained unit is made of sand at the top with thicker and most frequent clay-silt intercalations. Close to the top usually was found, for every drill hole, a bluish green mud (silt and clay) about 10 feet thick. Some gravelly sands are found in the section but are finer grained and much thinner than in the upper unit. The grain size generally decreases downward. The depth to the boundary of these two units is quite variable due

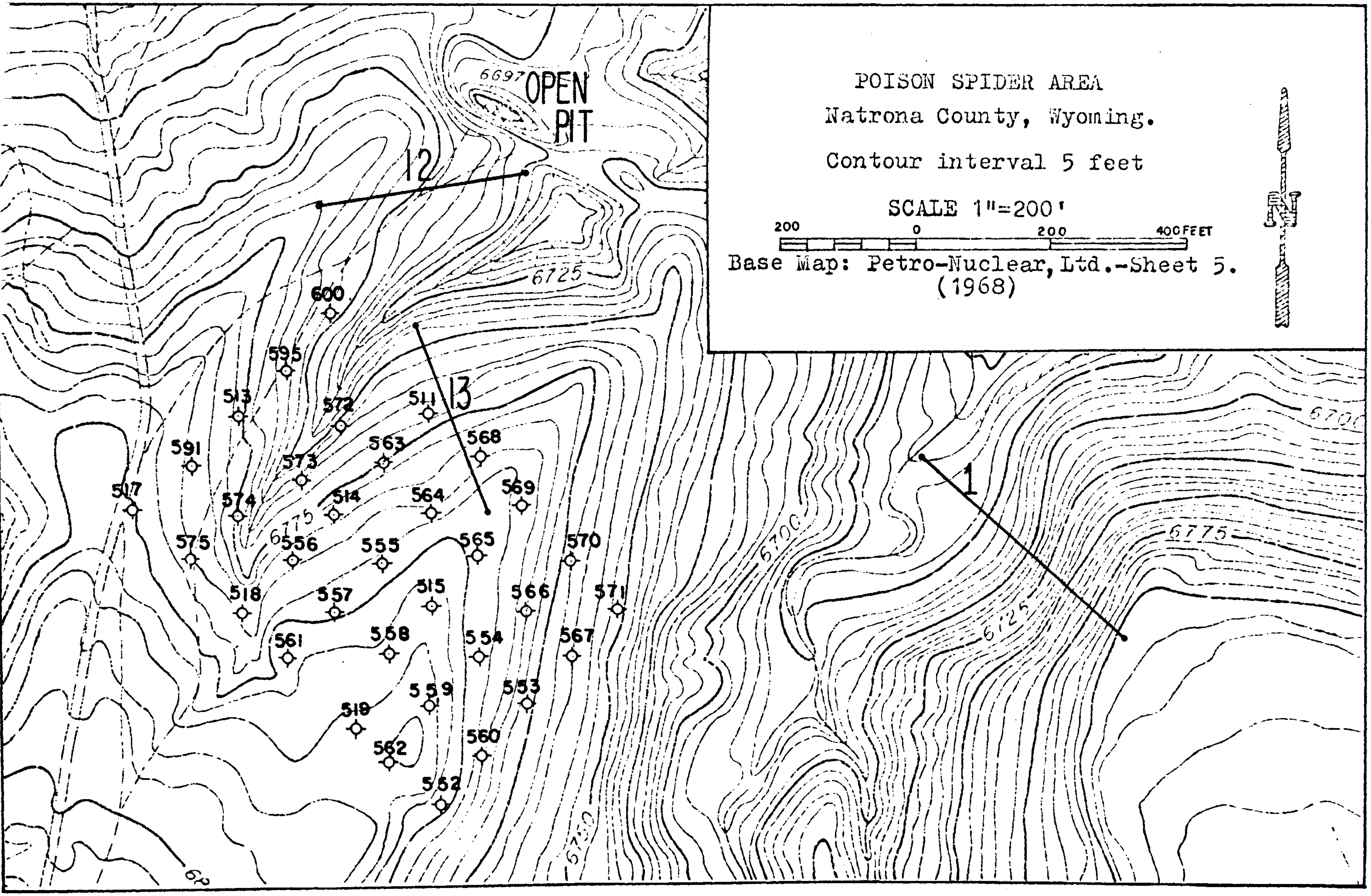


Figure 9. Index map showing the location of the 500 series of drill holes, the open pit, and the stratigraphic sections 1, 12, and 13.

to the different topographic elevations of the holes, but the boundary itself remains at an approximate absolute topographic interval of 6700-6725 feet above sea level (see Plates 3 and 4).

The sandy sediments in both the upper and lower units, are arkosic in composition.

B. Gamma Ray Logs

For each drill hole gamma ray and resistivity curves were logged. On Plates 3 and 4, ten lithologically correlative sections based on cutting observation and the corresponding gamma ray logs were drawn. Seven of these sections (A, B, C, D, E, F, G) have been made along the SW-NE direction (Plate 3), and three along the NW-SE direction (K, L. M, Plate 4).

Based on the gamma logs readings the highest mineralization always is found within the upper coarse lithologic unit at a topographic interval ranging from 6700 to 6750 feet a.s.l. for the different drill holes. The lower fine-grained unit also creates some radioactive peaks on the gamma logs, but they are very low in intensity and thickness, therefore the discussion will be focused on the upper lithologic unit.

The effect of radon gas on the gamma logs was checked in the area. Hole 554 was logged three times, and hole 555 was logged twice at approximately 24 hour intervals. No major disagreements were found for the values of the maximum radioactive peaks, therefore it is assumed that all the readings are not affected by the presence of radon gas.

Figure 10 shows the distribution of the mineralization in the 34 drill holes, and Figure 11 represents its average thickness. Besides, an interval map for the sediments overlying the maximum mineralized layer, is shown as Figure 12. It indicates that the uranium-bearing zone lies 60-70 feet deep along the ridge and 20 to 30 feet deep for the holes on the ravines.

The mineralized zone generally presents a maximum peak and secondary ones with quite variable values, and also the values of the maximum peaks for different holes have a wide range of fluctuation. Hole 555 was the one with the highest reading recorded (5720 counts per second), and the lowest value is found in hole 571 (475 counts per second).

Figure 10, as already mentioned, shows the distribution and intensity (counts per second)of the mineralization whose highest values seem to be located close to the topographic highs. Downslope the values diminish, with local exceptions. The thickness of the mineralized zone (Fig. 11), varies from 1.5, to a maximum of 12 feet in hole 573.

C. General Lithology

From the composite lithologic analysis of the 500-series of drill holes and the stratigraphic sections measured in the area, the following conclusions are obtained:

1. The lithology of the Wind River Formation in the area of Poison Spider is predominantly clastic, sandy in most of the cases (arkosic and muscovite-rich).

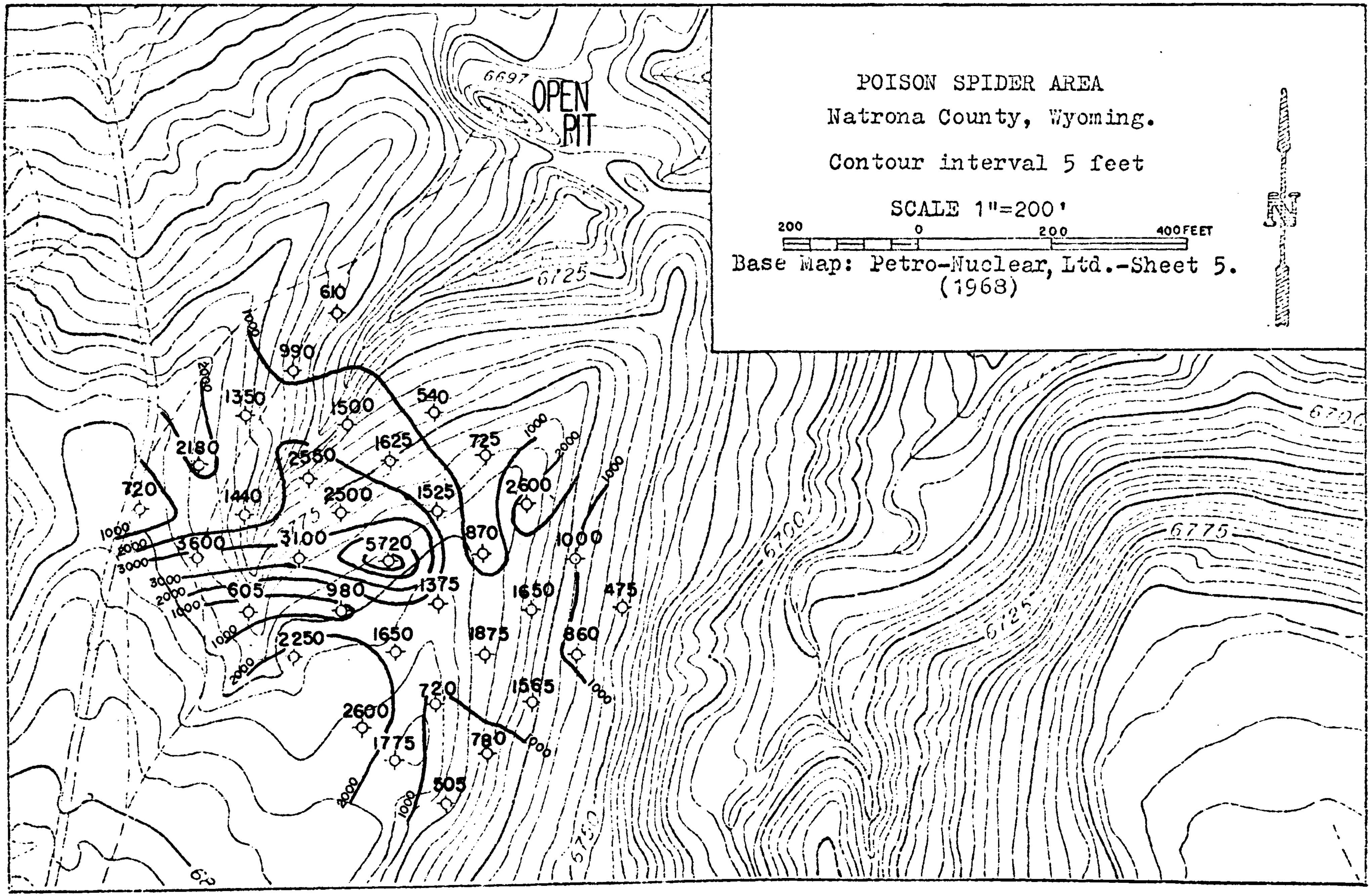


Figure 10. Map showing the distribution of the mineralization in counts per second. Data from the gamma ray logs. Contour interval: 1,000 c.p.s.

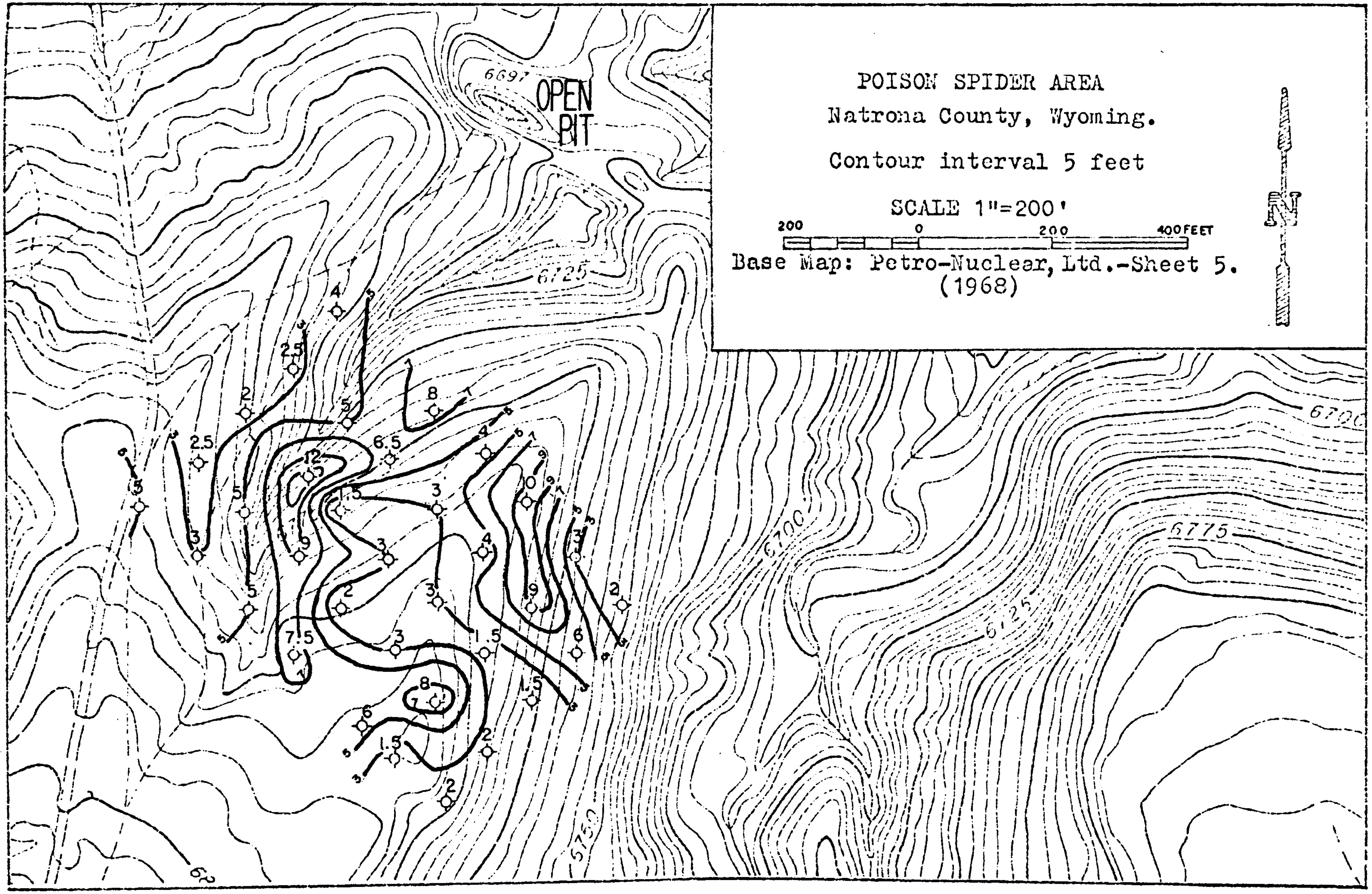


Figure 11. Isopach map of the mineralized zone. The thicknesses were obtained from the gamma ray logs as shown in Figure 18.

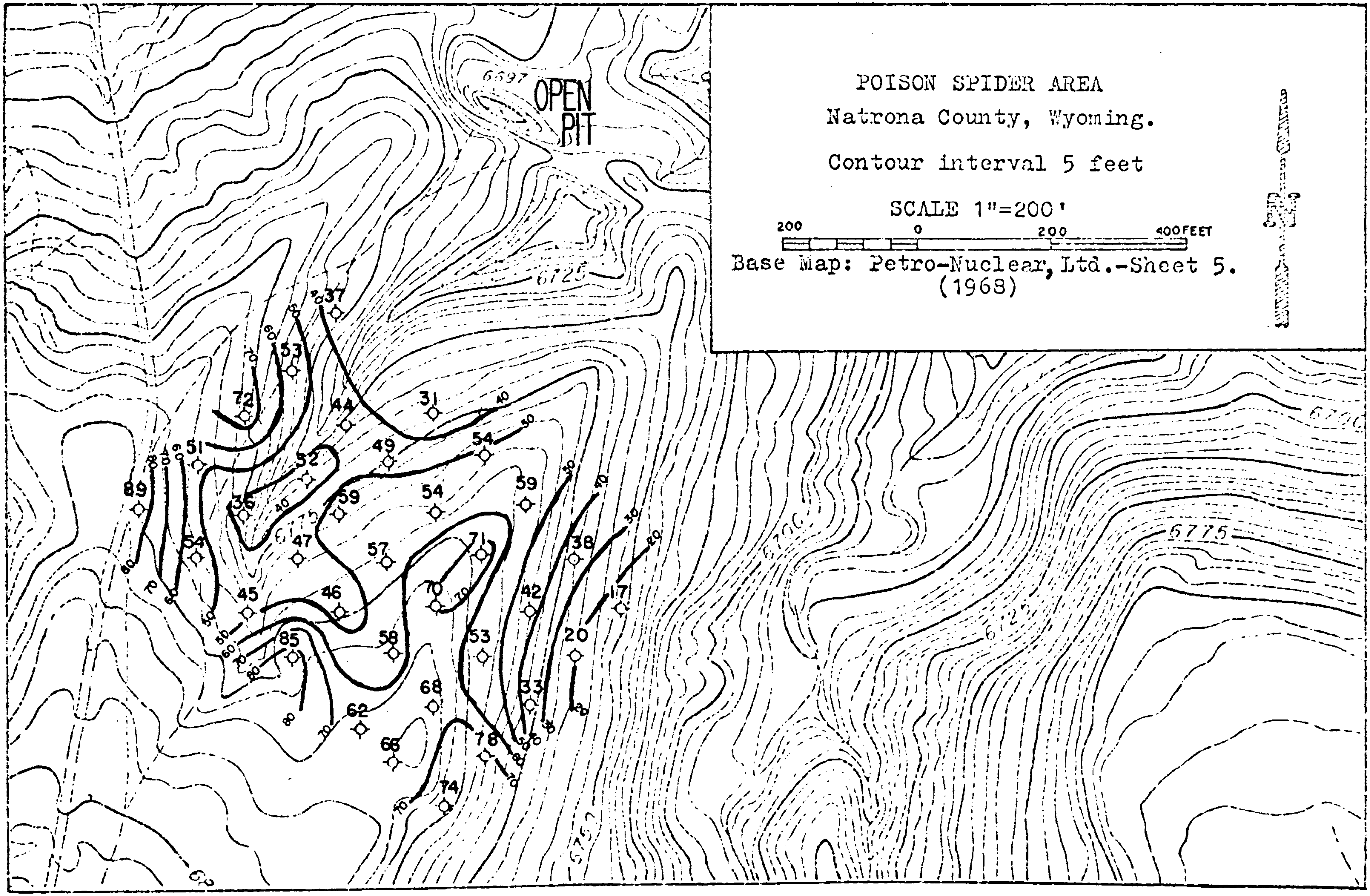


Figure 12. Interval map of the sediments overlying the mineralized zone (highest radioactive anomaly in the gamma ray logs). Contour interval: 10 feet.

2. The lithology is quite variable in both the vertical and horizontal directions, as is to be expected from fluvial sediments and associated channelled structures.
3. The grain size slightly decreases downward, but within most of the coarser sedimentary units, as a rule the size increases toward the base.
4. The upper part of the section is coarser grained and more gravelly than the lowermost, where the clay intercalations are frequent and thicker.

The open pit stratigraphic sequence was sampled and studied in the greatest detail. It was the only section where the uranium-bearing carbonaceous layer could be examined since the stratigraphic interval in which it occurs is equivalent to that with the highest radioactive anomalies in the 500-series of holes.

D. Characteristics of the Gamma-Ray - Resistivity Logs in the 500-Series of Holes

1. The boundary between the upper coarse and lower fine-grained lithologies for the drill holes, is placed in a local increase in the resistivity curve. Its elevation varies from 6700 to 6725 feet above sea level.

2. The elevation at which the highest radioactive anomaly (in the upper section) is found in the logs varies from hole to hole, but always in the 6700-6750 feet interval.

3. Almost for every hole drilled a bluish green mud (silt and clay), several feet thick, is the characteristic lithology of the upper part of the lower fine-grained unit.

E. Characteristics of the Open Pit Section and Correlation with the Cuttings

1. The highest radioactive anomaly for this section was found associated with a carbonaceous-rich mud layer, 1.5 to 2 feet thick, at an elevation of about 6725 feet above sea level. Comparing these data to that from the drill holes the stratigraphic equivalence between the radioactive anomalies in the logs and the carbonaceous layer in the open pit is obvious.

2. More than 2 feet below the lower boundary of the uranium-bearing carbonaceous mud, a pure clastic channel deposit more than 4 feet thick is found. Its lithologic character compared with the finer-grained adjacent beds will account for an increase in the resistivity curve. Based on this local resistivity increase on the logs, the boundary between the upper and lower lithologic units in the 500-series of drill holes was placed here.

3. More than 7 feet below the channel deposit mentioned above, a bluish green muddy sediment is present in the open pit section (see Chapter 4). This lithology was clearly identified in the cuttings and it characterizes the upper portion of the lower fine-grained unit in the drill holes.

Chapter VI

DRILL HOLES ON SOUTH FLANK OF RATTLESNAKE RANGE

400 Series Drill Holes

A. Lithology

Only 7 holes in the entire project were drilled south of the Rattlesnake Range; all were within the Petro-Nuclear, Ltd., Poison Spider Property. Two of them on the Wind River Formation (413 and 414), and the others (421 to 425) over outcropping White River Formation (Fig. 4). The holes are located in section 30 (413, 414), and section 31 (421 to 424), and section 32 (425).

A general lithologic description, based on cutting examination, is given for each above mentioned drill hole:

HOLE 413

	Thickness (feet)
WIND RIVER FORMATION TOP	
Sand to fine gravel, very pale yellowish orange, clayey. Some calcite grains and chips in the cuttings larger than 0.5 inches.................	40
Sand, fine to medium, clayey, with some iron oxide only in the upper 25 feet. Clay-silt bluish green intercalations are present........	100
Sand, fine to very coarse in the uppermost 35 feet then becoming a medium to very coarse gravelly sand...	70
TOTAL THICKNESS...........	210 feet

HOLE 414

	Thickness (feet)
WIND RIVER FORMATION TOP	
Sand to fine gravel, silty-clayey. Cutting show abundant chips up to 0.8 inches long.......	40
Sand, medium grained, silty-clayey. Locally at certain horizons, the character of the lithology is more clayey-silty than sandy. A general increase of silt-clay downward, bluish green in color. In the lowest 35 feet the sand becomes more abundant...........................	95
TOTAL THICKNESS...........	135 feet

HOLE 421

	Thickness (feet)
WHITE RIVER FORMATION - Lower member TOP	
Silt, light gray, sandy and very calcareous, increasing in clay content downward.............	45
----------------APPROXIMATE CONTACT----------------	
WIND RIVER FORMATION Sand, yellowish gray, coarse to gravelly, arkosic, partly calcareous. It contains fragments of quartz, feldspar, chert and granitic rocks up to 1 inch long. Clay, bluish green, occurs as intercalations from inches to more than 1 foot thick..................................	110
------------------FAULT CONTACT?------------------	
WHITE RIVER FORMATION(?) Silt-sand intercalations, very calcareous some gravelly with fragments of chert; very few dark igneous and metamorphic rocks toward the base. The average grain size decreases downward..	245
TOTAL THICKNESS..........	400 feet

HOLE 422

	Thickness (feet)
WHITE RIVER FORMATION - Lower member	
TOP	
Silt, light gray, some sandy	280
Sand, medium to very coarse, gravelly and silty. Locally chips reaching 0.7" long; chips generally dark green metamorphic rocks, dark igneous rocks, chert, etc. Abundant light gray silt-clay intercalations	120
TOTAL THICKNESS	400 feet

HOLE 423

	Thickness (feet)
WHITE RIVER FORMATION - Lower member	
TOP	
Silt, light gray, locally sandy	170
Gravel and gravelly sand at top with abundant chips more than 0.5" long, mainly of black and dark green metamorphic rocks, dark igneous rocks, and a few granitic rocks. Downward becomes a gravelly sand, silty, locally arkosic with few chips of granitic rocks, pale brown chert, and dark rocks. Silt intercalations become very abundant in lowermost 80 feet with a few thin clay beds	220
TOTAL THICKNESS	390 feet

HOLE 424

	Thickness (feet)
WHITE RIVER FORMATION - Upper member	
TOP	
Silt, light gray, locally sandy	60
Gravel, sandy matrix, intercalations of gravely sand and silt	215
WHITE RIVER FORMATION - Lower member	
Silt, light gray, sandy with fine gravelly intercalations	280
TOTAL THICKNESS	555 feet

HOLE 425

	Thickness (feet)
WHITE RIVER FORMATION - Upper member	
TOP	
Silt, light gray	40

Gravel, sandy silty matrix, abundant sand and silt intercalations	280
WHITE RIVER FORMATION - Lower member	
Silt, light gray, sandy	280
TOTAL THICKNESS	600 feet

Plate 5 is an attempt to reconstruct the structure of the area south of the Rattlesnake Range with a general correlation based on lithologic logs of the drill holes and their resistivity curves.

The faulting pattern of the area, their location and displacement shown in Plate 5, has been based entirely on Rich's work (1962), because the author of this thesis has been unable to recognize them in the thesis area.

According to Rich (1962) the faults are part of the North Granite Mountain Fault Zone. They are poorly exposed, and many of the faults can be detected only as linear features on aerial photographs. Also he records (p. 510),

> The fault planes dip northward at angles ranging from 60° to 85°.
>
> The displacement of the Oligocene and Miocene rocks along the North Granite Mountain Fault Zone is thought to be the result of Post-Miocene adjustment along a pre-existing fault zone. Geophysical data indicate that the displacement of the Wind River and older formations along the fault zone may be as much as 5,000 feet with the strata on the north side of the fault dropped relative to those on the south side. On the other hand, surface data indicate that the Post-Wind River strata along the fault zone are displaced about 175 feet and the strata on the south side of the fault are dropped relative to those of the north side. Thus the relative displacement of the Oligocene and Miocene rocks is in the reverse direction and of considerable less magnitude than that in the Wind River and older formations.

B. Correlation

Drill holes 413 and 414 are entirely in the uppermost part of the Wind River Formation, which shows an apparent dip of a few degrees toward the southeast. In adjacent areas to the west, south of the Rattlesnake Range, the Wind River Formation also shows along ravines an apparent dip of more than 10° toward the south (Fig. 6).

Drill hole 421 was placed on an outcrop of the White River Formation, close to the stratigraphic contact with the Wind River Formation. The uppermost part is represented by the typical light gray silt of the White River Formation. The top of the Wind River is encountered at a depth of 40-45 feet. At the 110-245 foot depth interval (lowermost unit of Drill hole 421 log) the sediments became more silty with light colors. They are thought to be possibly White River Formation sediments, which will be proved or not when future work will have a closer subsurface lithologic control in the area.

To explain the lithologic repetition of the White River Formation a high angle reverse fault dipping north was assumed on Plate 5, with the strata on the south side of the fault dropped relative to those on the north side (according to Rich, 1962). The fault affecting the drill hole 421 has been assumed on the following basis:

1. The lithology in the lowermost part of the unit in the 110-245 foot interval would seem to be similar to that of the White River Formation in the area.
2. On Rich's geologic map (1962) a high angle reverse fault is present very close and south of the geographic location of hole 421 (North Granite Mountain Fault).

The presence of the fault affecting the stratigraphic section of hole 421 is presented as a possibility in this thesis work, since the data available does not give enough evidences for a unique conclusion: The resistivity curve for the hole 421 does not present any discontinuity that can be accounted as a change from Wind River to White River downward (at the horizon where the fault is assumed to be present).

An attempt to recognize the formations by heavy mineral study was unsuccessful because of the poor quality and mixed character of the cuttings. Although some metamorphic, and dark colored igneous(?) rocks have been identified from the cuttings of the lowermost part of the drill hole 421 (similar to those found in the White River Formation in holes 422-423), they are not abundant enough to prove or not the presence of the White River lithology.

Holes 422 and 423 are entirely drilled in the lower member of the White River Formation. Both holes contain an upper silty section, which changes to a gravel to gravelly sand downward. The coarse-grained lithology is locally rich in dark green metamorphic and dark igneous rocks.

Holes 424 and 425 were drilled on the outcropping upper member of the White River Formation, reaching also the lower member.

The upper member in both holes is characterized by the basal sandy gravel already described. The lower member consists of sandy silt, light gray, with gravelly sand intercalations. The boundary of the lower-upper member of the White River Formation is marked by the sharp lithologic change and by the sudden variation of the resistivity curves.

C. Gamma Ray Logs - 400 Series of Drill Holes

Neither the Wind River nor the White River Formation show any mineralized zone according with the gamma ray logs of drill holes 413, 414, 421, 422, 423, 424, and 425. The maximum radioactive anomaly of the area, south of the Rattlesnake Range is in the Wind River Formation in Hole 413, with a maximum peak of 170 counts per second.

Within the White River Formation, the maximum anomaly recorded is of about 130 counts per second for holes 421 and 422. Due to the complete lack of mineralization in the area, no quantitative interpretation of the gamma ray logs was made.

Chapter VII

LABORATORY AND FIELD PROCEDURES

A. Collection of Samples

Seventy-seven samples, representatives of Wind River Formation were collected from 10 measured stratigraphic sections (Fig. 4, Plates 1 and 2) in section 24, T. 32 N., R. 85 W. Because the sandy units were considered better suited for comparison and interpretation, most of the samples were taken from sands or gravelly sands, but some finer grained units were also analyzed. Samples were collected from lithologic entities which are believed to make up a sedimentation unit. A sedimentation unit is considered, according to Otto (1938, p. 575), "That thickness of sediment which was deposited under essentially constant physical conditions".

B. Laboratory Work

After examination under a binocular microscope, 59 sandy samples were selected for mechanical and heavy mineral analysis. The following procedure was then used for the mechanical analysis:

1. Approximately 80 grams of most samples were disaggregated, and each sample accurately weighed.
2. The samples were sieved in a Tyler Ro-Tap Sieve Shaker for 10 minutes, through a set of Tyler screens with mesh openings of 16000, 8000, 4000, 2000, 1000, 500, 250, 125 and 62 microns.
3. Each amount retained on each sieve was weighed and also examined under a binocular microscope for determination of

the percent of aggregate grains present. The percent of these were excluded and the percent corrected weight on every screen was calculated.

4. Histograms and cumulative curves were drawn and analyzed according to the method employed by Passega (1952 and 1964) and Royse (1968). When plotting the histograms, the weight percent of the pan fraction was arbitrarily drawn within the 1/16 to 1/32 millimeter interval (only for plotting purposes).
5. The results of the mechanical analyses were tabulated and shown graphically in the Appendix, and Plates 1 and 2.

As the 59 samples analyzed have, without exception, more than 50 percent of sand-size material content (average 82 percent), the terms muddy and gravelly were arbitrarily defined for a better understanding of the lithology. A sand is considered muddy (silty-clayey) when the mud content is 15 percent or more. A sand is considered gravelly when the gravel content equals or exceeds 5 percent.

C. Objectives and Results

The objectives of the size analysis studies, particularly in this research work, can be summarized as follows: 1) Recognition of environment of deposition; 2) distinguishing stratigraphic units; and 3) better knowledge of the grain size distribution.

1. Environment

a. Evidence Based on Field Observation

The fluvial character of the Wind River Formation was determined by direct and indirect field and laboratory evidences, sedimentary structures, petrology, texture and associated lithologies. In the open pit, more than 70 feet deep, a well-exposed stratigraphic sequence can be observed (see Lithologic Description, Chapter 4). The medium to coarse sand, gravelly at base, of the sedimentary unit d of the pit (Plate 1), occurs in a channel-fill with a basal contact sharply disconformable and irregular. Unit f (Open Pit, Plate 1) is a carbonaceous-uranium rich sandy mud (silt and clay), where plant remains are highly abundant. The evidence that suggests that the Wind River Formation was deposited by a fluvial regime are:

1) Sudden lithologic variations, both in horizontal and vertical directions, which makes a detailed correlation work a very difficult task.
2) Mineralogically immature sediments (arkosic, muscovite-rich).
3) Fossil content low to absent.
4) Presence of silty clays and silts with abundant carbonaceous material, leaves, etc.
5) Poor to moderate sorting and roundness.
6) Lenticular clay bodies.

b. Evidence Based on CM Pattern - General Information

Another approach to the problem of environmental recognition, but in this case via size analysis, is the preparation of a CM pattern.

Passega (1957, 1964) believes that if sediments of an environment are represented in a diagram by plotting C, (an approximation of the maximum grain size) against M, (the median) the sample point pattern obtained is characteristic of the depositional agent. This resulting diagram is called a CM pattern.

According to Passega they are sharply defined and vary considerably with the type of depositional agent. Passega (1957, p. 1952) records,

> The parameters of a group of samples of a depositional environment, plotted on a graph, define sample points. As numerous examples will show, the distribution of these points is closely related to the depositional processes. Patterns formed by the sample points characterize by their shape and arrangement of points the principal depositional agents.

Two parameters of the grain size distribution of individual samples are particularly significant:

M, the median sample size

C, the one percentile grain size (the size such that one percent of the sample is coarser than this size).

Passega emphasizes that the coarse fraction of a sediment is more representative of the depositional agent than the fine fraction, which could be incorporated into the sediment after deposition, or transported independently of the coarser particles. For this reason a preference is given to representation of the coarse fraction, defining the parameter C as an approximation of the maximum grain size which would measure the ability of a stream to transport. The parameter M (median or average coarseness) is the only one defined by both, coarse and fine fractions, of the sediment.

According to Passega (1957, 1964) it is possible, with CM diagrams, to distinguish between two types of bottom tractive currents: those that roll particles, and those that support them in suspension near the bottom. (Rivers, marine currents, and wave touching bottom are tractive currents). A complete CM pattern for tractive current deposit was compiled by Passega (1964, Fig. 1) which is illustrated in this thesis as part of the Figure 13.

In the above-mentioned figure, the general pattern is divided into segments characterized by different slopes (Segments NO, OP, PQ, QR, and RS). Every one of these segments identifies a characteristic way of transportation for three key size particles, which are obtained graphically from the diagram (as C values) at the junction of the segments OP-PQ, PQ-QR, and QR-RS. The values of the parameter C defined by the junction of segments OP and PQ, PQ and QR, and QR and RS are called C_r, C_s, and C_u respectively. The possible ways of transportation of sediments in a stream are: uniform suspension, graded suspension, and rolling. Segments PQ, QR, and RS are characteristics of sediments transported by rolling, as a graded suspension, and as a uniform suspension respectively.

The value C_u, of C at point R, generally is the largest grain size transported as uniform suspension, the value of C_s, of C at point Q, corresponds to the largest size transported as a graded suspension. Passega notes (1964, p. 832), "The particles larger than C_s are found only in the bed of the river, never in suspension. These particles probably are transported by rolling." The value C_r of C for segment OP is suggested to be the optimum diameter for rolling (better than smaller or larger grains).

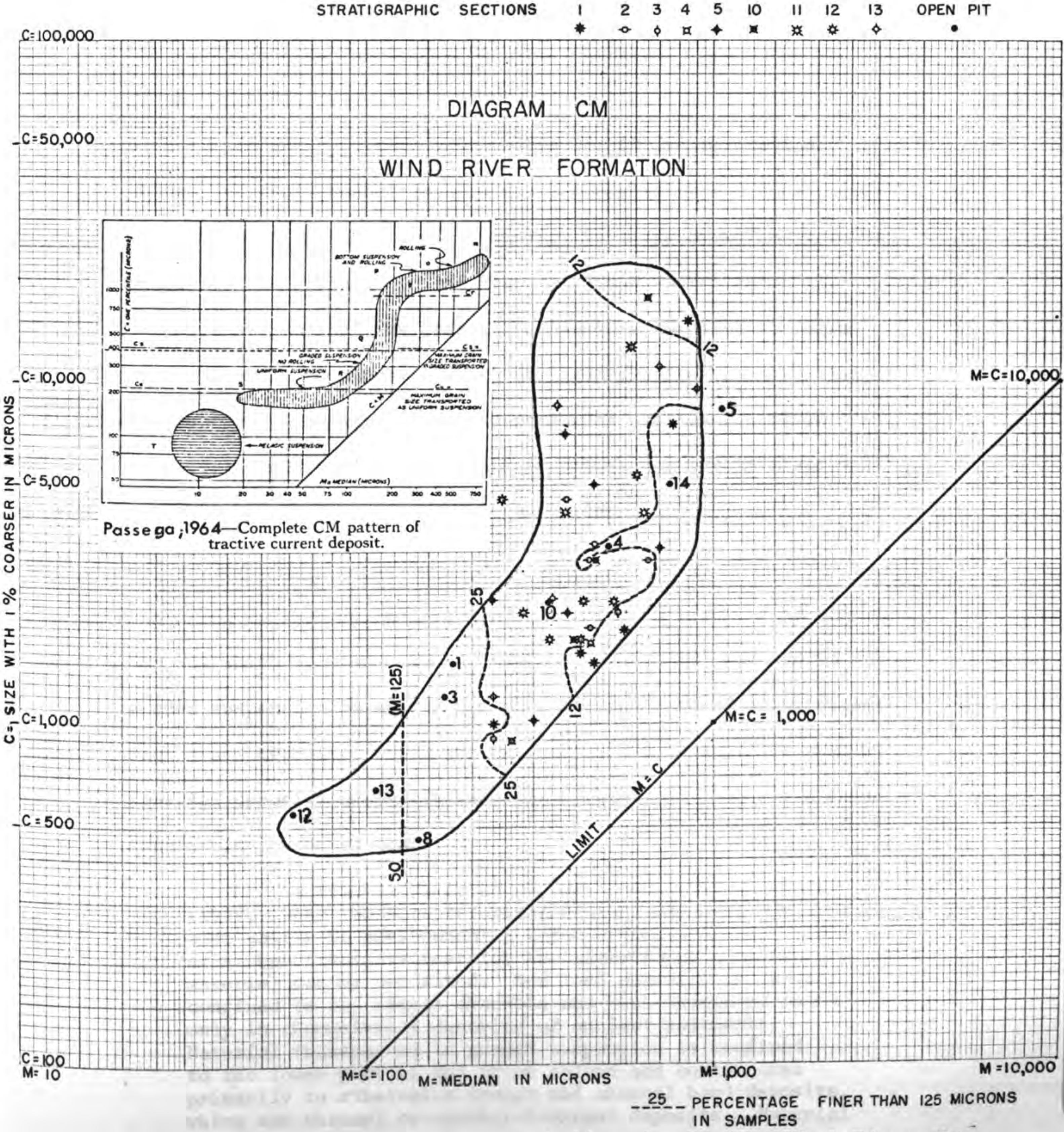


Figure 13. CM Pattern of the coarser sediments in the Wind River Fm. The Open Pit samples are identified by the field specimen number used elsewhere in the text.

A more recent and practical approach for the interpretation and genetic significance of the CM patterns was made by Royse (1968). His work concerns the Tongue River and Sentinel Formations (Paleocene of the High Plains), and is a general application of the CM diagrams with simple and important conclusions for CM interpretations. He points out that channel to back swamp deposits have a characteristic arrangement and shape, in CM patterns, by means of which it could be easily identified. Unlike Passega, Royse incorporates the so-called "Pelagic suspension" (by Passega, 1964) into the fluvial regime to represent some deposits which are identified with back swamp environment phenomena. Thus the composite pattern for river-transported sediments, as defined by Royse, for the CM diagram is:

Pelagic suspension
Uniform suspension
Graded suspension
Bed load

Samples which form the pelagic suspension, uniform suspension and graded suspension in the CM pattern, are interpreted to represent back swamp deposits, flood plain material, and channel or channel proximal deposits respectively. Royse (1968, p. 1174) as a final conclusion commented that:

> Of the several basic CM patterns defined by Passega (1957, 1964) those representing fluvial deposits yield most easily to environmental interpretation because modes of stream transport restrict the environment in which material can be deposited. Bed load material is largely confined to the stream channels and thus should be found only in channel-fill deposits of ancient sediments. Material transported in graded suspension is confined to the lower part of the water column and contributes primarily to substratum (point and channel bar) deposits, which are channel or channel-proximal deposits. Material

> in the upper part of the water column is uniform, both in maximum particle size and in total concentration. It is this material which is carried over the stream banks, onto the flood-plain, and into flood basins during periods of flood, resulting in vertical accretion or topstratum deposition.

According to Passega (1957), the CM pattern has to be plotted on logarithmic paper; the line determined by the values C=M is designated as the limit of the diagram, or limit C=M. To the left of limit C=M, the sample points can fall in any part of the diagram. Thirty samples at least have to be represented. Each sample should be a deposit of homogeneous sedimentation, and the 30 or more samples should represent all textures available. Passega advises that the diagram should show the percentage by weight of particles smaller than 125 microns (1/8 mm) which, according to that author, are the materials usually transported in suspension. Then such percentages boundaries (50, 25, and 12 percent) were drawn in Figure 13 to show the variations of this percentage for the Wind River Formation diagram.

c. Wind River Formation - CM Diagram

Forty-nine clastic samples of sedimentary units from 10 stratigraphic sections of the Wind River Formation were compiled to construct a CM pattern, shown as Figure 13. Clay and fine silt samples were not represented on the diagram. The degree of dispersion of the plotted data could reflect fluctuations in transport competency, shifting of the main stream locations, etc., resulting in a vertical sequence of different fluvial environments. The agreement found between the type of sediments (coarse clastic) plotted on the CM diagram and their supposed interpretation is very interesting.

As mentioned before, only the coarser lithology of the Wind River Formation was sieved and plotted. The average sample is a sand with the modal class in the 1.0 to 0.5 millimeters interval, some gravelly. The gravel concentrations are common, and there is a general increase in grain size downward within the same sedimentation unit. In Figure 13 both the Wind River Formation CM pattern and the complete CM pattern of tractive current deposits (Passega, 1964, p. 831) are shown. By visual comparison it can be established that the Wind River Formation diagram corresponds to the section PQR of the complete diagram. The pattern of the sample points for the Wind River Formation is almost in a perfect agreement with the portion PQR of the general diagram.

The field observation of channel-filling materials (units d and h, Plate 1) and associated deposits in the open pit, gives sufficient support to consider most of them of channel and channel proximal origin. Therefore, the fluvial regime and the fluvial environments (channel and channel proximal) of the coarser fractions of the Wind River Formation are clearly defined in the CM diagram. The 49 samples plotted delineate mainly the graded suspension pattern and the area where particles start rolling, or, in other words, they represent channel proximal and channel deposits respectively. Only three samples would be included in the uniform suspension pattern, being interpreted as flood plain material. Therefore, the points Q and R can be located, and the C values, C_u and C_s, obtained graphically from the diagram. As the 49 samples represented do not include the plots of fine sediments of the Wind River Formation the CM diagram obtained is incomplete due to the fact that this finest facies was not analyzed.

Nineteen out of 49 samples form the pattern interpreted as channel deposits (where the method of transportation for the sizes above C_s is rolling); 27 of the samples form the graded suspension pattern interpreted as channel proximal deposits (where C_s is the maximum grain size to be transported as graded suspension); and 3 samples fall in the uniform suspension pattern, interpreted as flood plain (top stratum) material. A more detailed examination of the CM pattern for the open pit samples is warranted because the lithologic specimens could be collected without contamination and also all three kinds of fluvial deposits mentioned above are known to be represented here.

d. Open Pit - CM Pattern

A detailed lithologic description of the open pit can be obtained from the description of the stratigraphic sections in Chapter IV. Samples 1, 3, 4, 5, 8, 10, 12, 13 and 14 from the open pit (Plate 1) are represented on the CM diagram.

Channel Deposits: Samples 4, 5 and 14, according to the CM diagram interpretation, are considered to be channel deposits. Samples 4 (top) and 5 (bottom) of unit d were taken from a channel deposit. It is a yellowish gray sand, medium-coarse at the top to well rounded coarse gravelly sand and sandy gravel at the very base (larger particles 6 inches long). Both samples are unimodal.

Sample 14 of unit k is a coarse gravelly sand, coarse sand, and some gravel (Gr. 12.6%; Sd. 81.6%; Silt-Clay 5.9%). The grain size increases downward.

Transportation by rolling had played an important role for this deposit, at least for the coarsest particles. A very rough estimation of the minimum current velocity that was required for the streams to transport the coarser fractions of the sediments analysed (Wind River Formation), could be made by consulting Hjulstrom's graph (1939, p. 10).

As the largest grain sizes for the sediments studied are within the 16-32 mm interval, the required velocity to transport that size would range from 100 to 140 cm/sec.

Channel Proximal Deposits: Samples 1, 3 and 10, according to the interpretation of the CM diagram, are considered to be channel proximal deposits. To be noted here is the increase in silt-clay material with an almost negligible gravel content. Sample 1 of unit a (Gr. 0.4%; Sd. 81.1%; Mud 18.5%) is defined as a muddy sand, fine grained, with discontinuous thin intercalation of a dusky red clay, rich in calcium carbonate.

Sample 3 of unit c (Gr. 0.2%; Sd. 78.8%, Mud 21.0%) is a fine muddy sand, with some quartz particles up to 4 mm across.

Sample 10 of unit i (Gr. 1.6%; Sd. 87.5%; Mud 10.7%), is a medium grained sand. It represents the top sample of a sedimentary unit where the size decreases downward. It can be noticed that these sediments are fine grained sands with an appreciable clay-silt content. The very coarse sand and gravel material, although present in minor amounts, are very significant to define in which of the fluvial environments the samples were deposited. These sediments seem to belong to an environment out of but proximal to the main channel current, where the velocity is slower and subjected to changes due to local phenomena. These fluctuations are responsible for the deposition of extreme grain sizes (mud and gravel) in the same sedimentary unit. As a final conclusion, these three samples (1, 3, and 10) are interpreted as channel proximal deposits, which were transported as a graded suspension.

Flood Plain Deposits: Samples 8, 12 and 13, according to the CM diagram, are considered to be flood plain deposits. In these samples the high content of silt-clay material is significant, ranging from 26.6 to 49.7 percent. No gravel is present in either of the three lithologies.

They are fine grained sands with a large percentage of very fine grained sand and mud. Sample 8 of unit g (Gr. 0.0%; Sd. 73.3%; Mud 26.6%) is a fine to very fine sand, muddy with carbonaceous intercalations (rich in plant remains) no thicker than 3 millimeters.

Sample 12 of unit i (Gr. 0.0%; Sd. 50.2%; Mud 49.7%) is a very muddy fine sand, pyrite rich. It is the bottom sample of a sedimentary unit where the grain size decreases downward.

Sample 13 of unit j (Gr. 0.0%; Sd. 66.6%; Mud 33.4%) is a fine to very fine sand, muddy.

For the three samples described above, what is very significant for the interpretation of their environment of deposition, is the complete absence of gravel, the negligible amount of coarse sand, the surprising abundance of mud material, the presence of carbonaceous intercalation (sample 8), and the abundance of pyrite (sample 12).

All these characteristics are in complete correspondence with the position of these three samples on the CM diagram: flood plain deposits which were transported as a uniform suspension. The three sample median are very close to, or smaller than 125 microns which is the minimum grain size usually transported in suspension (Passega, 1957). The presence of authigenic pyrite seems to indicate swampy conditions prevailing in the environment of deposition.

2. Distinguishing Stratigraphic Units

The second objective of the size analysis study was to differentiate and characterize the samples stratigraphic units. Most of the samples analyzed for the Wind River Formation are sandy-rich with variable amounts of fine gravel and mud (silt + clay). The average figures for the above mentioned samples are: gravel about 6 percent, sand 82 percent, and mud 12 percent. The samples have a range, in gravel content from 0.0 to 39.5 percent; sand from 50.2 to 94.1 percent; and mud from 1.6 to 49.7 percent.

Only one sample from the uppermost part of the lower member of the White River Formation was selected for mechanical and pipette analyses due to the uniform lithology of the outcrops (Fig. 7). The upper member of the White River Formation was not studied in detail for this thesis, and only a general lithologic description is given. The mechanical and pipette analysis show that the outcropping lower member of the White River Formation is a sandy silt: 36.0 percent of sand, 63.6 percent of silt and 0.3 percent of clay. The reamining sample analyzed belongs to the fluvial terrace capping stratigraphic section 2 (sample unit S2-1, Plate 2). It belongs to the lowermost and finer-grained part of the terrace deposit: 55.9 percent of gravel content, 41.2 percent of sand, and 3.0 percent of mud (silt + clay)(see Fig. 8).

3. Grain Size Distribution

The third and last objective of the size analysis study was the graphical representation of the size frequency distribution, the determination of vertical and horizontal trends of the median diameters in measured stratigraphic sections, and the plotting of the size constituents on triangular diagrams. From the above mentioned diagrams it was possible to infer the chief grain size constituents, approximate sorting and symmetry of the distribution for every sample, the average modal class and general character and abundance of the coarser and finer admixtures for the composite lithology.

a. Triangular Diagrams - Wind River Formation

The 59 samples of the Wind River Formation were plotted on two ternary gravel-sand-mud diagrams (Figs. 15 and 16). Most of

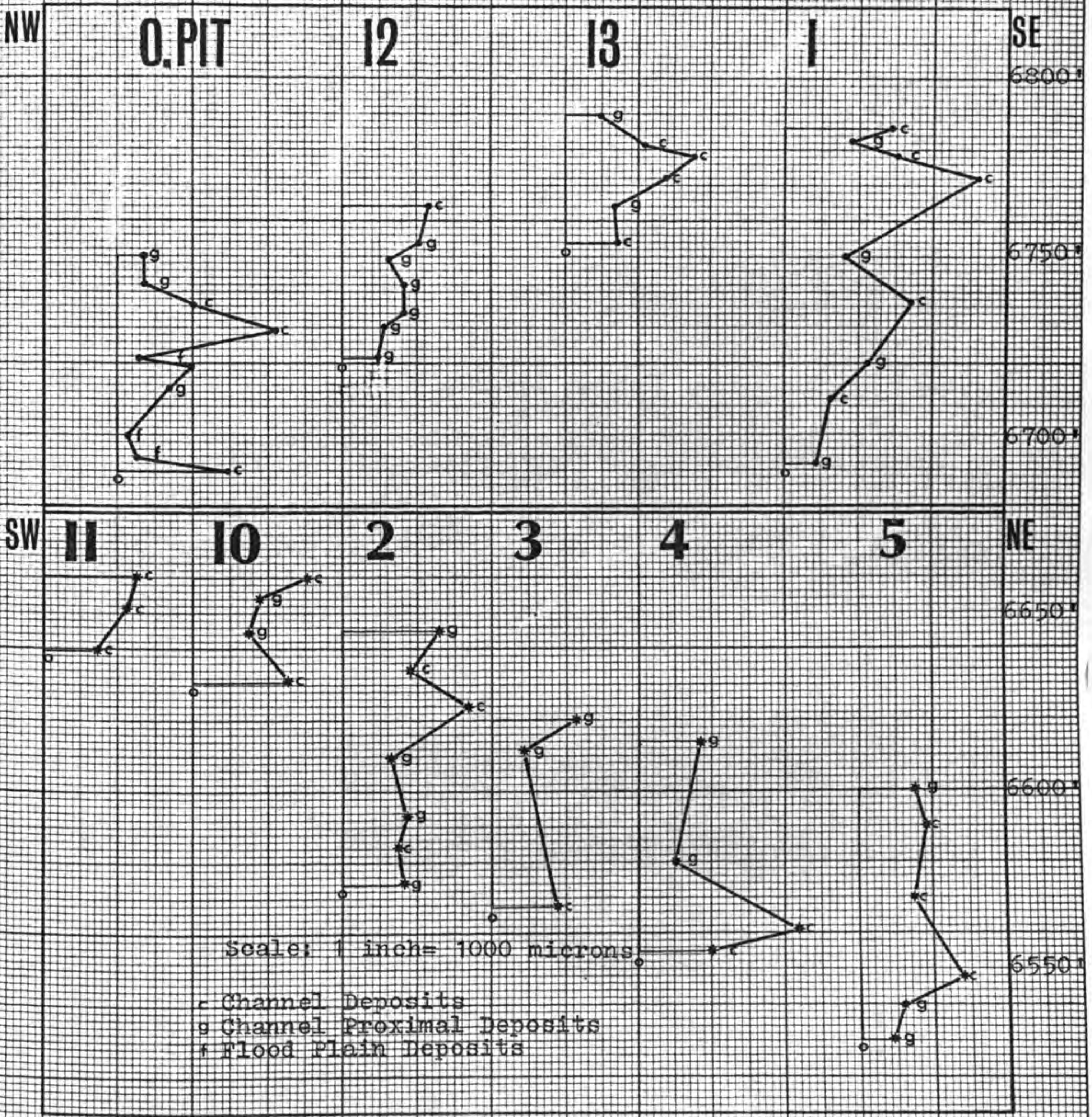
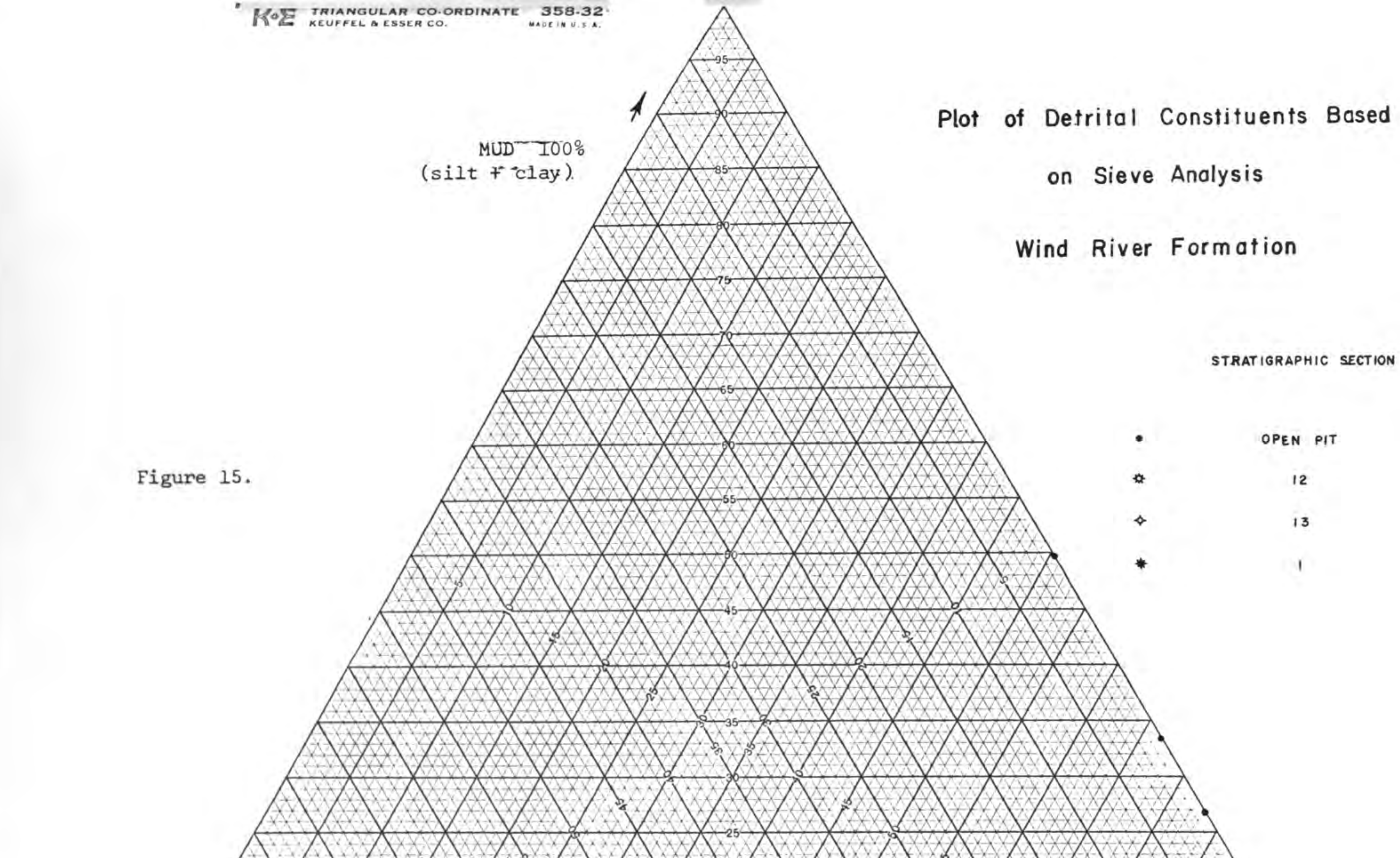


Figure 14. Graphs showing "trends" of the median diameter for the sandy sedimentary units in the stratigraphic sections of the Wind River Formation. The values plotted were taken from the cumulative curves. For each point is indicated the type of fluvial deposit to which it belongs, as determined from the CM diagram.

Figure 15.



Plot of Detrital Constituents Based on Sieve Analysis

Wind River Formation

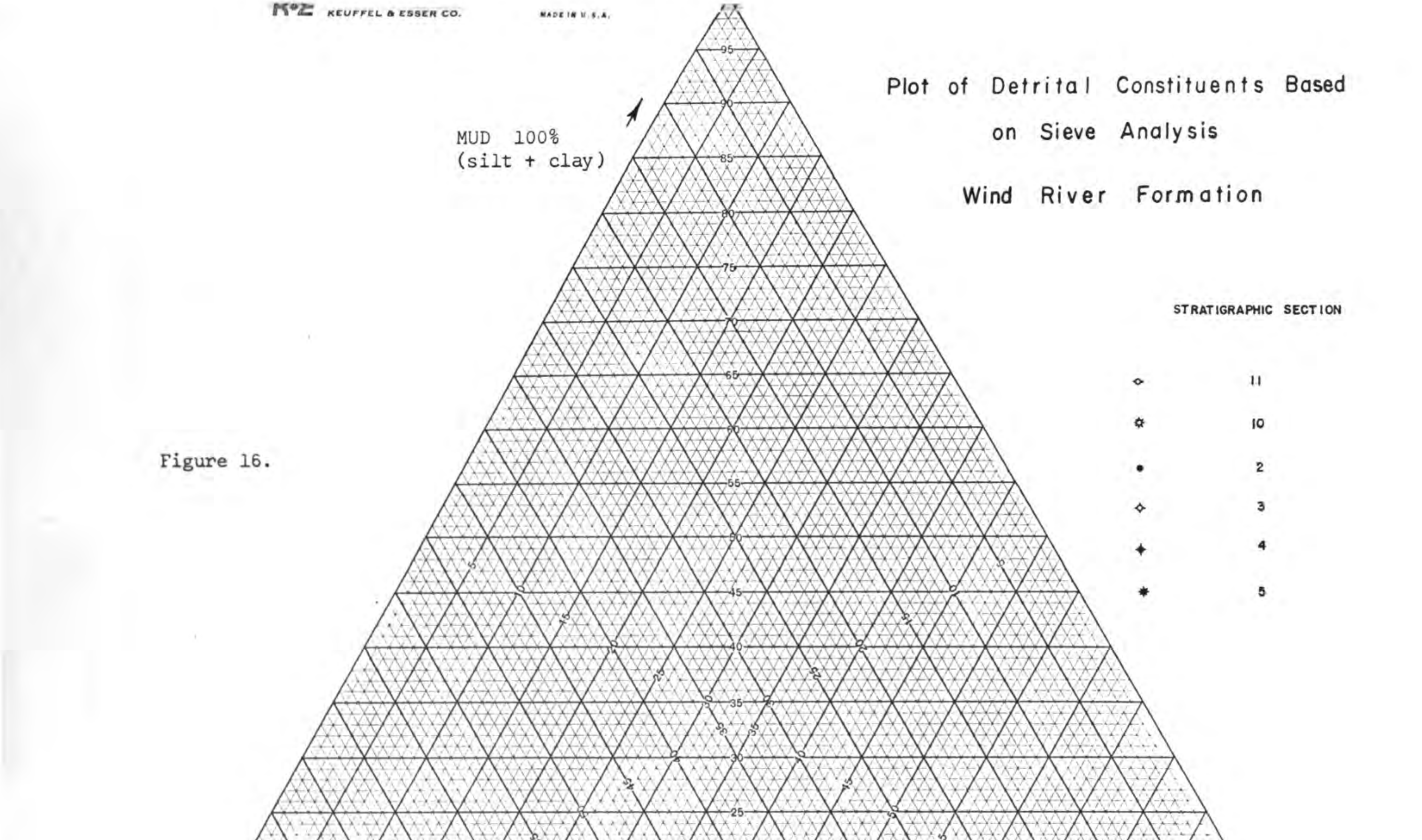
STRATIGRAPHIC SECTION

● OPEN PIT
✡ 12
✧ 13
✱ 1

Plot of Detrital Constituents Based on Sieve Analysis

Wind River Formation

Figure 16.



the samples are sand-rich, with an average textural composition of 6 percent of gravel, 82 percent of sand, and 12 percent of mud. The gravel content, for different samples, varies from 0.0 to 39.5 percent, the sand from 50.2 to 94.1 percent, and the mud from 1.6 to 49.7 percent.

Thirty out of 59 samples, according to the diagrams have a textural composition ranging from 0.0 to 10 percent for gravel material, 70 to 90 percent for sand material, and 10 to 30 percent of muddy sediments. The remaining samples contain considerably more gravel or mud material.

b. Histograms - Wind River Formation

For each sample with sieve analysis prepared a corresponding histogram and cumulative curve was drawn (see the Appendix).

Generally, the sediments are moderately well-sorted with the modal class in the 0.5 to 1.0 mm interval. The maximum range found in the analyzed sediments is the 32 millimeters to clay interval. Almost all the samples are unimodal, coarse- to medium-grained sand.

c. Median Diameter - Wind River Formation

For each sample, the median diameter (from the cumulative curve) was plotted to note whether there are any vertical trends in a measured section. Figure 14 is the graph drawn for all the stratigraphic sections, and illustrates the procedure. The abscissa represents median diameter, increasing in size grade from left to right (scale 1 inch = 1000 microns). The ordinate represents the mechanically analyzed samples in a section, plotted at the stratigraphic level where they were taken.

The graph shows that the median grain size of the sediments lies within the sand grade (61 to 1300 microns), medium- to coarse-grained on the average; the graphs also show, although there are some sudden increases, a general decrease of the median size downward. The variability of grain size is suggested in the same figure in which the mean diameter varies between very fine and very coarse grades. In Figure 14 there is also indicated, to the right of every median diameter, the fluvial environment of deposition as determined from the CM pattern.

As was expected, the sudden increases in the median diameter correspond to the coarsest channel deposits, the intermediate values correspond to the channel proximal deposits and the minimum values to the flood plain sediments. As shown, no lateral trends are readily apparent, therefore any value for correlation (based on median diameter size) does not appear obvious. Further statistical treatment may show otherwise.

D. Heavy Minerals - Wind River Formation

The following procedure was used to prepare the heavy minerals for study:

1. A 20 gram representative portion of the sample was obtained with a micro-splitter.
2. The isolated representative sample was separated in bromoform (d=2.87) in a specially constructed Fraser-like

tube as outlined by Krumbein and Pettijohn (1966, p. 339) to obtain the heavy minerals.

3. Both heavy and light minerals were mounted on slides and examined for roundness, sphericity, and general mineral content.
4. The heavy minerals from the 59 selected representative samples were examined only in a qualitative way, and approximate percentages of the mineral types were obtained by using a graphic comparison chart for visual percentage estimation (Folk, 1951).

5. The results of the heavy mineral examination are shown in Figure 17, together with the heavy mineral analysis for the White River Formation (lower member) and a terrace deposit.

All the heavy mineral slides from the Wind River Formation show an almost constant heavy mineral suite, with no appreciable vertical or horizontal mineralogical variations. An average abundance of diagnostic heavy mineral for the Eocene Wind River Formation in the thesis area is as follows,

Opaque Minerals (25 percent): Magnetite, Ilmenite, and minor amounts of leucoxene.

Non-Opaque Minerals are mainly represented by garnet (30 percent), epidote (25 percent), hornblende with variable occurrence (from zero to a maximum of 20 percent), and a group of heavy minerals (about 10 percent) including zircon, sillimanite, rutile, monazite, etc.

The blue green variety is the most abundant kind of hornblende present in the slides. Very few grains of red brown hornblende were present.

	Wind River Fm. 59 Samples	White River Fm. 2 Samples	Gravel Deposits 1 Sample
Hornblende (Blue Green)	C to R	A	C
Hornblende (Greenish Brown)	R	C	C
Hornblende (Reddish Brown)	R	C	C
Augite		R	C
Hypersthene		R	R
Garnet	C	R	C
Epidote	C		
Zircon	R	R	R
Sillimanite	VR	R	
Rutile	VR	VR	
Monazite	VR		
Apatite			VR
Andalusite			R
Magnetite	C	R	R
Ilmenite	C	R	R
Leucoxene	R	VR	

Explanation

VA	Very abundant	>60%
A	Abundant	41-60%
C	Common	6-40%
R	Rare	1-5%
VR	Very rare	<1%

Figure 17. Distribution of heavy minerals in the Wind River Formation, White River Formation, and terrace gravel deposits.

The only exceptions to this average heavy mineral content of the Wind River Formation were found in three slides (Open Pit, unit i - samples 10 and 12, and unit k - sample 14). In these samples authigenic pyrite represents 60 to 90 percent of the heavy mineral content. The remaining heavy minerals are the same as described for the average mineralogical composition. Magnetite and garnet were the two minerals with highest values of sphericity and roundness. Zircon ranges from subangular to rounded with an average low sphericity. The remaining minerals are very angular to subangular with low sphericity.

A striking characteristic of the heavy minerals of the Wind River Formation is the abundance and size of the garnet minerals. Generally, the garnet is well-rounded, highly spherical, colorless to pale orange and it is, generally, the mineral with the largest diameter.

E. Provenance

The wide range in size, the subangular character of the larger particles, the arkosic composition locally muscovite-rich, the presence of heavy minerals from granitic sources are compatible with the conclusion, already mentioned by Rich (1962), that the coarse-grained facies of the Wind River Formation was derived mainly from a granitic area. The Granite Mountains, about 10 miles south of the mapped area is considered as the most probable source area.

Chapter VIII

STRUCTURE IN THE THESIS AREA

A. Folding and Faulting

By determining the dip between correlative beds in the measured stratigraphic sections (Plate 2) in section 24, T. 32 N., R. 85 W., the Wind River Formation has been found to have a gentle apparent dip of about 2° northward. South of the crest of the Rattlesnake Range the Wind River Formation dips more than 10 to 15 degrees toward the south. According to this field evidence, the surficial formations of the Rattlesnake Range form a broad asymmetric anticline structure with a very gentle dip toward the north, and with the steeper flank toward the south. This anticlinal structure, seems to have had a close control over the final concentration and preservation of the mineralization in the whole Poison Spider area. Field evidence gathered by and available to the writer did not substantiate the occurrence of faulting in the area. Nevertheless, Rich (1962) in his map showed several faults, delineated as both inferred and concealed, crossing sections 31 and 32, T. 32 N., R. 84 W. of the thesis area. These faults are considered to be a part of the north Granite Mountains Fault Zone, and according to Rich (1962) they are poorly exposed in the thesis area and only can be detected as linear features on aerial photographs. They are high angle faults dipping northward with the strata on the south side of the fault dropped relative to those on the north side. Moreover, Denson (1968, written communication) visualizes the Wind

River and White River Formations, within and in the vicinity of the thesis area, as being broken by high-angle west-trending gravity faults with major displacement down on the south. The exact date of the faulting is not known, but inasmuch as rocks of Pliocene age are displaced by faults similar to the North Granite Mountains Fault in adjacent areas, it is assumed that the major movements on the faults in the vicinity and in the thesis area are post-Pliocene in age.

B. Geomorphology

The most interesting and unique geomorphological feature of the area north of the Rattlesnake Range is the northeastern trend of ridges and streams. As there is neither lithologic nor structural control in that direction, it is assumed that the original paleo-slope after the formation of the Rattlesnake anticline was toward the northeast. The different levels, at least three, of gravel deposits capping most of the ridges north of the Rattlesnake Range, are interpreted as piedmont terraces and terrace deposits.

C. Geologic History

Marine conditions prevailed for most part of Paleozoic and Mesozoic times in the area, although interrupted by intervals of erosion. Near the end of the late Cretaceous time, the epicontinental sea withdrew from the area, and the Tertiary basins of Wyoming began to form as a result of the Laramide Orogeny. One of the initial pulsations of this orogeny is reflected by the angular unconformity between upper Cretaceous sediments and the Paleocene Fort Union Formation.

By the beginning of Eocene time the Wind River Basin, as we know it now, was well delineated. The Late Paleocene or the earliest Eocene time was marked by a powerful deformation affecting most of the area. The unconformity at the base of the early Eocene Wind River Formation is clear evidence of this crustal deformation. The mountain blocks rose while the basin subsided. Whereas over most of the Wind River Basin the Wind River Formation consists mainly of variegated to drab claystone and siltstone with interbedded sandstones, in the thesis area it consists mainly of a coarse arkose sand. This localized lithology suggests that surrounding highlands were exposed to erosion which produced the sediments deposited in the basin area. Therefore, the Granite Mountains, 10 miles south of the thesis area, is considered to have been the source area of a northeastward trending large alluvial fan composed principally of arkosic sediment derived from these Precambrian rocks.

After the deposition of the Wind River Formation, volcanic activity was widespread. Centers were located in the Yellowstone Park-Absaroka area and along the Rattlesnake Hills Anticline. These rocks of middle and late Eocene age are not represented in the thesis area.

The major movement on the North Granite Mountain Fault Zone is believed to have taken place during middle and late Eocene times (Rich, 1962), with subsequent erosion. The beginning of

Oligocene deposition was the inauguration of a sedimentary cycle which continued into the late Tertiary times, which resulted in a nearly complete burial of all the mountain ranges in the area. For this reason Oligocene strata contains only a small amount of material derived from the Precambrian rocks.

Volcanic activity increased in the Yellowstone-Absoroka region, and a considerable amount of ash, possibly transported as pyroclastic material contributed a substantial part of the White River sediments. The increase in volcanic activity that began with Oligocene time is clearly reflected by the influx of heavy minerals of volcanic origin in the Oligocene formations. The White River Formation shows an abrupt increase in the amount of hornblende and the appearance of augite in comparison with the Eocene Wind River Formation.

Some time after the deposition of Miocene and Pliocene rocks the North Granite Mountains Fault Zone was reactivated resulting possibly in the southward tilting of the rocks south of the fault.

The exact date of the folding for the Rattlesnake Anticline cannot be determined in the thesis area, but inasmuch as the Wind River Formation participated in the structure the folding events are Post-Eocene in age. The area has been subjected, since upper Tertiary times, to prolonged erosion periods resulting in the present topographic relief.

Chapter IX

ECONOMIC GEOLOGY

A. Occurrence and Evaluation of the Radioactive Mineralization

Many of the Wind River sediments in the thesis area are radioactive, but only a minor amount of uranium mineralization was found. Radioactivity data were obtained by use of a portable scintillation counter, analyses in the laboratory of rocks and quantitative interpretation of gamma ray log. The highest radioactive anomalies of the area occur in the Wind River Formation in association with a carbonaceous siltstone in section 24, T. 32 N., R. 85 W. No significant radioactive anomaly was detected on the surface or in the subsurface of the White River Formation in the thesis area.

The radioactivity data obtained by use of a portable scintillation counter were already shown for the stratigraphic sections in Chapter 4 and on Plates 1 and 2. The highest radioactivity readings were found, in the open pit, associated with the carbonaceous sediments.

Chemical analysis of the same rocks have also been released, the highest values of U_3O_8 for the whole area ranging from 0.016 to 0.059 percent.

The gamma ray logs from the 500 series of drill holes provide additional information for the radioactive anomaly present in section 24, T. 32 N., R. 85 W. The five gamma ray logs with the highest radioactive anomaly in the area, were quantitatively analyzed to get the corrected grade percentage of U_3O_8 and the results are shown in the following paragraphs (see also Chapter 10).

Hole Number	Thickness of Mineralization feet	Corrected Grade Percent U_3O_8
519	6.0	0.02
555	1.6	0.08
556	9.2	0.03
569	11.4	0.02
575	2.0	0.05

The economic limit for the uranium mineralization is considered to be 0.05% U_3O_8 by Petro-Nuclear Limited. Therefore, as it can be seen from the chemical analysis and from the results of the gamma ray logs interpretation, the mineralization present in the area investigated has no economic value at present, due to its low grade character.

Chapter 10 is a summary of the U.S. Atomic Energy Commission quantitative method of interpretation of gamma ray logs. It was used in this text to calculate the grade percent of uranium of the holes above mentioned.

B. Occurrence of Uranium in the Earth's Crust

Before the subject of genesis of uranium deposits in the thesis area can be discussed, a few of the essential properties and characteristics of this element must be mentioned.

Uranium is distributed all over the earth's crust with minute amounts in nearly every kind of rock and natural waters. The estimated average concentration in the earth's crust as a whole is about 0.0003 percent, or about 3 grams per ton of rock; in sea water its concentration is about 1 gram per thousand tons (Nininger, 1955). Uranium occurs mainly as oxides, hydroxides, sulfates, phosphates, vanadates, carbonates, arsenates, and silicates. It is not known to occur as a native element, or as sulfosalts, arsenides, sulfides, or tellurides. Nearly all igneous rocks contain uranium in trace amounts. An average uranium content for major igneous rock types is given by Heinrich (1958, p. 166):

Rock Type	Uranium, ppm
Ultramafic	0.03
Gabbroic	0.94 - 0.96
Intermediate	1.4 - 3.0
Granitic	2.8 - 4.0

Autoradiographic studies and leaching experiments indicate, that uranium in igneous rocks is concentrated mainly in accessory minerals, in minute inclusions in minerals, and in some loosely-bound form, along fractures and grain boundaries. Substantial amounts of uranium are chemically so weakly attached that leaching of the disintegrated or pulverized rocks with dilute acid (either HCl or HNO_3) can dissolve significant fractions, as much as 40 percent of the original uranium content of the rock (Heinrich, 1958).

The acid-leachable fraction is derived mainly from interstitial material, from some accessory minerals, especially allanite, and sometimes from partly soluble accessories such as apatite. Uranium occurs in nature in the tetravalent and hexavalent state; and in unaltered igneous rocks it is present in the tetravalent state.

The U^{4+} ion is concentrated in late magmatic fractions and in accessory minerals largely because its relatively large ionic radius hinder the entrance into the structure of most common essential silicate minerals.

C. Geochemical Considerations

1. As mentioned before, uranium occurs in nature in the tetravalent and hexavalent state. Much of the uranium in the earth's crust, which is contained largely in igneous rocks, is in the tetravalent state. Under oxidizing conditions near the surface (zone of weathering), the tetravalent uranium generally is readily oxidized to the hexavalent state, in the form of the divalent uranyl ion, UO_2^{++}, a unit of sufficient stability to preserve its identity in solution.

The generally much greater solubility of uranyl compounds relative to those of tetravalent uranium is one of the most important differences in the geochemistry of uranium.

2. Carbonaceous matter or H_2S could reduce, in nature, uranyl solutions at temperatures below perhaps 100°C (Gruner, 1956B). Another excellent reductant for uranyl solutions is the H_2S or S^{2-} ion, which commonly is associated with decaying plant material.

3. One of the most significant properties of the uranium ions, from the geological point of view, is their great affinity for carbonaceous and other organic materials.

4. By experiments (Gruner, 1956B) has demonstrated that the uranium might be transported long distances in groundwaters: bicarbonates of Ca, Mg, and Na, very common in nature, are able to form with uranium compounds which yield the apparently very stable U-tricarbonate ion $[UO_2(CO_3)_3]^{4-}$ in a solution saturated with CO_2. They could carry the metal long distances through almost neutral environments until reducing conditions are met.

D. Factors Affecting the Uranium Concentration

Weathering and erosion of huge volumes of uranium-bearing rocks release uranium which would be incorporated in the regional water flow and may be either carried out of the region or reconcentrated in suitable environments. As pointed out by Klepper and Wyant (1955), this final distribution largely depends on several factors such as climate, topography, and lithology of the area. Climate is considered as the most important of the mentioned factors, which will finally determine whether the uranium is retained or exported from the region.

In a humid climate, the weathering is intense and the drainage toward the sea will permanently remove the uranium from the area. But given arid or semiarid conditions with interior basins and intermittent drainage toward the sea, the results will be quite different. Leaching agents, as bicarbonates of Ca, Mg, and Na (Gruner, 1956B), extract from the rocks uranium which becomes incorporated in the ground water flow until reducing conditions are encountered. Whether the uranium transported in solution will form precipitated concentrations in the sediments, will depend largely on factors such as, a) the concentration of uranium in the flow, b) the continuity of the flow over the area for a relatively long period of time, and c) the presence of an appropriate reduction, such as organic material, in the sediments which would cause the reduction of the uranyl ion and its precipitation.

Regarding this last mentioned factor, not all carbonaceous matter is equally effective in removing uranium from solution. According to Vine (1962, p. 153),

> Because coal is a heterogeneous mixture of different types of carbonaceous constituents with widely differing chemical and physical properties, it seems reasonable to expect that these various constituents may differ considerably in their capacity to hold uranium...
>
> Petrographic investigations of uraniferous coaly carbonaceous rocks indicate that all types of carbonaceous matter probably contain uranium but that uranium shows a slight preference for the more degraded attrital material, including amorphous humic matter, and in one group of deposits possibly for yellow waxy matter in the attritus. Permeability of the rocks and availability of uraniniferous solutions seems to influence the distribution of the uranium far more than the proportions of different carbonaceous substances.

McKelvey and others (1955) have concluded that the introduction of uranium in the carbonaceous sediments must take place before coalification. Relatively pure coal that has not been disturbed has very low permeability which inhibits the later introduction of epigenetic uranium.

Regarding the forms of occurrence for the uranium in coaly carbonaceous rocks, Vine (1962, p. 159) has considered five possible forms of occurrence, with the maximum likely to be concentrated in any given form is as follows:

		Percent
1.	Inherent uranium	0.00x
2.	Diagenetically fixed adventitious uranium	0.x
3.	Detrital uranium minerals	0.000x
4.	Epigenetic uranium minerals	0.x
5.	Epigenetically fixed adventitious uranium	x

As can be seen, the uranium introduced epigenetically into coaly carbonaceous rock could represent a considerable portion of the total amount present.

E. Uranium-Bearing Carbonaceous Deposits in the Thesis Area

The occurrence of the radioactive anomalies in association with carbonaceous beds in the thesis area has been observed in section 24, T. 32 N., R. 85 W. This common characteristic for the highest radioactive mineralization of the area suggests that the concentration of the uranium was controlled mainly by the composition of the rock.

The distribution of the uranium in the coal bed (open pit unit f; Chapter 4) is irregular. The uppermost section is the most uraniferous with 0.059% of U_3O_8, decreasing downward to 0.016% of U_3O_8 at the base of the layer.

The irregular downward decrease of uranium within the coal bed, the relation of the carbonaceous layer to superjacent permeable sediments, and the lithologic control over the mineralization indicates that the uranium was introduced after deposition of the enclosing rocks presumably by groundwater action.

In several uraniferous districts of the western United States detailed studies have indicated a direct correlation between the presence of uranium mineralization and organic materials. The deposits are regarded as having been formed by circulating waters that collected the metal disseminated through the rocks and deposited it in contact with carbonaceous material. Experiments by Gruner (1956A) and others have demonstrated that an excellent reductant for uranyl solutions is H_2S or the S^{2-} ion, which commonly is associated with decaying plant material. Moreover, Denson and Gill (1955, p. 416) record,

> Lignite from South Dakota has been shown to be a good extractor of uranium from solution (Moore, 1954). Non-radioactive lignite from the Slim Buttes, S. Dakota, was immersed in a solution of uranyl sulfate containing 200 parts per million uranium (ppm). After 19 days the lignite contained 0.19 percent uranium, and the solution contained 2.0 ppm uranium. The experiment confirms in a striking manner the affinities of carbonaceous material for uranium pointed out by I. M. Tolmachen (1943) and S. Szalay (1954).

All these evidences reaffirm the epigenetic character of the mineralization within the thesis area.

F. Availability of Uranium in Igneous and Other Rocks

Although the epigenetic origin of the uranium deposits seems most likely, the aim of this section is to discuss the possible ultimate source or source areas for the uranium in the Poison Spider area. The most common rock types cited in the literature regarded as source of uranium for sedimentary deposits, are the tuffaceous materials and decaying granitic or arkosic rocks. Hydrothermal solutions are also considered as a uranium source.

The presence of granitic masses south of the thesis area regarded as the source for the arkosic sediments of the Wind River Formation can be considered as one of the original contributors of uranium to the regional flow. It can be assumed either the decaying granitic masses directly released the uranium, or that the arkosic sediments derived from these masses originally contained the radioactive element which was subsequently concentrated by solution and precipitation in approximately the present conditions of the mineralized bodies.

Moreover, pyroclastic rocks might serve as sources from which disseminated elements could be leached by ground water to be redeposited in underlying sedimentary strata in more concentrated form. Several examples in the literature have been found to identify tuffaceous sediments as the primary source for uranium. Denson and Gill (1955, p. 416) studying uranium-bearing lignite deposits in eastern Montana and North and South Dakota report:

> The uranium ion is believed to have been held as a disseminated constituent in the volcanic ash or tuffaceous material in the rocks of the White River Group and the Arikaree Formation. Subsequent release or displacement of the uranium may have been accomplished by weathering and ultimate devitrification of the volcanic materials. Whatever the reasons for the displacement, carbonaceous materials are believed to have acted as filters to concentrate and fix the uranium.

Volcanic ash and pyroclastic debris in the earlier stages are of a texture/permeability that permits easy movement of water, resulting therefore in a rapid leaching and alteration which should easily remove uranium even when sparsely present.

Regarding the uranium content in ground water in the Hiland-Clarkson Hill area, Rich (1962) presents the results of 71 water samples collected from different Tertiary formations of this area. The average uranium content determined in water associated with

Eocene and older rocks is 8.8 ppb, whereas for water associated with Oligocene and younger rocks the average is 5.0 ppb. All these samples were collected from apparent uranium-free areas.

Samples taken from a known mineralized area (Section 4, T. 31 N., R. 83 W.) average 61 ppb. Concerning the above data and its geological significance, Rich (1962, p. 528, 529) comments:

> A few water samples contained more than an average amount of uranium, and those containing the highest concentration, exclusive of the ones from known mineralized areas, were at or near the axis of the syncline that forms the southeastern end of the Wind River Basin. These data suggest that any uranium that may have accumulated in the Hiland-Clarkson Hill area was removed from the point of original deposition by the leaching of ground water and reconcentrated along the axis of the syncline or carried out of the mapped area.

As the largest and most widespread tuff beds of the area are in the Oligocene White River and Miocene Arikaree Formations, overlying unconformably most of the older formations, it can be assumed that leaching ground waters may possibly have carried uranium from them into other sediments.

G. Tectonism and its Relation with the Mineralization in the Poison Spider Area

According to the evidence mentioned in the preceding sections, the mineralization is controlled by stratigraphic and lithologic factors within the thesis area. However, in a regional view, folding and faulting could have affected the final emplacement and grade of the mineralization. Rich (1956A, 1956B, 1967) mentions that tectonic features such as the Rattlesnake Anticline and the reactivation of the North Granite Mountains Fault Zone have materially affected the movements of ground water within the Wind River Formation. The Rattlesnake Hills are assumed to have acted as a barrier to streams flowing northeastward and northwestward from the Granite Mountains. Regarding the faulting effects Rich (1962, p. 529) records,

> The stratigraphic and structural relations suggest that, because of the Post-Miocene southward regional tilting, the flow of uranium-bearing ground water in the Oligocene and Miocene rocks south of the North Granite Mountain Fault Zone was reversed from northward (Basinward) to a southward (Mountainward) direction. This change in direction of groundwater movement in the Post-Wind River rocks may have been prevented not only further trapping of uranium-bearing water in the areas where the Wind River Formation is now exposed, but may also have caused leaching of previously formed uranium deposits below the unconformity at the base of the White River Formation.

Chapter X

QUANTITATIVE INTERPRETATION OF GAMMA RAY LOGS

A. Introduction

Only a few gamma ray logs from the 32 drill holes discussed in Chapter 5 were quantitatively interpreted. The analysis was focused on the logs with higher gamma ray reading (in counts per second) to determine the concentration of gamma ray-emitting elements in the Wind River Formation. The quantitative method used was developed by the U.S. Atomic Energy Commission (Scott _et al._, 1960). The method will be outlined in the following paragraphs. The definition of several terms to be used is considered necessary:

Mean Grade "G" is the mean concentration by weight of the radioactive element contained in a rock layer of thickness "T".

Grade Thickness "GT" is the product of the mean grade and thickness of the layer of radioactive material.

Instrument Dead Time "t" is the resolving-time loss inherent in all electronic counting equipment, when the instrument is incapable of registering new events.

Disequilibrium Ratio is represented by the ratio of the mean true grade, G_t, to the mean radiometric equivalent grade G of a mineralized zone, G_t/G. Petro-Nuclear Company Ltd. determined the value 0.25 as an average disequilibrium factor for the Poison Spider area.

Equivalent Uranium Percent (%e U_3O_8): This is the percentage of U_3O_8 obtained from the quantitative interpretation of the gamma ray logs anomalies, assuming that this radioactive anomalies are produced entirely by uranium mineralization. This value multiplied by the disequilibrium ratio gives the corrected grade percent of U_3O_8.

B. Theoretical Considerations

The method is based on the fact that the grade-thickness product of a mineralized zone intersected in the bore hole is determined by multiplying the area under the gamma-ray log curve by a constant of proportionally. The mean grade of the zone is determined, afterwards, by dividing the grade-thickness product by the zone thickness (Scott, et al., 1960). The general equation to show the relationship can be formulated as:

$$GT = kA$$

where G is the mean radiometric grade of uranium mineralization expressed in percent equivalent U_3O_8 by weight, T is the thickness of the mineralized zone in feet, k a constant of proportionality determined by instrument calibration, and A is the corrected area under the gamma ray log curve. The validity of this equation depends upon the proper application of corrections for the instruments and for variations of physical conditions in the vicinity of the bore hole.

The instruments correction has to be made because of the resolving time loss inherent in all electronic counting equipment (correction for dead time loss). According to Dodd and Droullard (1964, p. 7),

> The electronic instruments used in nuclear logging have a definite though small reaction and recovery time when the instrument is incapable of registering a new event. Because the nuclear events being counted are numerous and randomly, rather than regularly spaced, there is a probability for several of these events to occur during the instrument dead time and fail to be recorded. Particularly at high counting rates this loss causes a nonlinear response which can introduce significant errors.

Therefore, a correction for resolving-time loss is necessary, so the indicated counting rate of the instrument must be corrected for events not recorded during the instrument dead time.

The correction is based on the equation

$$N = \frac{n}{1-nt}$$

where N is the true or corrected counts per second, n is the observed counting rate, and t is the dead time in seconds.

Moreover, corrections are made for variations of physical conditions existing in the vicinity of the bore hole. The Atomic Energy Commission standard conditions are:

1. Bore hole diameter........................4 1/2 inches
2. Medium filling the bore hole.............Air
3. Bore hole casing.........................None
4. Free water in the formation..............12% (by weight)
5. Disequilibrium...........................$(G_t/G) = 1$

Any change from "calibration" or standard conditions requires a correction.

The correction for the first three parameters in the 500 series of drill holes is neglected. The holes are uncased, their diameters are in the standard range, and no data for hole fluid correction (in this case water) is available.

1. Free Water Correction

Free water in the formation is highly variable and should not be ignored since it moderates, scatters or absorbs gamma rays and neutrons. Therefore, a free water formation correction is available for the interpretation of the radioactive logs of the 500 series.

The water factor is 1.127 for all the logs analyzed in this text (data determined by the logging company).

2. Disequilibrium Factor

This has been already defined, and was given the 0.25 value for the Poison Spider area.

C. Practical Application

1. Determination of the Mineralized Zone Thickness

The mineralized zone boundaries are quite accurately represented by the half-amplitude point on the flank of the anomaly on the gamma ray logs. Therefore, the thickness is obtained by measuring the amplitudes of the peaks nearest to the top and bottom of the anomaly, and calculating the footage interval between the half-amplitude points on the logs, as shown in Figure 18.

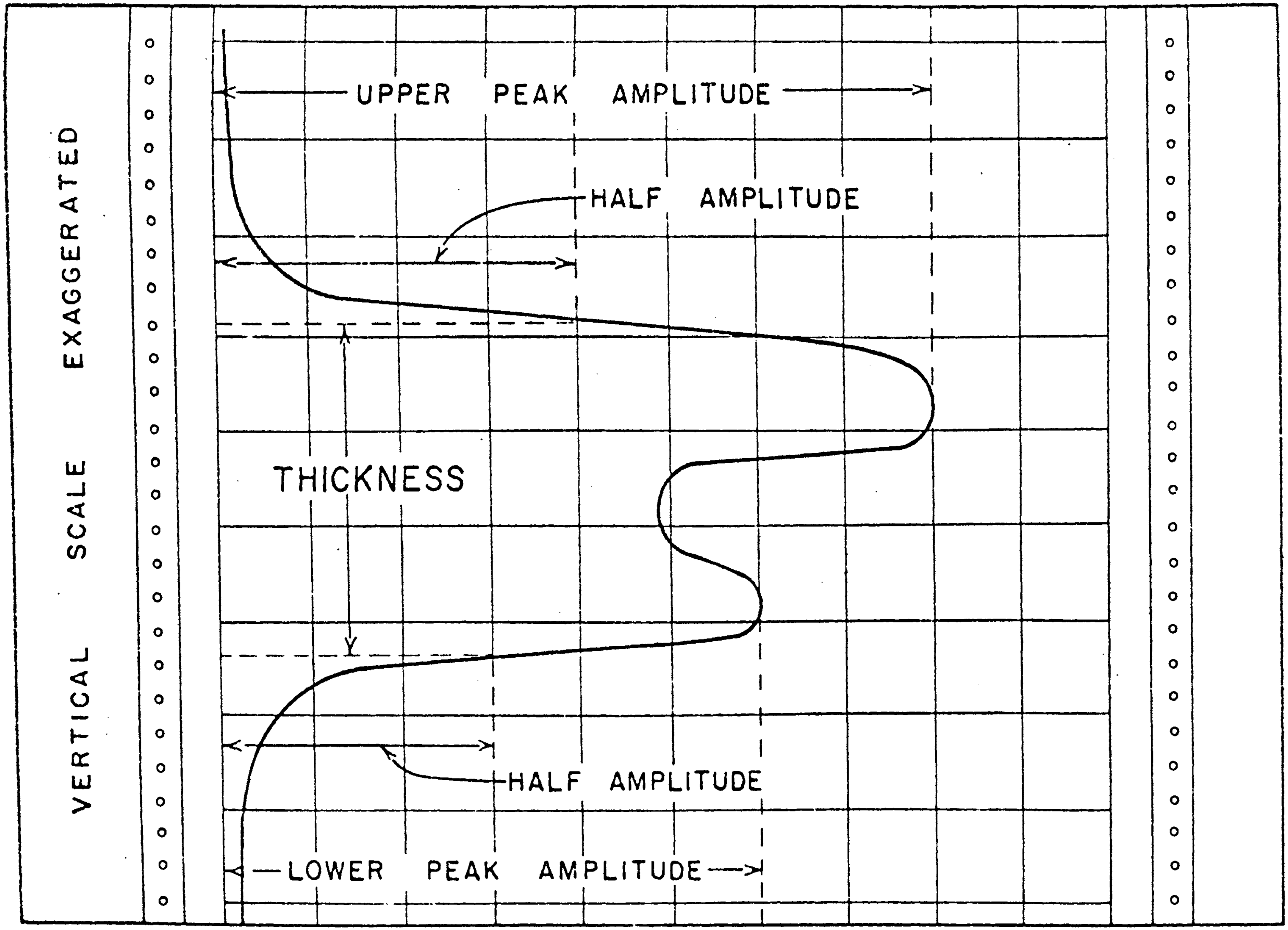


Figure 18 . Thickness determination. (From Scott, et al., 1960)

2. Determination of the Area Under the Gamma Ray Curve

For this purpose counting rate values at regular intervals should be obtained along the section of the curve analyzed. The first counting rate value is read at the previously-determined upper-half amplitude point. This value is called the first end value, E_1, as shown on Figure 19. Successive intermediate values designated by I_1, I_2, etc. are read at positions equivalent to half-foot depth intervals in the hole. The last intermediate value to be read is just above the lower boundary of the mineralized zone. The second end value, E_2, is read one interval below the last value, and just below the lower boundary of the zone analyzed (Fig. 19). Every one of the counting rates determined above must be corrected for dead time loss. This correction is based on the equation

$$N = \frac{n}{1-nt}$$

where N is the corrected counting rate, n is the observed counting rate, and t is the resolving time of the instrument (dead time in seconds). Figure 20 shows as the total area under the portion of curve analyzed can be subdivided into two "tail" areas and a central area. Each tail area extends to a point half-way between an E point and the adjacent I point. The value of the sum of the two tail areas is approximated by adding together the corrected counting rate values at E_1 and E_2 and then multiplying by a "tail factor" (1.38 for this case). The value of the central area under the curve is obtained by summing the intermediate values (corrected) represented by I_1, I_2, I_3, etc. (trapezoidal-type numerical integration).

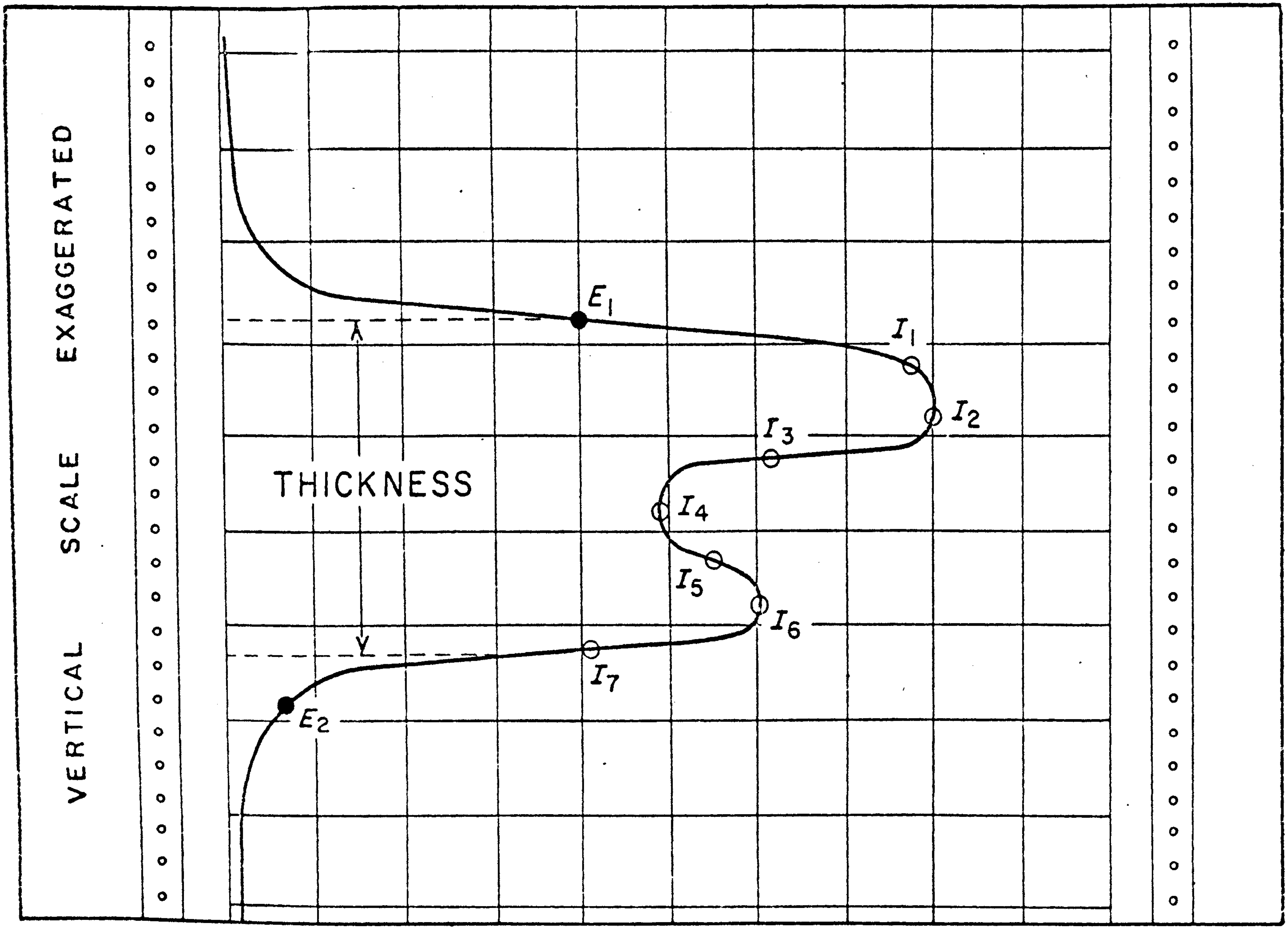


Figure 19. Numerical integration points. (From Scott et al., 1960

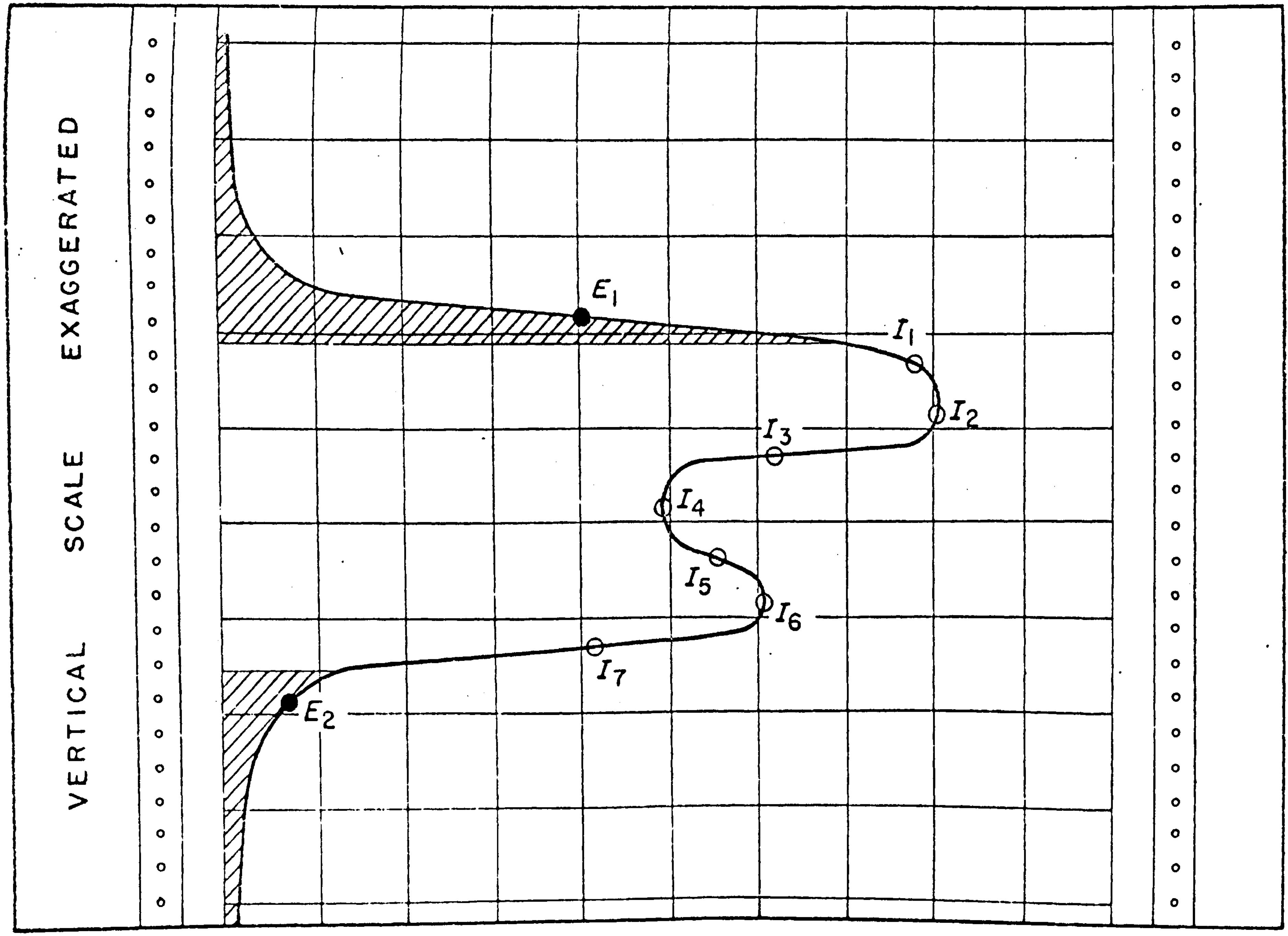


Figure 20 . Determination of tail areas and central area.
(From Scott *et al.*, 1960).

The total value for the area under the "anomalous" part of the curve, therefore, is determined by adding the value of the central area to that corresponding to the combination of both tail areas.

3. Corrections

The value of the total area should be corrected at this stage for free water content (Bore hole and hole fluid correction have been neglected). Therefore, the value of the total area is multiplied by the water factor (1.127). The resulting corrected value is then multiplied by the calibration factor, k, to obtain the mean grade thickness (GT), according with the equation already discussed:

$$GT = kA$$

The value for $k = 2.31 \times 10^{-5}$. The GT value obtained is then multiplied by the disequilibrium correction factor (0.25 for the Poison Spider area) to obtain the true grade thickness (G_tT). Finally, the corrected mean grade or true mean grace G_t is determined by dividing G_tT by the mineralized zone thickness T.

The gamma ray log interpretation just outlined was used, in the Poison Spider area, to get the corrected grade percentage of U_3O_8 for the drill holes with the highest radioactive anomalies (only the maximum peak for each hole was determined). The complete procedure, as described before, can be tabulated (for every hole studied) on the special forms from the U.S. Atomic Energy Commission following this discussion (Figs. 21-25).

D. Gamma Ray Log Data - Poison Spider Area

It is the intention in this section to gather and describe the general characteristics and factors defined for the logs surveyed in the 500 series of holes, Poison Spider area. The following data was used in the quantitative interpretation of some gamma ray logs:

k factor = 2.31×10^{-5}

Dead time = 16 micro seconds

Water factor = 1.127

Disequilibrium ratio = 0.25 (Data from Petro-Nuclear Ltd.)

Tail factor = 1.38 (Data from U.S. Atomic Energy Commission)

Horizontal scales - 1k: 1" = 100 counts per second
5k: 1" = 500 counts per second
10k: 1" = 1000 counts per second

Vertical scale: 1" = 10'

Logging speed = 10'/min.

The above data was used in the quantitative interpretation of 5 gamma ray logs to determine the grade percentage of U_3O_8. The calculations are shown in the following pages.

GJ-PD-14
(REV. 3/59)

Hole No. 519

UNITED STATES ATOMIC ENERGY COMMISSION

GRAND JUNCTION, COLORADO

GAMMA RAY LOG INTERPRETATION WORK SHEET

Claim
Company Petro-Nuclear Ltd.
LOCATION
Sec. 24 Twp 32 N. Rng 85 W.
Date logged July 11, 1968
Date interpreted
District Poison Spider State Wyoming

Log Operator
Interpreter
Unit Dead Time 16 u sec.
Water Factor 1.127
Other Factors
K Factor 2.31×10^{-5}
Range

Probe No.
Ratemeter No.
Unit No.
Tail Factor 1.38
Standard
Reading
Disequilibrium
Ratio 0.25

Inches	n	N	Inches	n	N
E_1	1300	1328			
E_2	800	810			
	$E_1 + E_2 =$	2138			
$E_1 + E_2 \times 1.38 =$		2950			
I 1	2175	2253			
2	2350	2442			
3	1750	1800			
4	1575	1616			
5	1450	1484			
6	1500	1537			
7	1575	1616			
8	1500	1537			
9	1450	1484			
10	1500	1537			
11	1650	1695			
12	1375	1406			

INTERVAL

Lower Boundary 67.0 ft.
Upper Boundary 61.0 ft.
Thickness 6.0 ft.
23,357 Σ Ncps
X 1.127 Correction Factor(s)
Corrected Area 26,323
X 2.31×10^{-5} K Factor
GT = 0.60
T = 6.0
Average grade % eU_3O_8 = 0.10

GT X Disequilibrium Ratio =
0.15
0.15 ÷ Thickness =
Corrected grade % U_3O_8 0.02

Figure 21.

GJ-PD-14
(REV. 3/59)

Hole No. 555

UNITED STATES ATOMIC ENERGY COMMISSION

GRAND JUNCTION, COLORADO

GAMMA RAY LOG INTERPRETATION WORK SHEET

Claim ________

Company Petro-Nuclear Ltd.

LOCATION

Sec. 24 Twp 32 N. Rng 85 W.

Date logged August 7, 1968

Date interpreted ________

District Poison Spider State Wyoming

Log Operator ________

Interpreter ________

Unit Dead Time 16 u sec.

Water Factor 1.127

Other Factors ________

K Factor 2.31 x 10^{-5}

Range ________

Probe No. ________

Ratemeter No. ________

Unit No. ________

Tail Factor 1.38

Standard Reading ________

Disequilibrium Ratio 0.25

Inches	n	N	Inches	n	N
E_1	3000	3151			
E_2	1550	1589			
	$E_1 + E_2$ =	4740			
$E_1 + E_2$ X 1.38 =		6541			
I 1	5000	5435			
2	5350	5851			
3	3300	3484			

INTERVAL

Lower Boundary 57.6 ft.

Upper Boundary 56.0 ft.

Thickness 1.6 ft.

21,311 Σ Ncps

X 1.127 Correction Factor(s)

Corrected Area 24,017

X 2.31x10^{-5} K Factor

GT = 0.55

T = 1.6

Average grade % eU_3O_8 = 0.34

GT X Disequilibrium Ratio = 0.14 ÷ Thickness =

Corrected grade % U_3O_8 0.08

Figure 22.

GJ-PD-14
(REV. 3/59)

Hole No. 556

UNITED STATES ATOMIC ENERGY COMMISSION

GRAND JUNCTION, COLORADO

GAMMA RAY LOG INTERPRETATION WORK SHEET

Claim
Company Petro-Nuclear Ltd.
LOCATION
Sec. 24 Twp 32 N. Rng 85 W.
Date logged August 9, 1968
Date interpreted
District Poison Spider State Wyoming

Log Operator
Interpreter
Unit Dead Time 16 u sec.
Water Factor 1.127
Other Factors
K Factor 2.31 x 10^{-5}
Range

Probe No.
Ratemeter No.
Unit No.
Tail Factor 1.38
Standard
Reading
Disequilibrium Ratio 0.25

Inches	n	N	Inches	n	N
E_1	1700	1747			
E_2	1600	1642			
	$E_1 + E_2$ =	3389			
$E_1 + E_2$ X 1.38 =		4677			
I 1	2350	2442			
2	1800	1853			
3	1850	1906			
4	2250	2334			
5	2500	2604			
6	2600	2713			
7	2550	2658			
8	2200	2280			
9	1900	1960			
10	1750	1800			
11	1650	1695			
12	1770	1822			
13	2000	2066			
14	2500	2604			
15	3000	3151			
16	2650	2767			
17	1900	1959			

INTERVAL

Lower Boundary 48.0 ft.
Upper Boundary 38.8 ft.
Thickness 9.2 ft.
43,291 Σ Ncps
X 1.127 Correction Factor(s)
Corrected Area 48,789
X 2.31x10^{-5} K Factor
GT = 1.12
T = 9.2
Average grade % eU_3O_8 = 0.12
GT X Disequilibrium Ratio = 0.28
0.28 ÷ Thickness =
Corrected grade % U_3O_8 0.03

Figure 23.

GJ-PD-14
(REV. 3/59)

Hole No. 569

UNITED STATES ATOMIC ENERGY COMMISSION
GRAND JUNCTION, COLORADO
GAMMA RAY LOG INTERPRETATION WORK SHEET

Claim
Company Petro-Nuclear Ltd.
LOCATION
Sec. 24 Twp 32 N. Rng 85 W.
Date logged August 19, 1968
Date interpreted
District Poison Spider State Wyoming

Log Operator
Interpreter
Unit Dead Time 16 u sec.
Water Factor 1.127
Other Factors
K Factor 2.31 x 10-5
Range

Probe No.
Ratemeter No.
Unit No.
Tail Factor 1.38
Standard
Reading
Disequilibrium Ratio 0.25

Inches	n	N	Inches	n	N
E_1	1500	1537			
E_2	1350	1380			
	$E_1 + E_2$ =	2917			
$E_1 + E_2$ X 1.38 =		4025			
I 1	2200	2280			
2	2300	2388			
3	2250	2334			
4	2500	2604			
5	2550	2658			
6	2100	2173			
7	1770	1822			
8	1800	1853			
9	1800	1853			
10	1700	1747			
11	1600	1642			
12	1570	1610			
13	1575	1616			
14	1550	1589			
15	1520	1558			
16	1380	1411			
17	1380	1411			
18	1500	1537			
19	1830	1885			
20	2000	2066			
21	2120	2194			
22	2000	2066			

INTERVAL

Lower Boundary 68.2 ft.
Upper Boundary 56.8 ft.
Thickness 11.4 ft.
46,322 Σ Ncps
X 1.127 Correction Factor(s)
Corrected Area 52,205
X 2.31×10^{-5} K Factor
GT = 1.20
T = 11.4
Average grade % eU_3O_8 = 0.10
GT X Disequilibrium Ratio = 0.30
0.30 ÷ Thickness =
Corrected grade % U_3O_8 0.02

Figure 24.

GJ-PD-14
(REV. 3/59)

Hole No. 575

UNITED STATES ATOMIC ENERGY COMMISSION

GRAND JUNCTION, COLORADO

GAMMA RAY LOG INTERPRETATION WORK SHEET

Claim
Company Petro-Nuclear Ltd.
LOCATION
Sec. 24 Twp 32 N. Rng 85 W.
Date logged August 19, 1968
Date interpreted
District Poison Spider State Wyoming

Log Operator
Interpreter
Unit Dead Time 16 u sec.
Water Factor 1.127
Other Factors
K Factor 2.31 x 10^{-5}
Range

Probe No.
Ratemeter No.
Unit No.
Tail Factor 1.38
Standard
Reading
Disequilibrium Ratio 0.25

Inches	n	N	Inches	n	N
E_1	2000	2066			
E_2	1650	1695			
	$E_1 + E_2$ =	3761			
$E_1 + E_2$ X 1.38 =		5190			
I 1	3450	3651			
2	3500	3708			
3	2850	2986			

INTERVAL

Lower Boundary 55.0 ft.
Upper Boundary 53.0 ft.
Thickness 2.0 ft.
15,535 Σ Ncps
X 1.127 Correction Factor(s)
Corrected Area 17,508
X 2.31x10^{-5} K Factor
GT = 0.40
T = 2.0
Average grade % eU_3O_8 = 0.20

GT X Disequilibrium Ratio = 0.10
0.10 ÷ Thickness =

Corrected grade % U_3O_8 0.05

Figure 25.

Chapter XI

SUMMARY AND CONCLUSIONS

The principal features of the sediments and associated mineralization in the thesis area, Poison Spider District, may be summarized by the following statements:

1. The lithology of the Wind River Formation in the Poison Spider area is predominatly a coarse, clastic, arkosic, and muscovite-rich sand.
2. The fluvial character of the Wind River Formation was proved by means of field evidence and a CM diagram. Channel, channel proximal, and flood plain deposits were identified. As a consequence of the fluvial character the lithology is quite variable both vertically and horizontally.
3. The carbonaceous material intercalated within the Wind River sediments is interpreted as swampy flood plain deposits.
4. The lithology and associated heavy minerals for the Wind River and White River Formations show striking differences, which reflect the post-Wind River increase in volcanic activity in the area.
5. The Wind River Formation delineates an asymmetric anticlinal structure, the Rattlesnake Range, with its steeper flank southward, where it is unconformably overlain by the tuffaceous White River Formation.

The evaluation and interpretation of the available geophysical and geological information within the thesis area has led to the establishment of several possible relationships between the local geology and the uraniferous mineralization. The relationships are presented below which might prove to be useful guides for future exploration, at least for deposits of the same character as the ones discussed in this text.

1. The mineralization of the thesis area is most likely of epigenetic character.
2. The uranium has been incorporated to the regional water flow by meteoric waters which derived the metal from terrigenous sediments resulting from the disintegration of Precambrian granitic rocks and/or Tertiary tuffaceous sediments.
3. Since the solutions apparently travelled considerable distances in sediments, the solution must have come into equilibrium with the surrounding sediments; precipitation was effected where materials were available to cause reduction of the uranyl ion.
4. The role of reduction in fixing uranium in coal or carbonaceous sediments is evidenced by the following observations:
    a. The presence of coarse, clastic, channel-type permeable sediments, overlying lignite beds, which show the highest uranium mineralization in the uppermost part.

b. The restriction of uranium mineralization to rocks with abundant organic material.

c. The spotiness distribution of the uranium is in complete agreement with the irregular distribution of the carbonaceous concentrations within the same horizon.

5. The mineralization is, within the same horizon, variable in both stratigraphic position and uranium content. That could be interpreted as due to variations in permeability, or in the amount and character of the carbonaceous matter which greatly influences the presence of uranium in the sediment.

6. The Rattlesnake structure and the reactivation of the North Granite Fault zone reversed the basinward direction of the regional water flow for the Poison Spider area. This change in direction of ground water movement not only has prevented the uranium-bearing ground water from reaching the thesis and adjacent areas, but possibly also removed by leaching a great part of the previously formed uranium deposits.

   The complete absence of mineralization in the southern slope of the Rattlesnake Range (400 series of drill holes) seems to prove the preceding paragraph. Therefore, only low grade uranium deposits are evidently left in the area, and future uranium exploration has to be focused out of the Poison Spider area, where structural and stratigraphic conditions may have concentrated the incoming mineralization.

7. All the preceeding conclusions were based on geological and geophysical data from the uppermost 200 feet of the Wind River Formation in the thesis area. Therefore, a future project which will involve deeper drilling operations (more than 200 feet) is considered to be worthwhile for checking the remaining lower section for any uranium mineralization of higher grade than that already analyzed.

BIBLIOGRAPHY

1. Denson, Norman M. and Gill, James R. (1955) Uranium-bearing lignite and its relation to volcanic tuffs in Eastern Montana and North and South Dakota. U.S. Geol. Survey Prof. Paper 300, pp. 413-418.

2. ________________ (1968) Personal communication.

3. Dodd, Philip and Droullard, Robert (1964) Some current concepts of nuclear borehole logging for uranium exploration and evaluation. U.S. Atomic Energy Commission, Grand Junction, Colorado.

4. Folk, Robert L. (1951) A comparison chart for visual percentage estimation. Jour. Sed. Petrology, vol. 21, no. 1, pp. 32-33.

5. Gruner, John W. (1956A) Concentration of uranium by carbon compounds. Economic Geology, vol. 51, pp. 284-285.

6. ________________ (1956B) Concentration of uranium in sediments by multiple migration-accretion. Economic Geology, vol. 51, pp. 495-520.

7. Heinrich, E. (1958) Mineralogy and geology of radioactive raw materials. McGraw-Hill Book Company, Inc., New York.

8. Hjulstrom, Filip (1939) Transportation of detritus by moving water. Recent marine sediments, edited by Parker D. Trask, published by the Amer. Assoc. of Petr. Geologists, Tulsa, Oklahoma, Part 1, Transportation, pp. 5-31.

9. Klepper, Montis R. and Wyant, Donald G. (1955) Uranium provinces. U.S. Geol. Survey, Prof. Paper 300, pp. 17-25.

10. Krumbein, W.C. and Pettijohn, F.J. (1966) Manual of sedimentary petrography. Appleton-Century-Crofts. Division of Meredith Corp., New York.

11. McKelvey, Vincent E., Everhart, Donald L., and Garrels, Robert M. (1955) Summary of hypotheses of genesis of uranium deposits. U.S. Geol. Survey, Prof. Paper 300, pp. 41-53.

12. Nininger, Robert D. (1955) Minerals for atomic energy. D. Van Nostrand Co., Inc., New York.

13. Otto, G.H. (1938) The sedimentation unit and its use in field sampling. Jour. of Geology, vol. 46, pp. 569-582.

14. Passega, R. (1957) Texture as characteristic of clastic deposition. Amer. Assoc. of Petr. Geologists, vol. 41, no. 9, pp. 1952-1984.

15. Passega, R. (1964) Grain size representation by CM patterns as a geological tool. Jour. of Sed. Petrology, vol. 32, no. 4, pp. 830-847.

16. Rich, Ernest I. (1956A) Hiland-Clarkson Hill Area, Natrona County, Wyoming. U.S. Geol. Survey, Trace Elements Investigations Report-620 (TEI-620), pp. 186-188.

17. _______________ (1956B) Hiland-Clarkson Hill Area, Natrona County, Wyoming, U.S. Geol. Survey, Trace Elements Investigation Report-640 (TEI-640), pp. 121-125.

18. _______________ (1957) Hiland-Clarkson Hill Area, Wyoming. U.S. Geol. Survey, Trace Elements Investigations Report-690, Book 2 (TEI-690), pp. 276-279.

19. _______________ (1962) Reconnaissance geology of Hiland-Clarkson Hill Area, Natrona County, Wyoming. U.S. Geol. Survey, Bull. 1107-G, pp. 447-540.

20. Royse, Chester F., Jr. (1968) Recognition of fluvial environments by particle-size characteristics. Jour. of Sed. Petrology, vol. 38, no. 4, pp. 1171-1178.

21. Scott, J., Dodd, P., Droullard, R., Mudra, P. (August, 1960) Quantitative interpretation of Gamma-ray logs. U.S. Atomic Energy Commission, Grand Junction, Colorado.

22. Soister, Paul E. (1968) Stratigraphy of the Wind River Formation in South-Central Wind River Basin, Wyoming. U.S. Geol. Survey, Prof. Paper 594-A.

23. Thompson, R.M. (1958) Geology and oil and gas possibilities of the Wind River Basin, Wyoming. Habitat of oil, edited by Lewis G. Weeks and published by the Amer. Assoc. of Petr. Geologists, Tulsa, Oklahoma, pp. 307-327.

APPENDIX

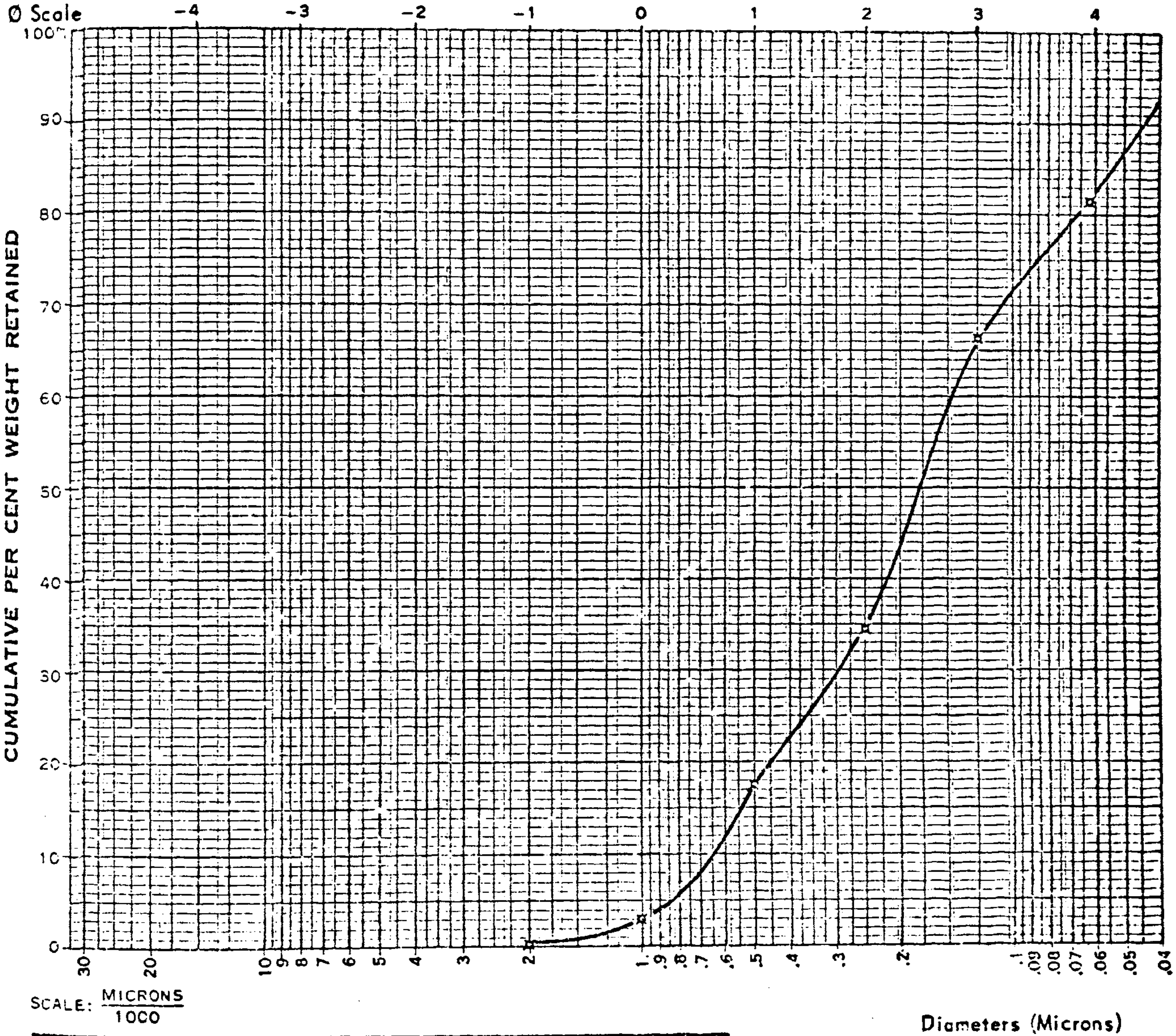
Wind River Formation

Histograms and cumulative curves prepared from sieve analysis for the samples of the measured stratigraphic sections.

Sample No. Open Pit-1

Screen Analysis

Muddy Sand



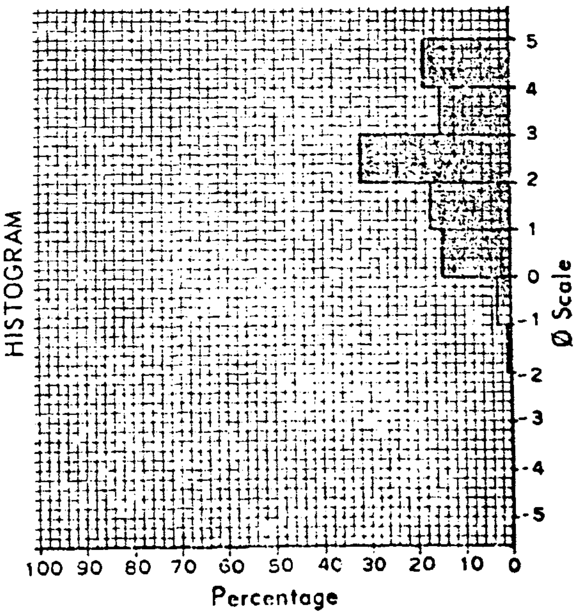
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2				
2	-1	0.25	0.4	0.25	0.4
1.00	0.00	1.50	2.7	1.75	3.1
(1/2) 0.5	1.00	8.00	14.4	9.75	17.5
(1/4) 0.250	2.00	9.48	17.0	19.23	34.5
(1/8) 0.125	3.00	17.77	31.9	37.00	66.4
(1/16) 0.062	4.00	8.41	15.1	45.41	81.5
Pan		10.28	18.5	55.69	100.0
	TOTAL	55.69	100.0		
	Loss				

Diameters (Microns)

1% = 1,500

50% = 175

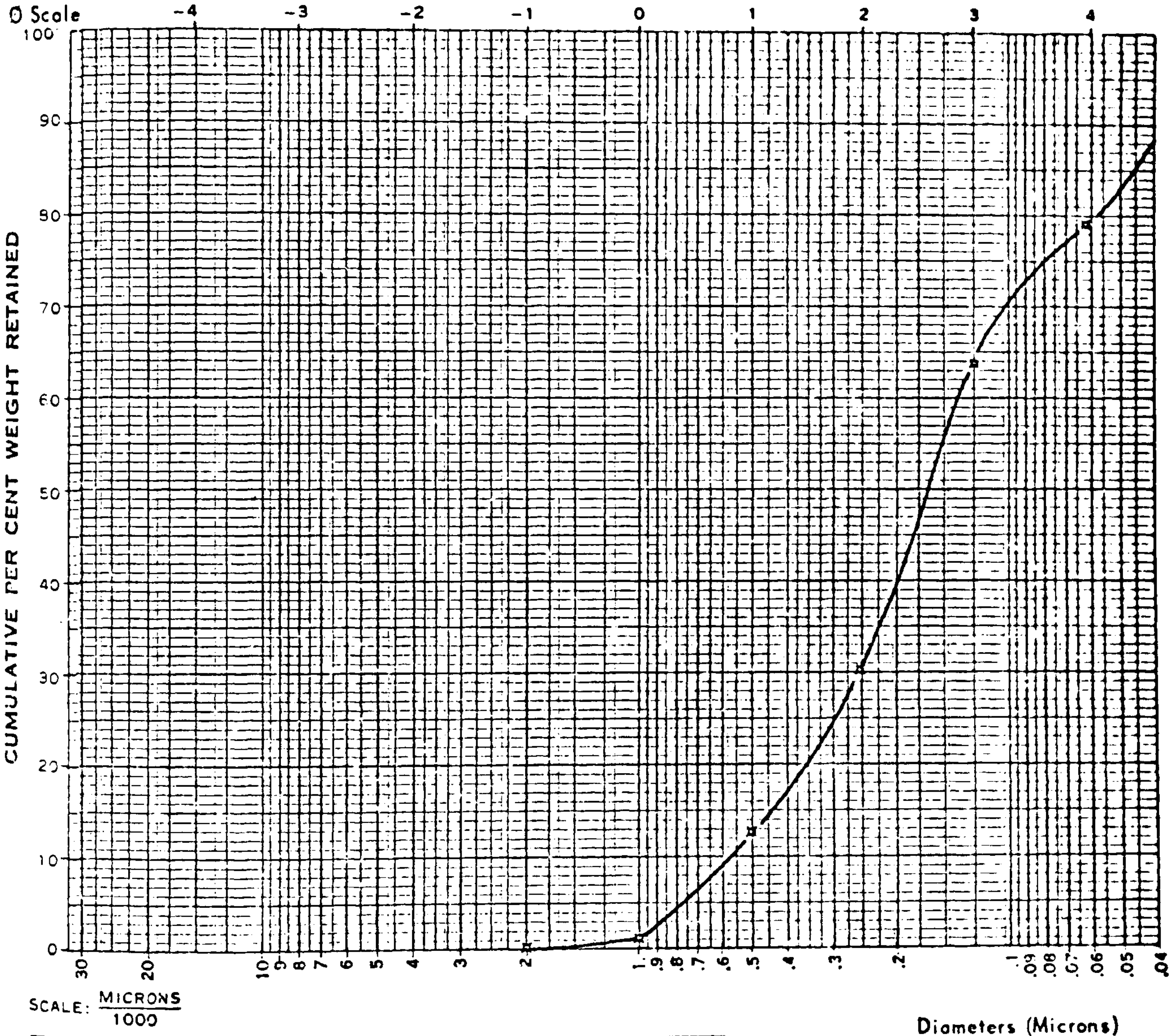
Modal Class (Ø Scale) = (2,3)



Sample No. Open Pit-3

Screen Analysis

Muddy Sand



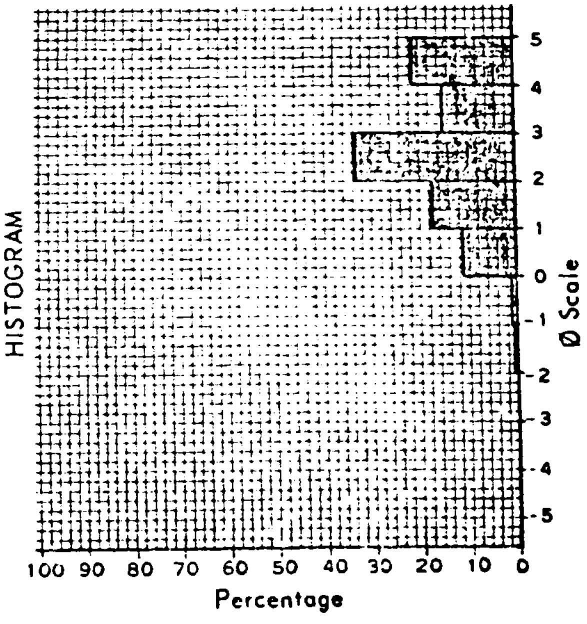
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2				
2	-1	0.13	0.2	0.13	0.2
1.00	0.00	0.75	1.1	0.88	1.3
(1/2) 0.5	1.00	7.67	11.6	8.55	12.9
(1/4) 0.250	2.00	11.50	17.4	20.05	30.3
(1/8) 0.125	3.00	22.13	33.6	42.23	63.9
(1/16) 0.062	4.00	10.00	15.1	52.23	79.0
Pan		13.85	21.0	66.08	100.0
	TOTAL	66.08	100.0		
	Loss				

Diameters (Microns)

1% = 1,200

50% = 165

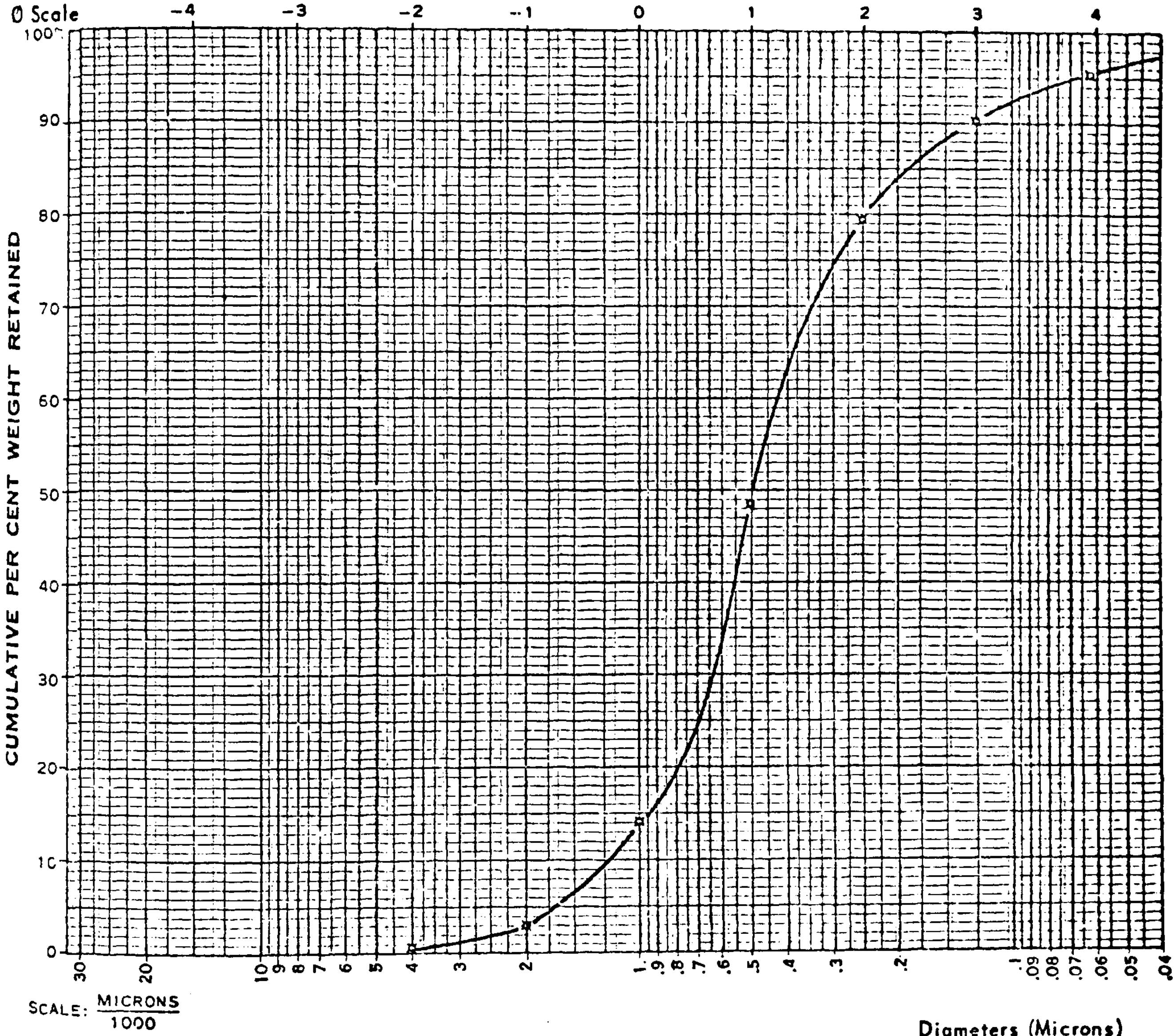
Modal Class (Ø Scale) = (2,3)



Sample No. Open Pit-4

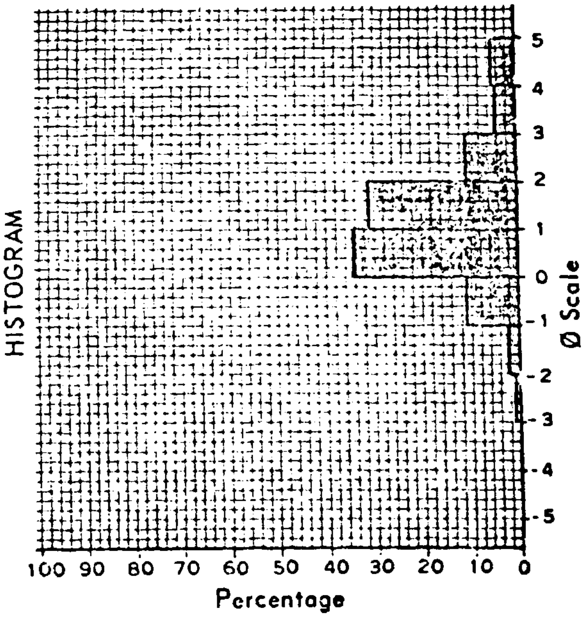
Screen Analysis

Sand



1% = 3,250
50% = 500
Modal Class (Ø Scale) = (0, 1)

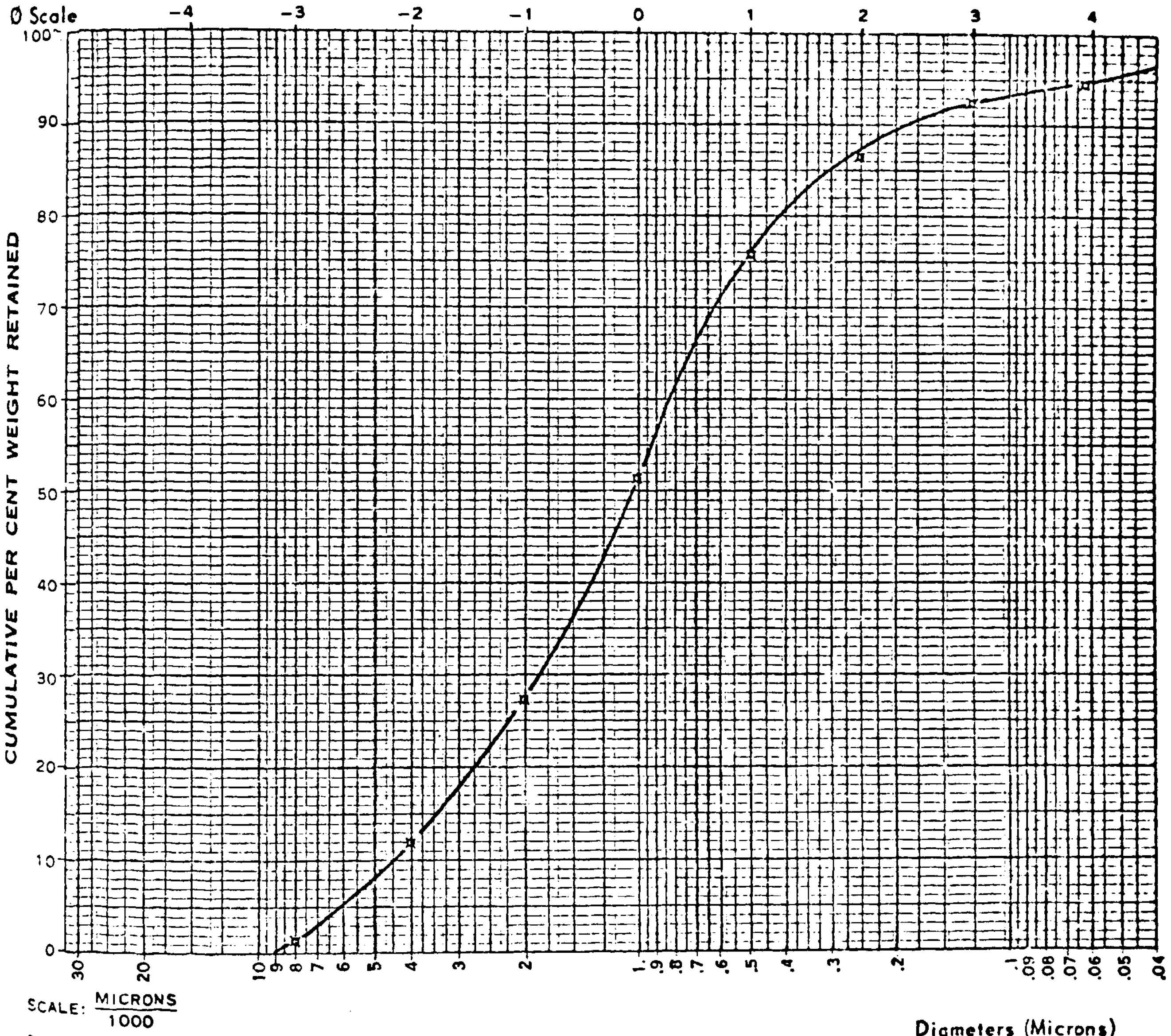
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2	0.64	0.8	0.64	0.8
2	-1	1.62	2.1	2.26	3.0
1.00	0.00	8.44	11.2	10.70	14.1
(1/2) 0.5	1.00	25.90	34.2	36.60	48.4
(1/4) 0.250	2.00	23.51	31.1	60.11	79.5
(1/8) 0.125	3.00	8.55	11.3	68.66	90.8
(1/16) 0.062	4.00	3.26	4.3	71.92	95.1
Pan		3.70	4.9	75.62	100.0
	TOTAL	75.62	99.9		
	Loss				



Sample No. Open Pit-5

Screen Analysis

Gravelly Sand



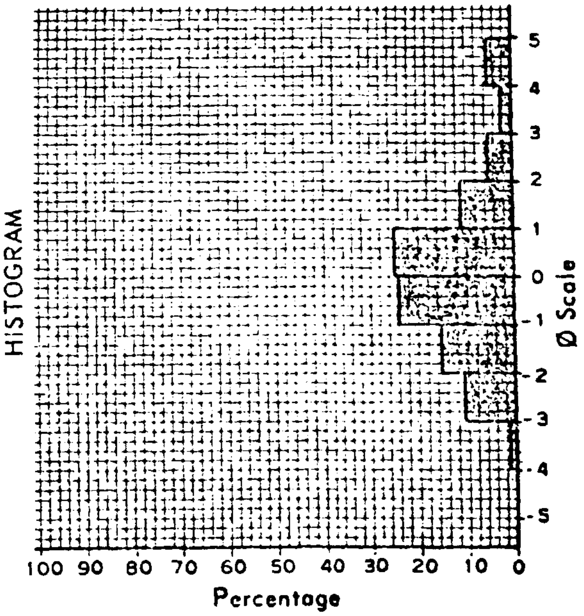
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3	1.04	1.4	1.04	1.4
4	-2	8.03	10.6	9.07	12.0
2	-1	11.60	15.3	20.67	27.3
1.00	0.00	18.16	24.0	38.83	51.2
(1/2) 0.5	1.00	18.75	24.7	57.58	75.9
(1/4) 0.250	2.00	8.34	11.0	65.92	86.9
(1/8) 0.125	3.00	4.30	5.7	70.22	92.6
(1/16) 0.062	4.00	1.60	2.1	71.82	94.7
Pan		4.00	5.3	75.82	100.0
TOTAL		75.82	100.1		
Loss					

Diameters (Microns)

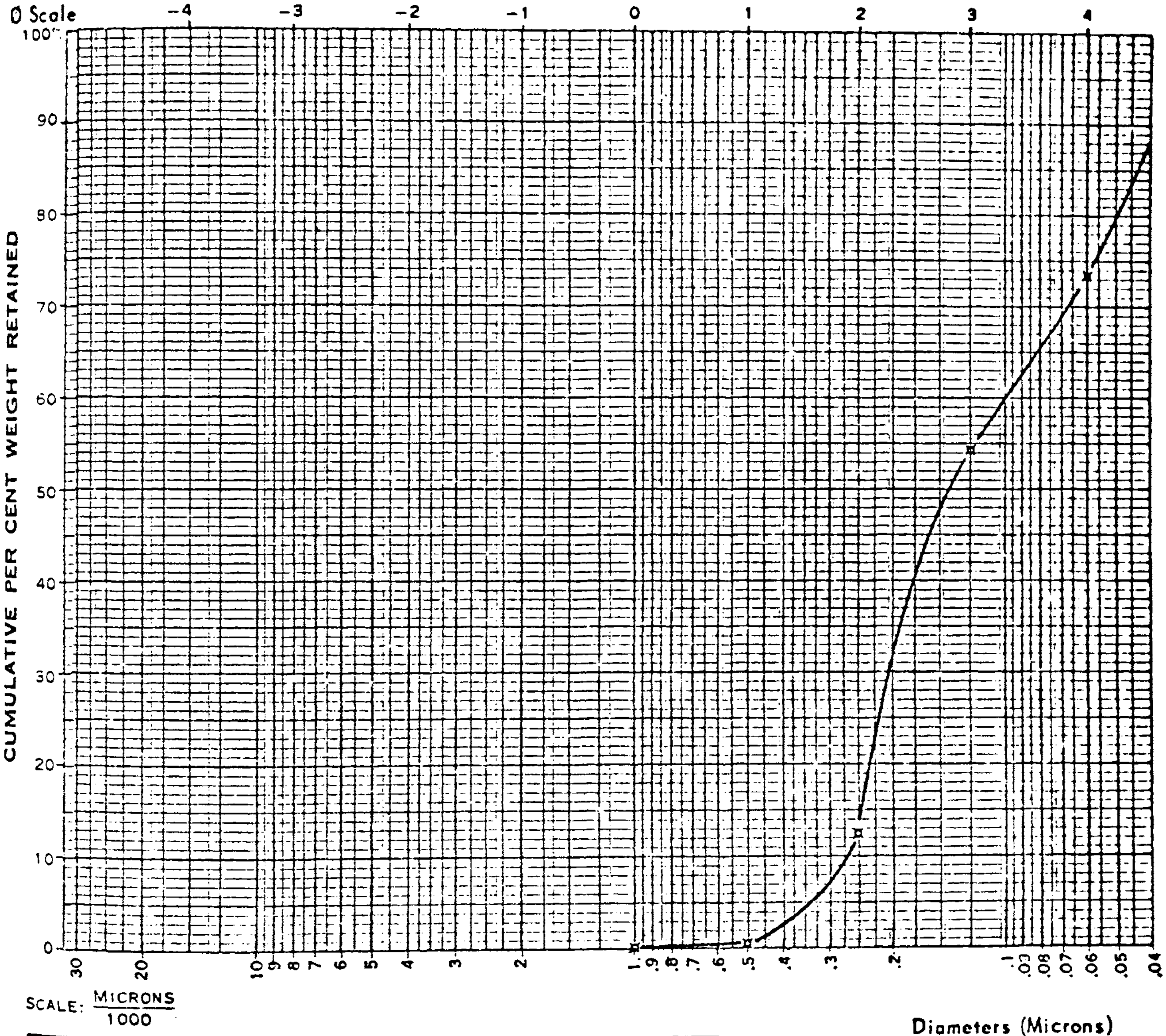
1% = 8,400

50% = 1,050

Modal Class (Ø Scale) = (0,1)



Sample No. Open Pit-8 **Screen Analysis** Muddy Sand



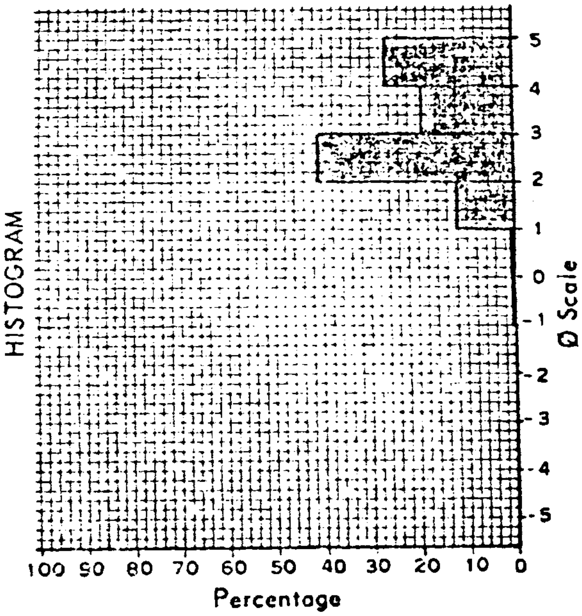
Diameters (Microns)

1% = 460

50% = 140

Modal Class (Ø Scale) = (2,3)

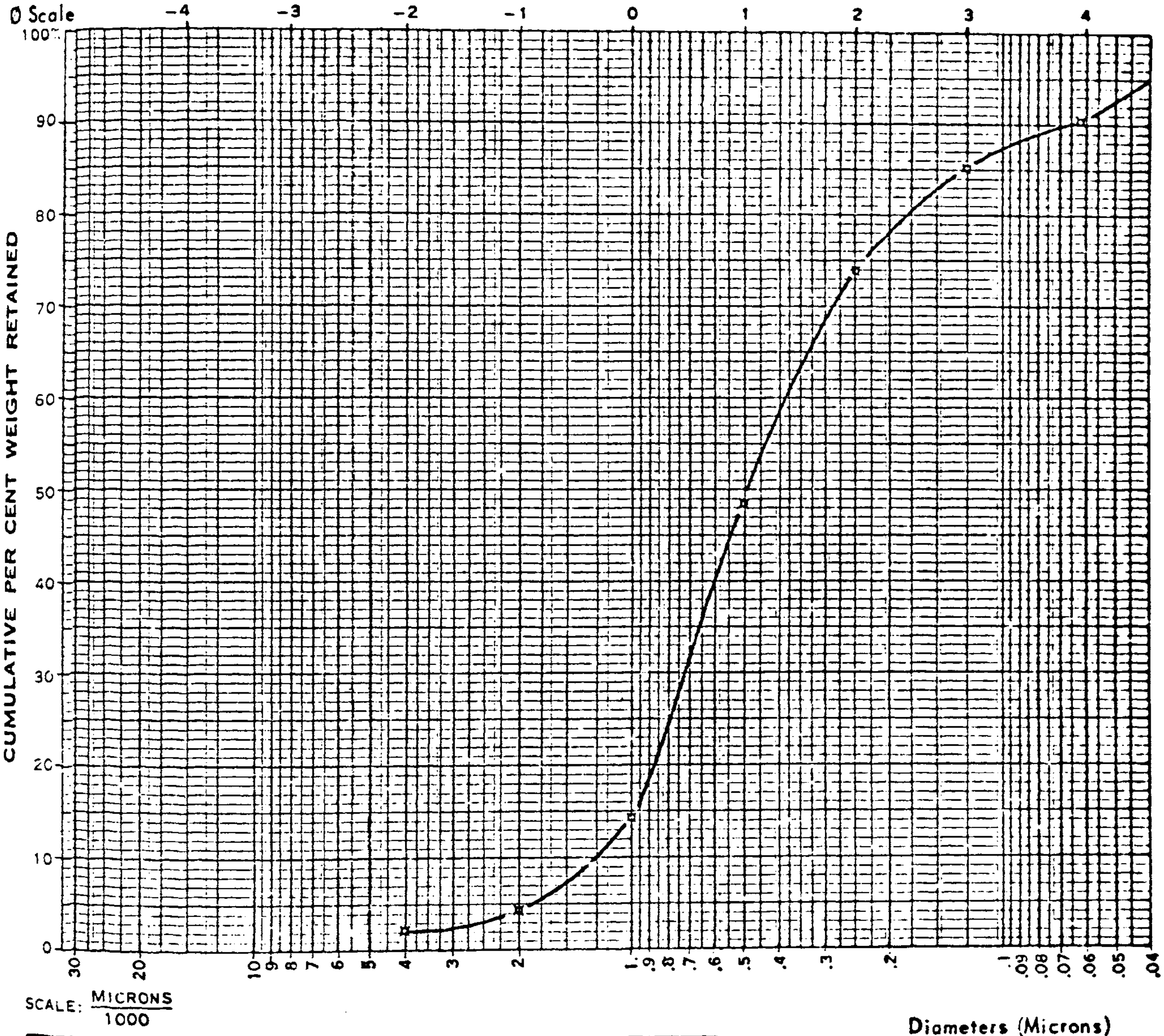
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2				
2	-1				
1.00	0.00	0.10	0.1	0.10	0.1
(1/2) 0.5	1.00	0.26	0.4	0.36	0.5
(1/4) 0.250	2.00	8.29	12.0	8.65	12.5
(1/8) 0.125	3.00	28.83	41.6	37.48	54.1
(1/16) 0.062	4.00	13.34	19.2	50.82	73.3
Pan		18.46	26.6	69.28	100.0
	TOTAL	69.23	99.9		
	Loss				



Sample No. Open Pit-9

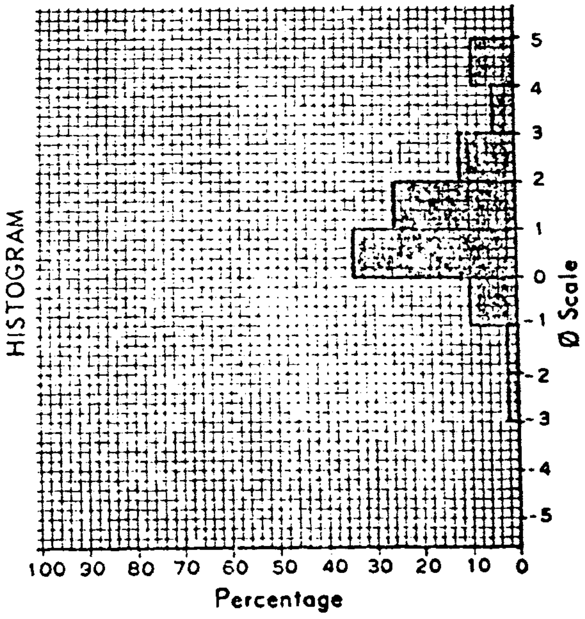
Screen Analysis

Sand



Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2	1.63	2.1	1.63	2.1
2	-1	1.69	2.1	3.32	4.2
1.00	0.00	7.93	10.0	11.25	14.2
(1/2) 0.5	1.00	27.06	34.3	38.31	48.5
(1/4) 0.250	2.00	20.08	25.4	58.39	74.0
(1/8) 0.125	3.00	9.39	11.9	67.78	85.8
(1/16) 0.062	4.00	3.62	4.6	71.40	90.4
Pan		7.55	9.6	78.95	100.0
TOTAL		78.95	100.0		
Loss					

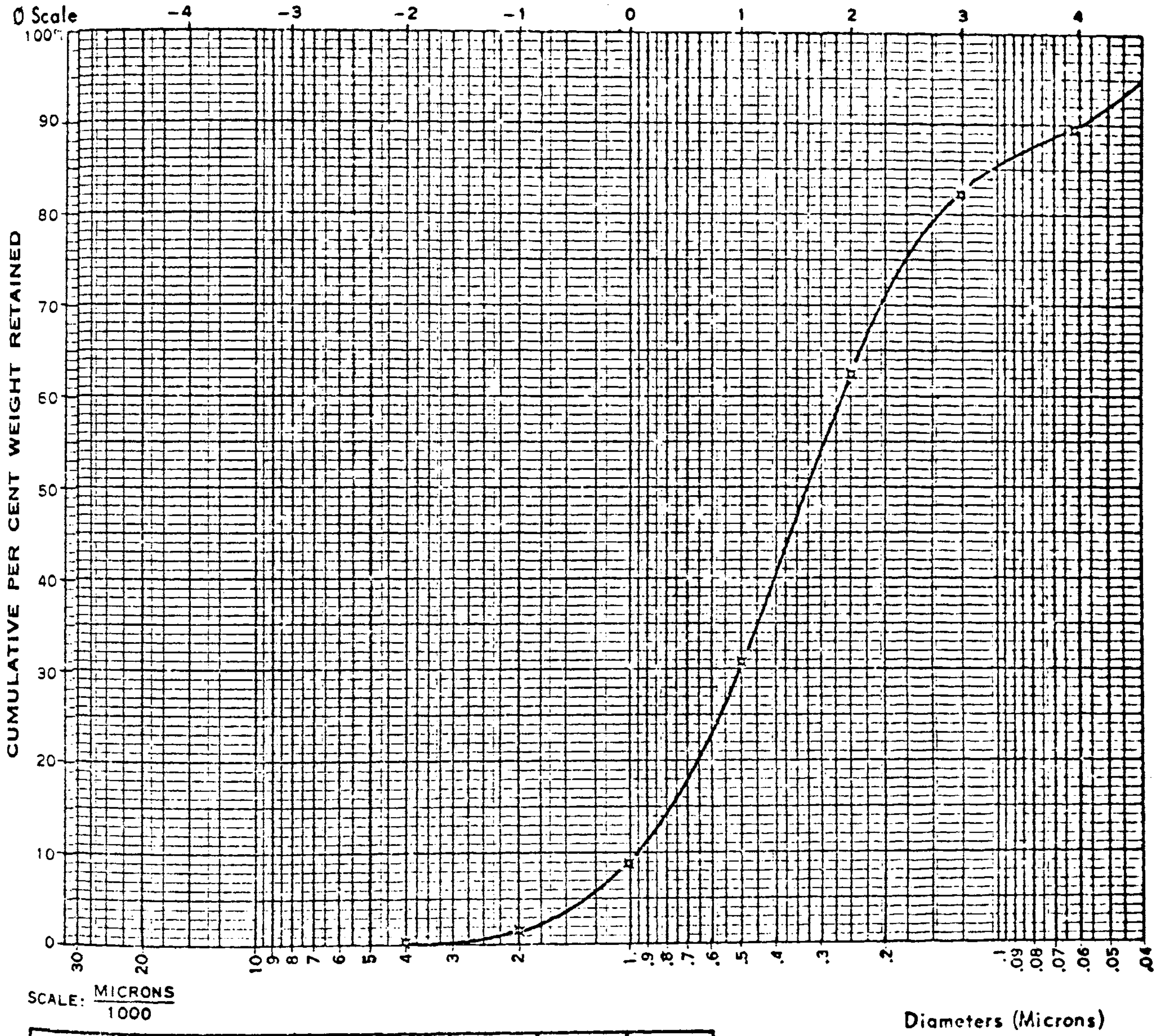
1% =
50% = 490
Modal Class (Ø Scale) = (0, 1)



Sample No. Open Pit-10

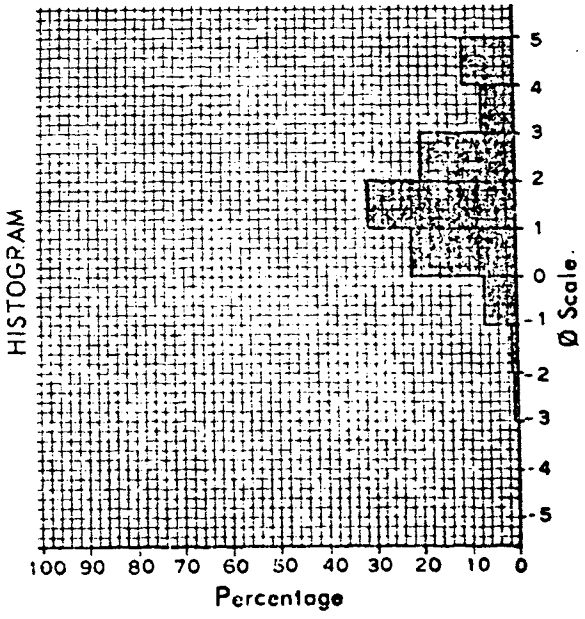
Screen Analysis

Sand



Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2	0.22	0.3	0.22	0.3
2	-1	1.00	1.3	1.22	1.6
1.00	0.00	5.30	7.1	6.52	8.8
(1/2) 0.5	1.00	16.35	22.0	22.87	30.8
(1/4) 0.250	2.00	23.53	31.7	46.40	62.5
(1/8) 0.125	3.00	14.70	19.8	61.10	82.3
(1/16) 0.062	4.00	5.15	6.9	66.25	89.3
Pan		7.96	10.7	74.21	100.0
	TOTAL	74.21	99.8		
	Loss				

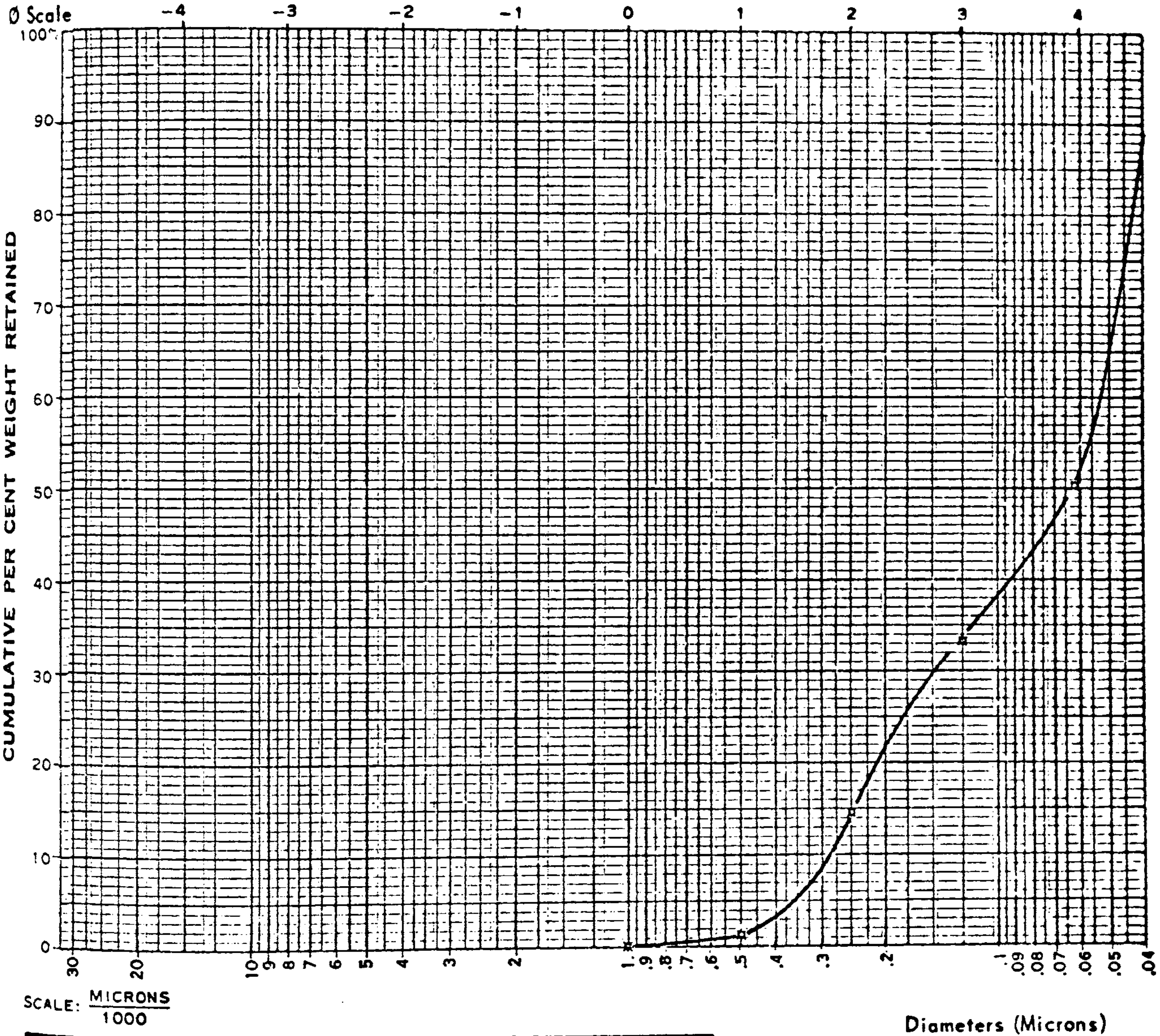
1% = 2,250
50% = 325
Modal Class (Ø Scale) = (1,2)



Sample No. Open Pit-12

Screen Analysis

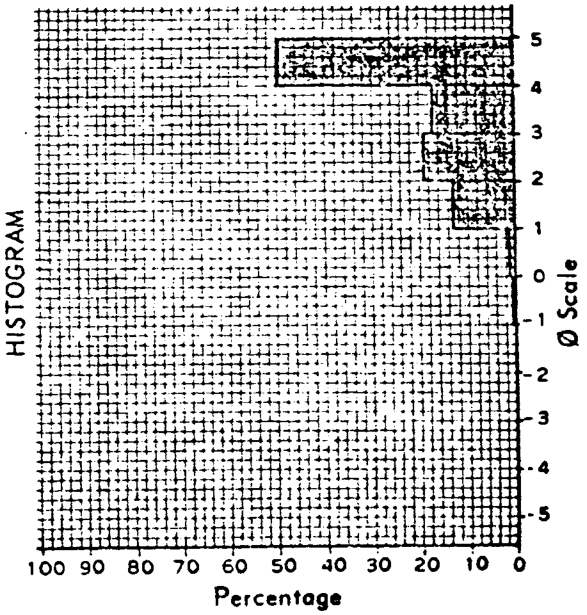
Muddy Sand



Diameters (Microns)

1% = 550
50% = 61
Modal Class (Ø Scale) = (4,5) Pan

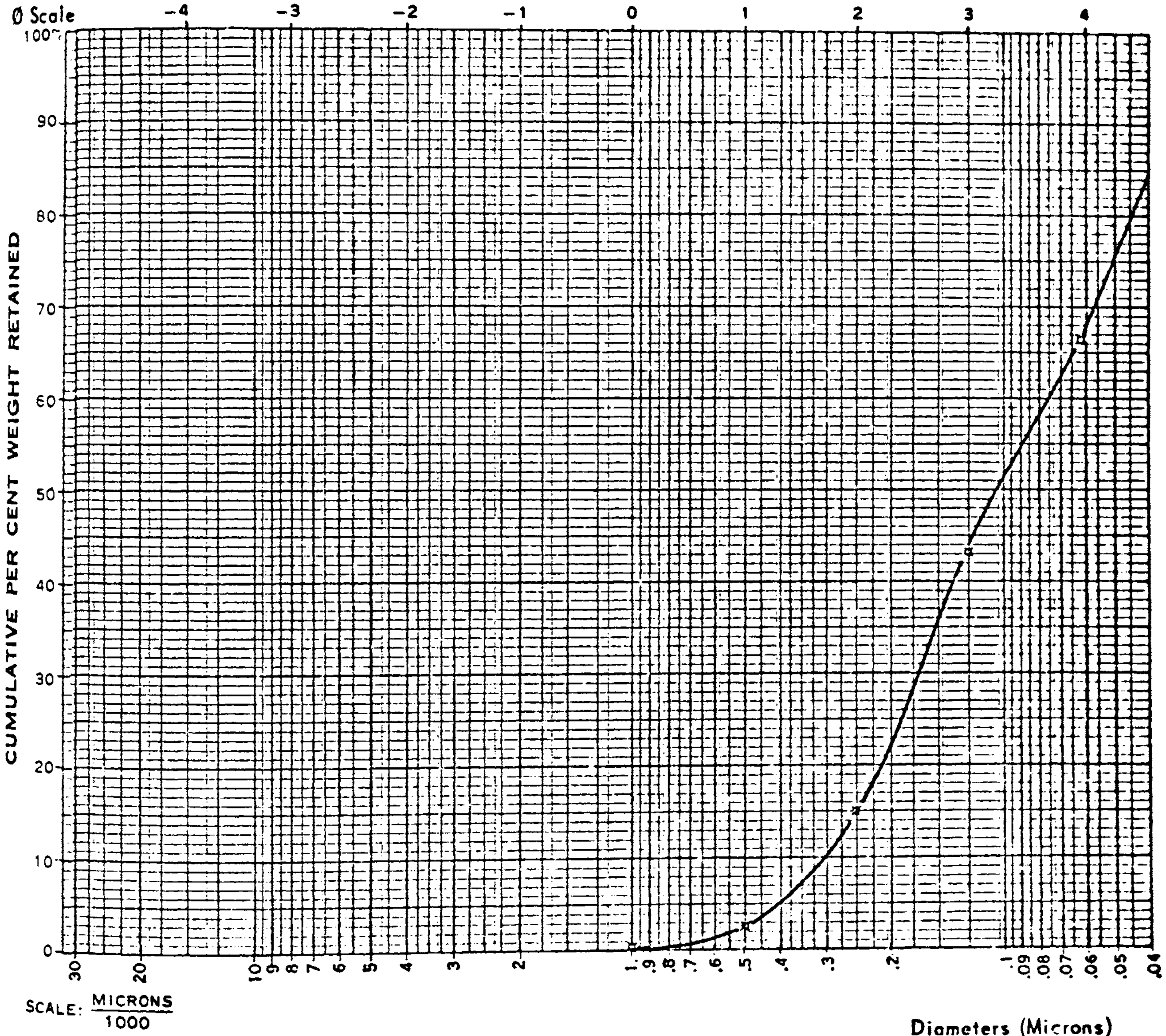
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2				
2	-1				
1.00	0.00	0.09	0.1	0.09	0.1
(1/2) 0.5	1.00	0.71	1.2	0.80	1.4
(1/4) 0.250	2.00	7.61	13.0	8.41	14.4
(1/8) 0.125	3.00	10.96	18.8	19.37	33.2
(1/16) 0.062	4.00	10.00	17.1	29.37	50.3
Pan		29.03	49.7	58.40	100.0
	TOTAL	58.40	99.9		
	Loss				



Muddy Sand

Sample No. Open Pit-13

Screen Analysis



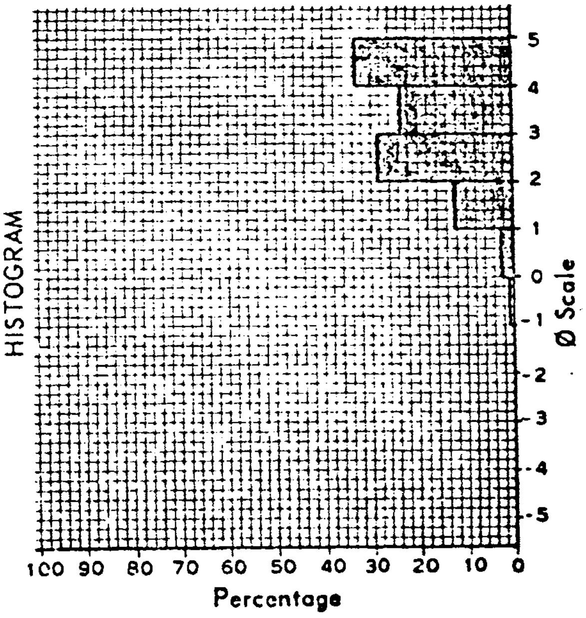
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2				
2	-1				
1.00	0.00	0.32	0.4	0.32	0.4
(1/2) 0.5	1.00	1.70	2.2	2.02	2.7
(1/4) 0.250	2.00	9.27	12.3	11.29	15.0
(1/8) 0.125	3.00	21.27	28.2	32.56	43.2
(1/16) 0.062	4.00	17.70	23.5	50.26	66.6
Pan		25.16	33.4	75.42	100.0
	TOTAL	75.42	100.0		
	Loss				

Diameters (Microns)

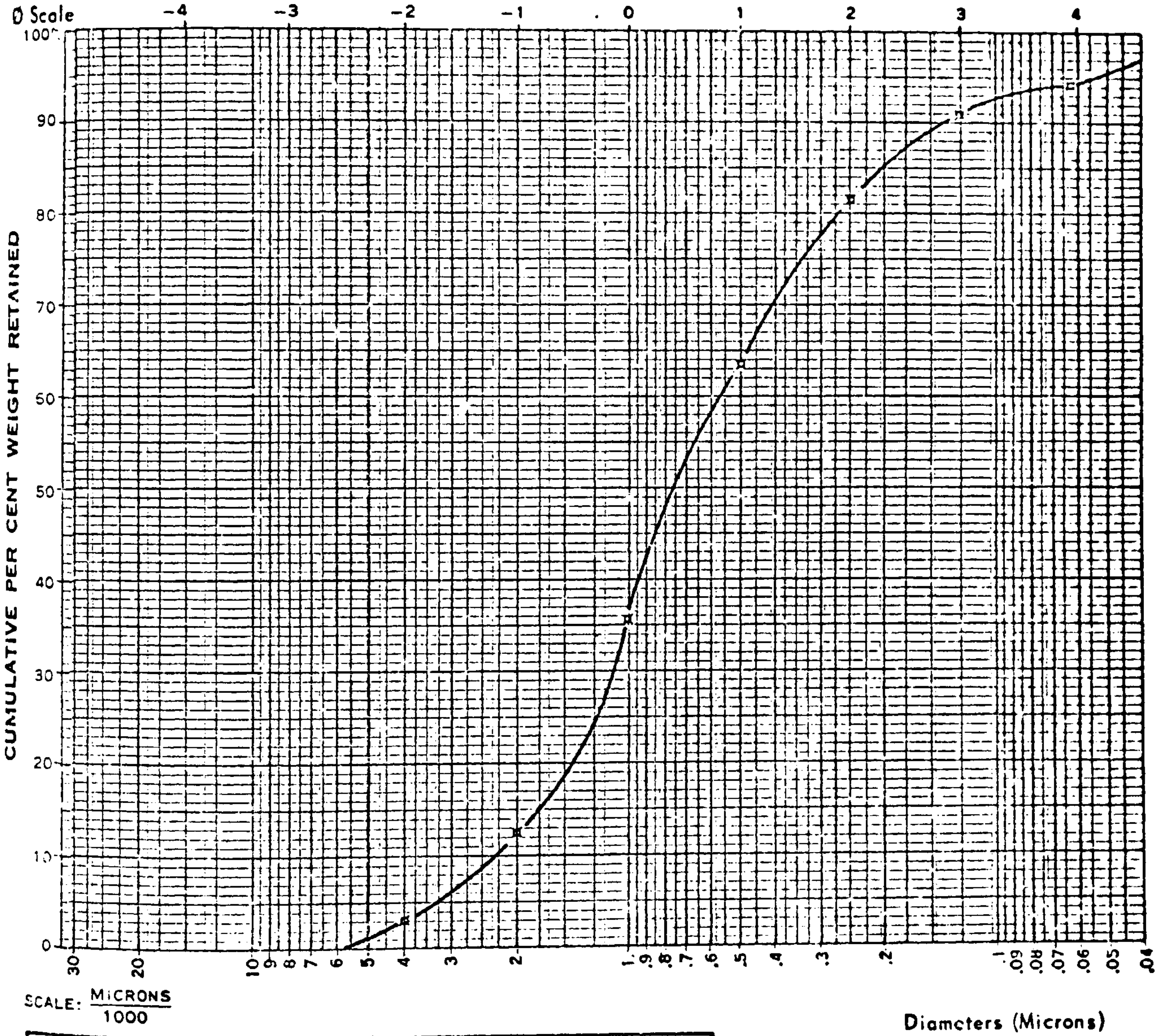
1% = 650

50% = 105

Modal Class (Ø Scale) = Pan (4,5) (2,3)

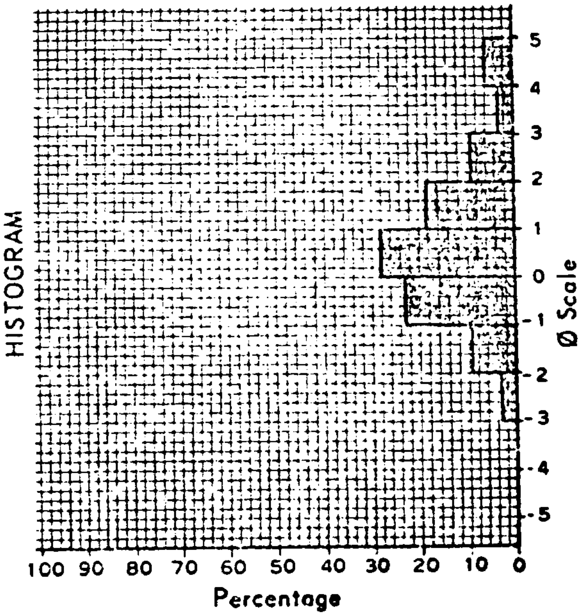


Sample No. Open Pit-14 **Screen Analysis** Gravelly Sand



Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2	2.40	3.1	2.40	3.1
2	-1	7.29	9.5	9.69	12.6
1.00	0.00	17.64	23.0	27.33	35.6
(1/2) 0.5	1.00	21.64	28.2	48.97	63.8
(1/4) 0.250	2.00	13.89	18.1	62.86	81.9
(1/8) 0.125	3.00	7.05	9.2	69.91	91.0
(1/16) 0.062	4.00	2.35	3.1	72.26	94.1
Pan		4.52	5.9	76.78	100.0
	TOTAL	76.78	100.1		
	Loss				

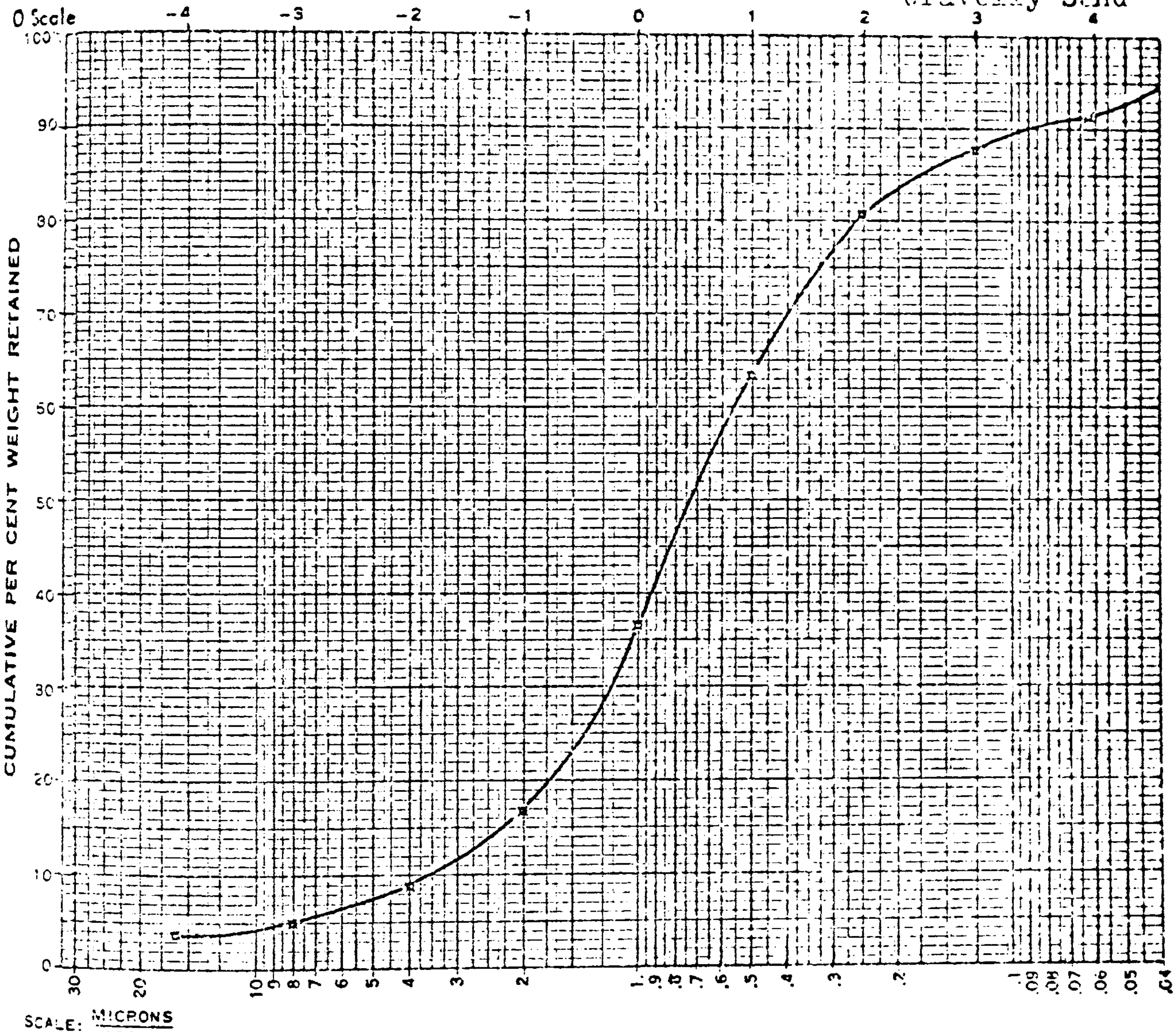
1% = 5,000
50% = 750
Modal Class (Ø Scale) = (0, 1)



Sample No. S 1-1

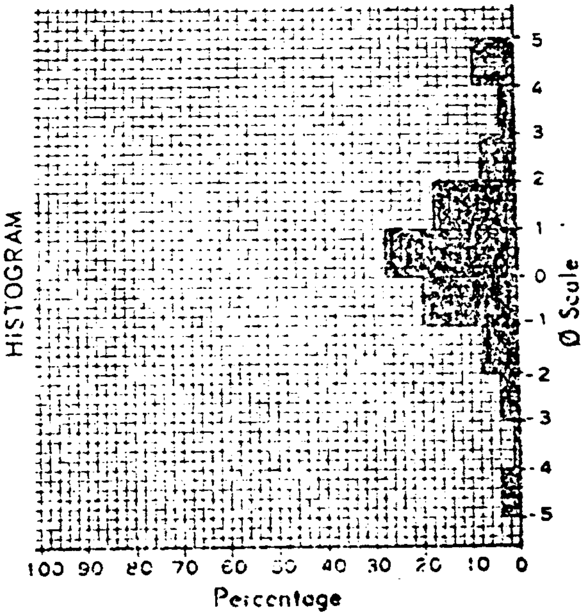
Screen Analysis

Gravelly Sand



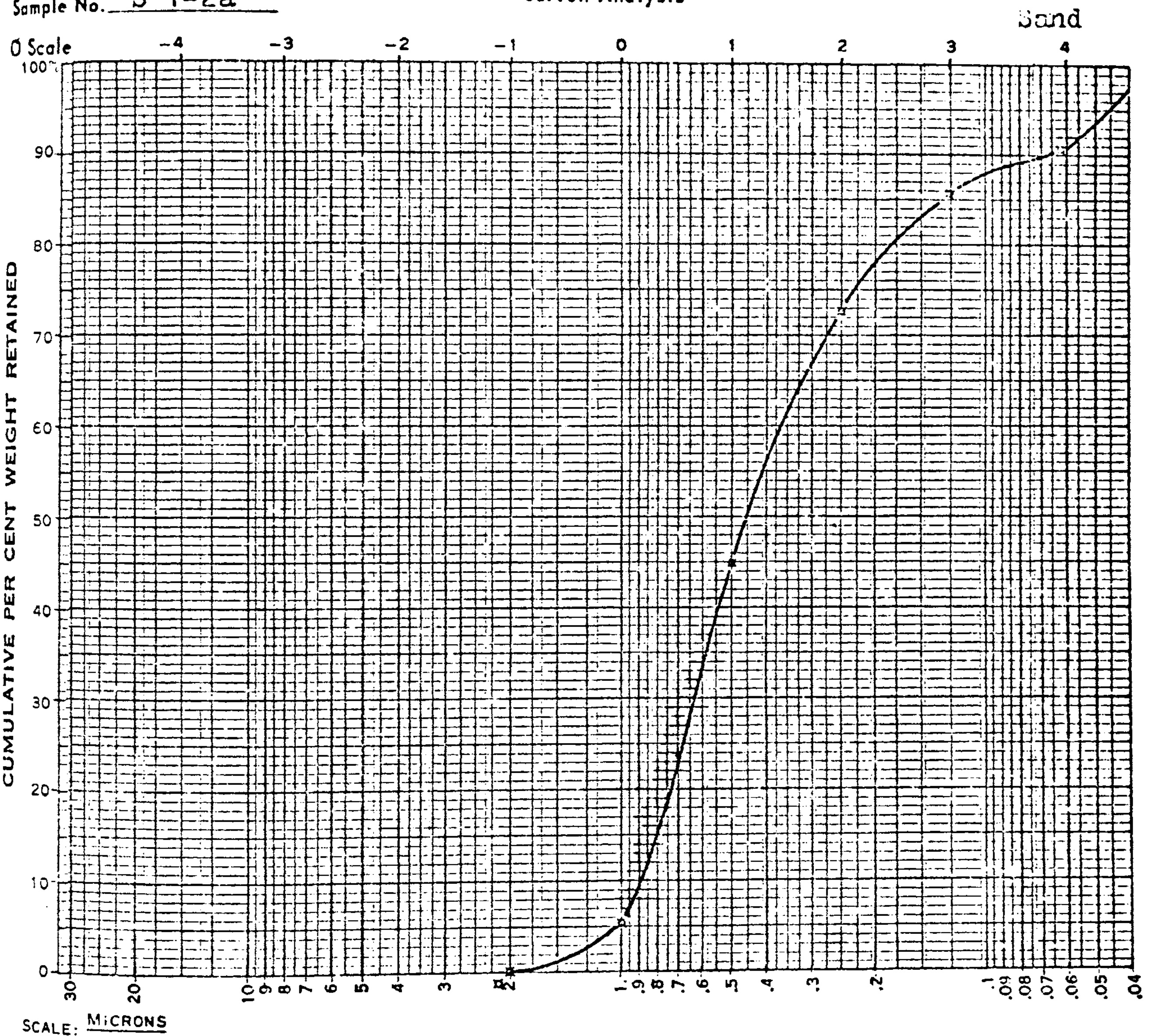
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4	3.54	3.9	3.54	3.9
8	-3	0.97	1.1	4.51	5.0
4	-2	3.50	3.9	8.01	8.9
2	-1	7.00	7.8	15.01	16.7
1.00	0.00	17.82	19.8	32.83	36.5
(1/2) 0.5	1.00	24.55	27.3	57.38	63.7
(1/4) 0.250	2.00	14.97	16.6	72.35	80.4
(1/8) 0.125	3.00	6.74	7.5	79.09	87.9
(1/16) 0.062	4.00	3.08	3.4	82.17	91.3
Pan		7.83	8.7	90.00	100.0
	TOTAL	90.00	100.0		
	Loss				

1% =
50% = 730
Modal Class (Ø Scale) = (0, 1)



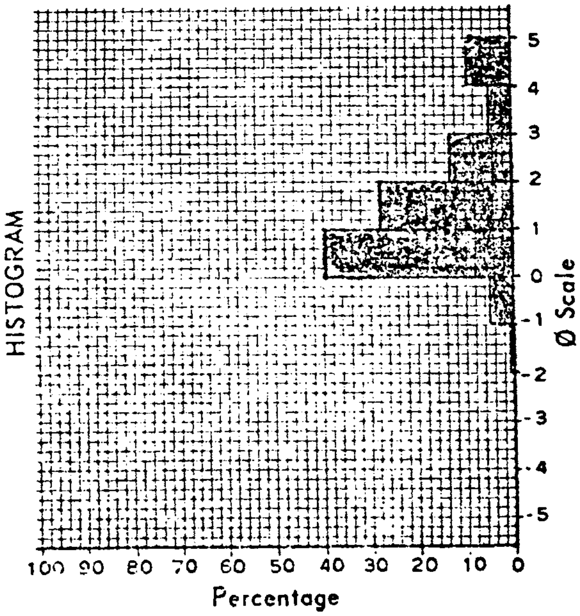
Sample No. S 1-2a

Screen Analysis



Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2				
2	-1	0.30	0.3	0.30	0.3
1.00	0.00	4.54	5.1	4.84	5.4
(1/2) 0.5	1.00	35.40	39.5	40.24	44.9
(1/4) 0.250	2.00	24.94	27.8	65.18	72.8
(1/8) 0.125	3.00	11.51	12.9	76.69	85.6
(1/16) 0.062	4.00	4.37	4.9	81.06	90.5
Pan		8.51	9.5	89.57	100.0
	TOTAL	89.57	100.0		
	Loss				

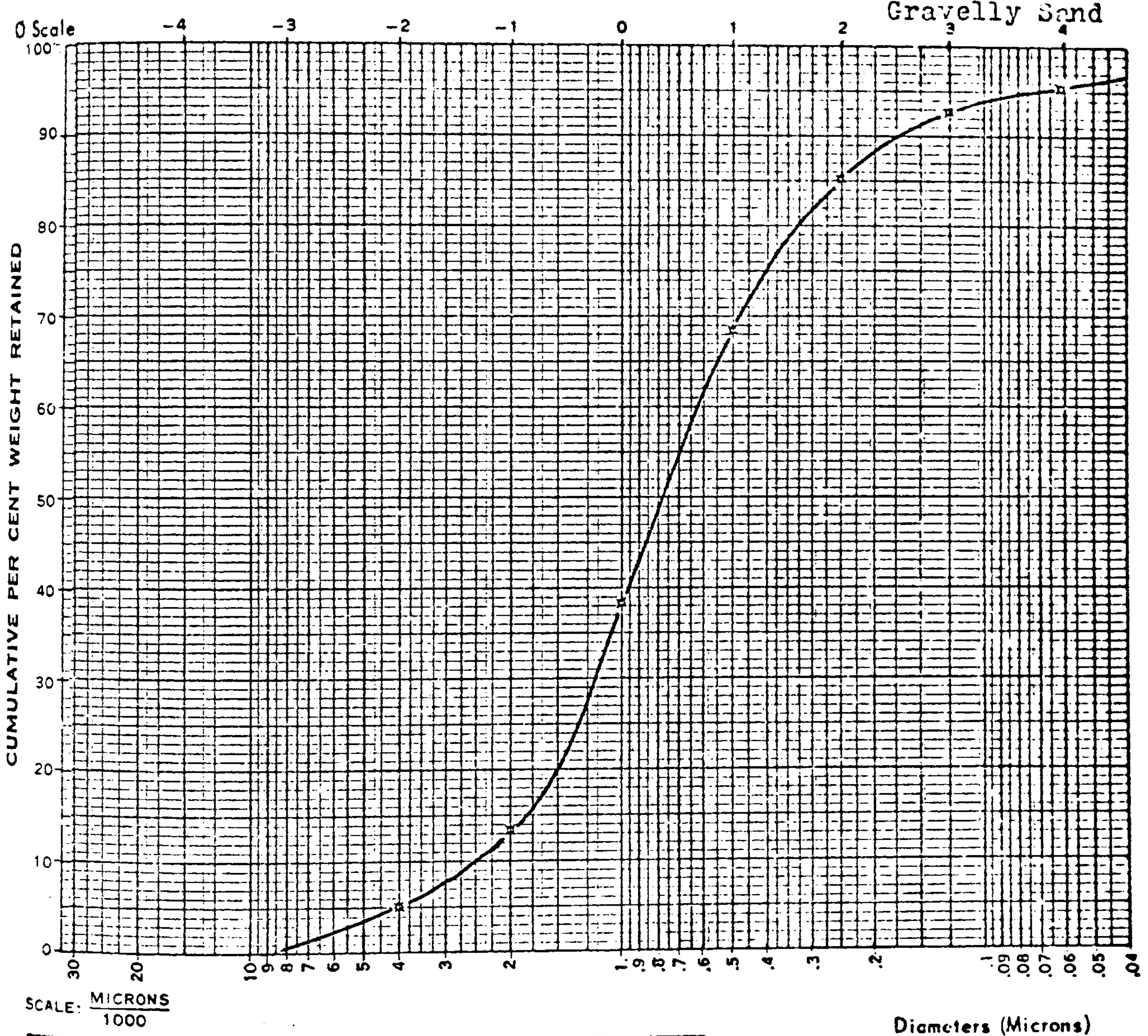
1% = 1,500
50% = 450
Modal Class (Ø Scale) = (0, 1)



Sample No. S 1-2b

Screen Analysis

Gravelly Sand

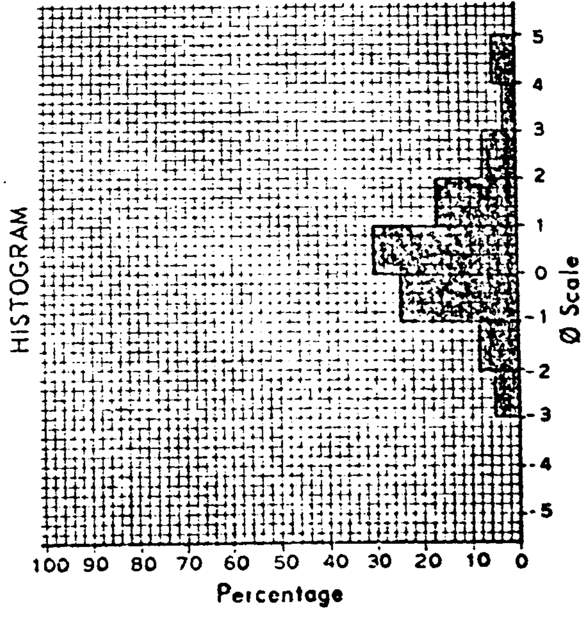


Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2	4.05	5.1	4.05	5.1
2	-1	6.77	8.5	10.82	13.6
1.00	0.00	19.59	24.6	30.41	38.2
(1/2) 0.5	1.00	24.16	30.3	54.57	68.5
(1/4) 0.250	2.00	13.33	16.7	67.90	85.3
(1/8) 0.125	3.00	5.88	7.4	73.78	92.7
(1/16) 0.062	4.00	2.20	2.8	75.98	95.4
Pan		3.63	4.6	79.61	100.0
	TOTAL	79.61	100.0		
	Loss				

1% = 7,500

50% = 757

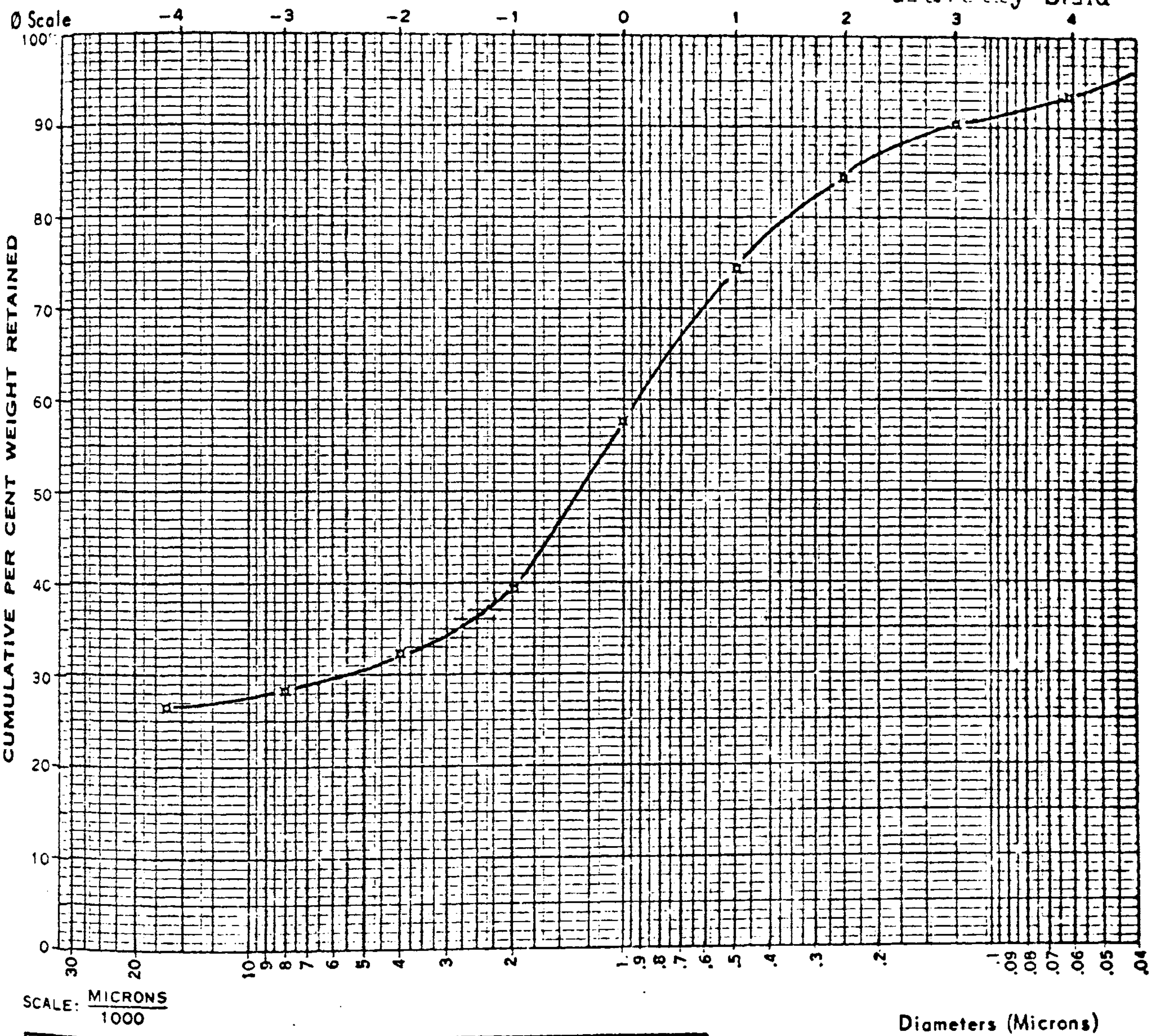
Modal Class (Ø Scale) = (0,1)



Sample No. S 1-3

Screen Analysis

Gravelly Sand

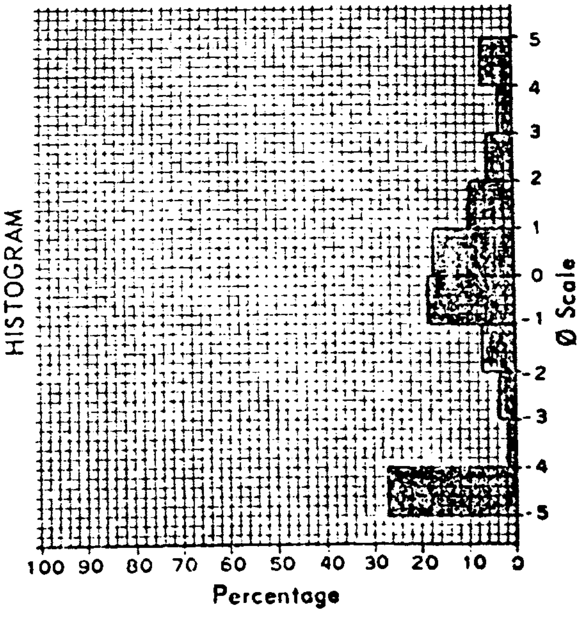


Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4	19.78	26.5	19.78	26.5
8	-3	1.45	1.9	21.23	28.4
4	-2	2.85	3.8	24.08	32.3
2	-1	5.42	7.3	29.50	39.5
1.00	0.00	13.56	18.2	43.06	57.7
(1/2) 0.5	1.00	12.85	17.2	55.91	74.9
(1/4) 0.250	2.00	7.20	9.6	63.11	84.6
(1/8) 0.125	3.00	4.21	5.6	67.32	90.2
(1/16) 0.062	4.00	2.35	3.1	69.67	93.4
Pan		4.95	6.6	74.62	100.0
	TOTAL	74.62	99.8		
	Loss				

1% =

50% = 1,300

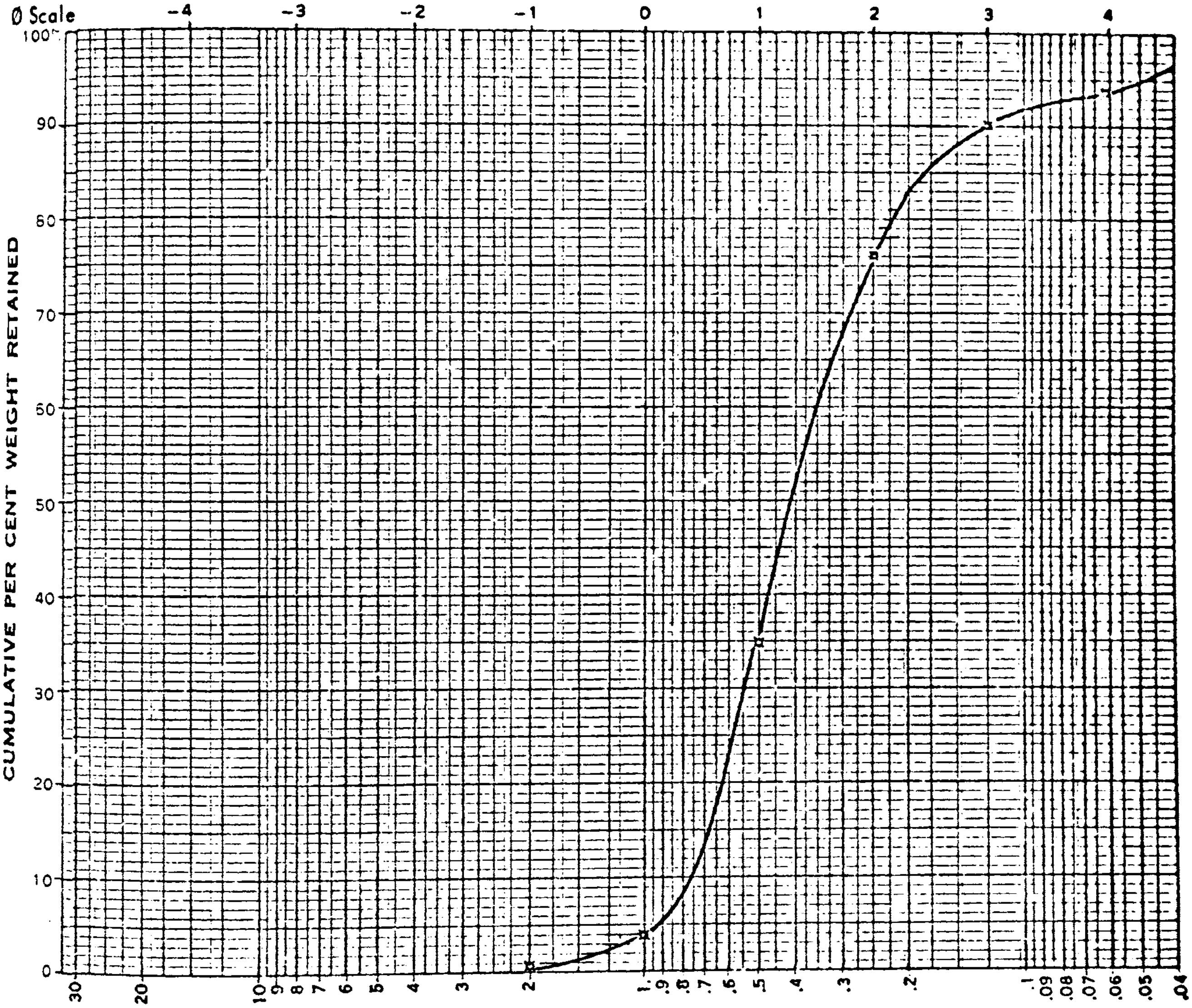
Modal Class (Ø Scale) = (-5,-4)(-1,0)



Sample No. S 1-5

Screen Analysis

Sand



SCALE: $\frac{\text{MICRONS}}{1000}$

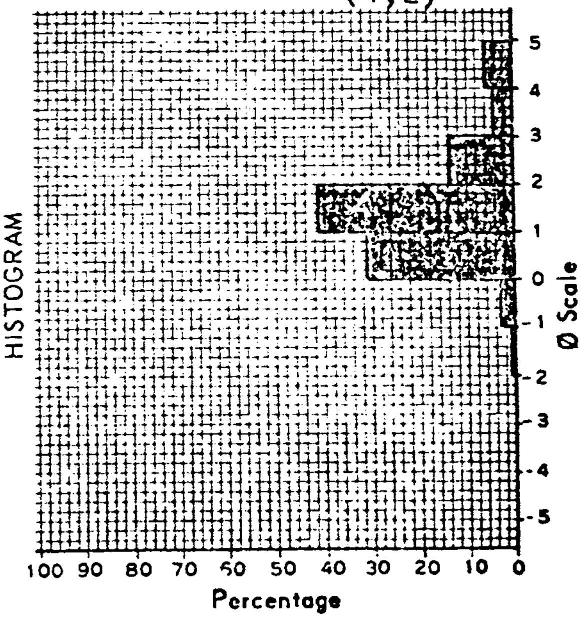
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2				
2	-1	0.55	0.7	0.55	0.7
1.00	0.00	2.41	3.0	2.96	3.7
(1/2) 0.5	1.00	24.81	31.1	27.77	34.
(1/4) 0.250	2.00	33.09	41.4	60.86	76.2
(1/8) 0.125	3.00	11.02	13.8	71.88	90.0
(1/16) 0.062	4.00	3.26	4.1	75.14	94.1
Pan		4.74	5.9	79.88	100.0
	TOTAL	79.88	100.0		
	Loss				

Diameters (Microns)

1% = 1,600

50% = 410

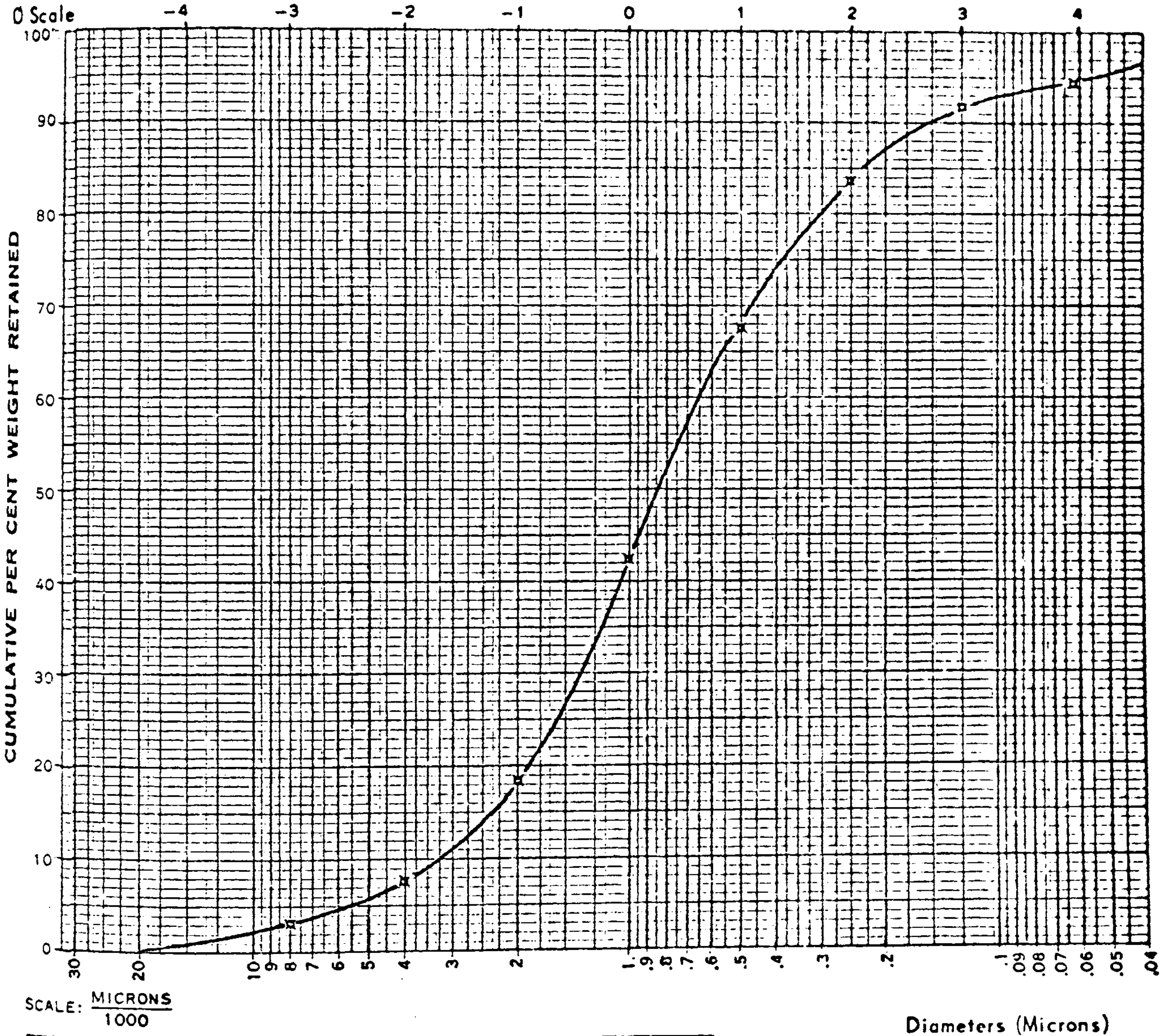
Modal Class (Ø Scale) = (1,2)



Sample No. S 1-6

Screen Analysis

Gravelly Sand



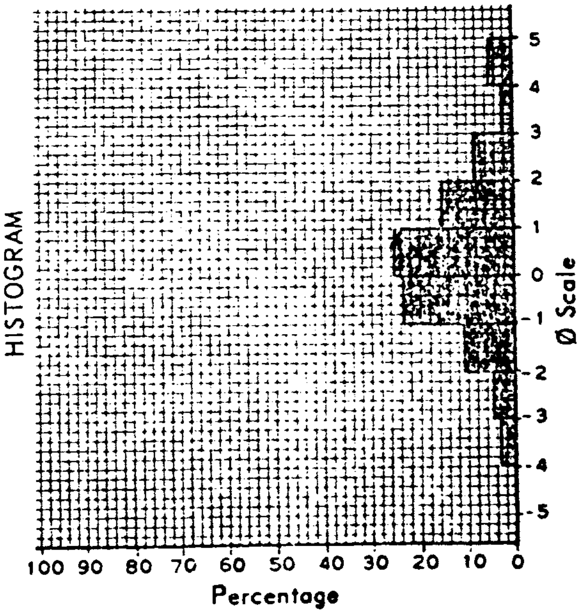
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3	2.46	3.3	2.46	3.3
4	-2	3.37	4.6	5.83	7.9
2	-1	8.02	10.9	13.85	18.8
1.00	0.00	17.39	23.6	31.24	42.5
(1/2) 0.5	1.00	18.76	25.5	50.00	67.9
(1/4) 0.250	2.00	11.49	15.6	61.49	83.6
(1/8) 0.125	3.00	6.23	8.5	67.72	92.0
(1/16) 0.062	4.00	1.30	2.4	69.52	94.5
Pan		4.06	5.5	73.58	100.0
	TOTAL	73.58	99.9		
	Loss				

Diameters (Microns)

1% = 15,000

50% = 850

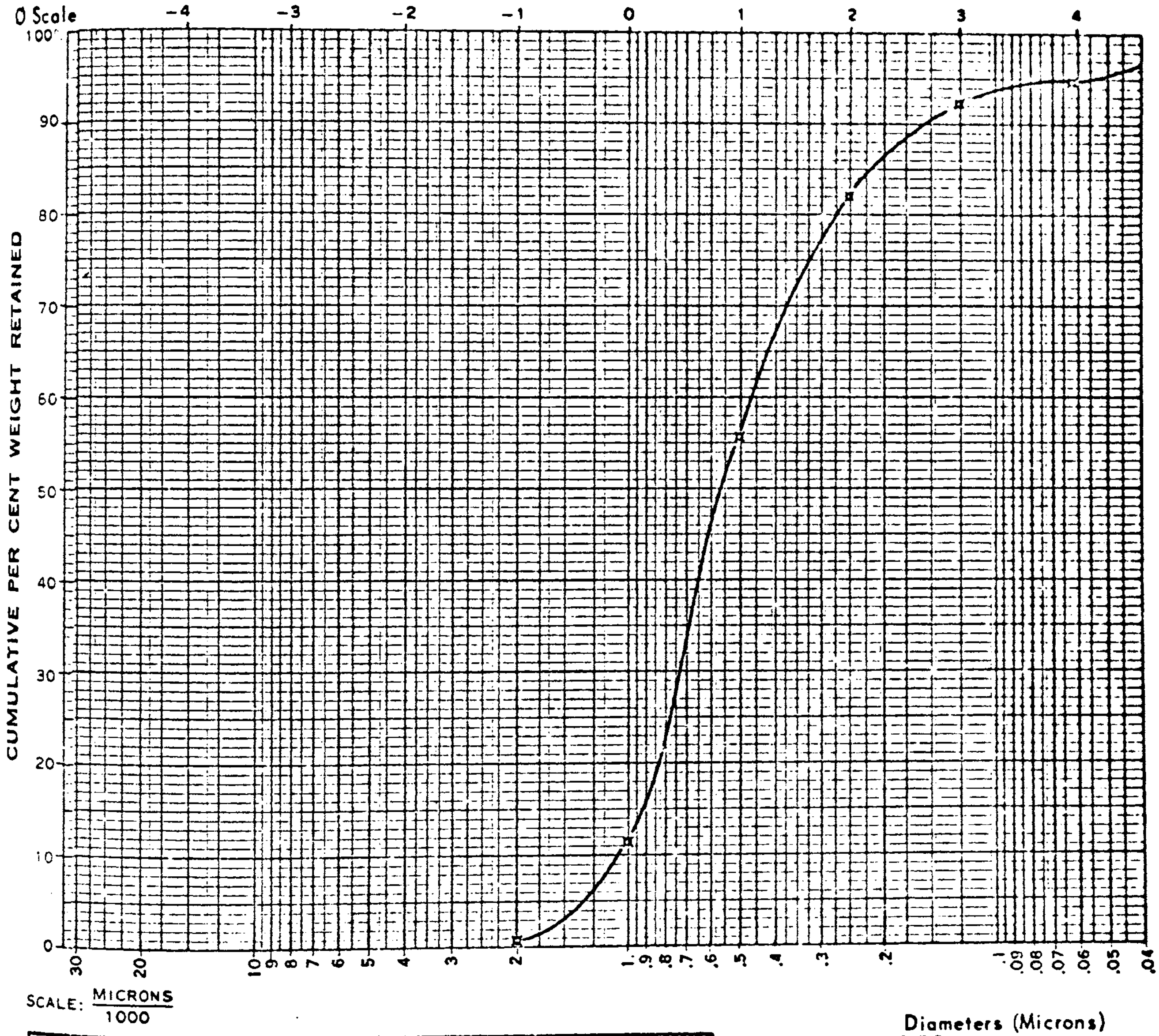
Modal Class (Ø Scale) = (0, 1)



Sample No. S 1-7

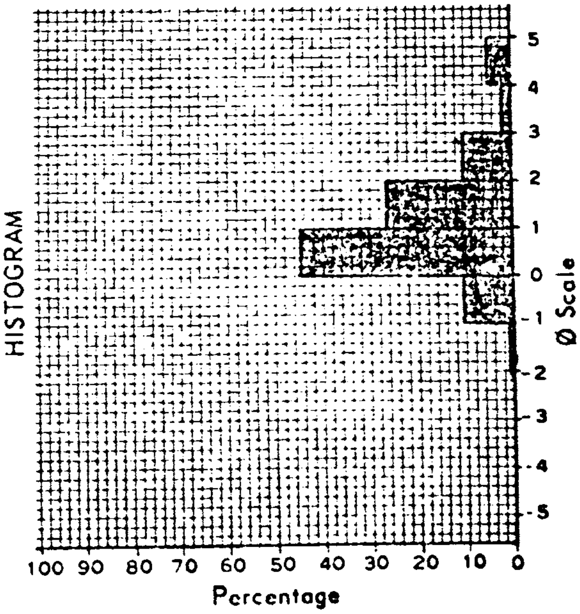
Screen Analysis

Sand



Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2				
2	-1	0.64	0.8	0.64	0.8
1.00	0.00	8.03	10.5	8.67	11.4
(1/2) 0.5	1.00	33.98	44.5	42.65	55.9
(1/4) 0.250	2.00	19.95	26.2	62.60	82.1
(1/8) 0.125	3.00	7.75	10.2	70.35	92.2
(1/16) 0.062	4.00	2.03	2.7	72.38	94.9
Pan		3.90	5.1	76.28	100.0
	TOTAL	76.28	100.0		
	Loss				

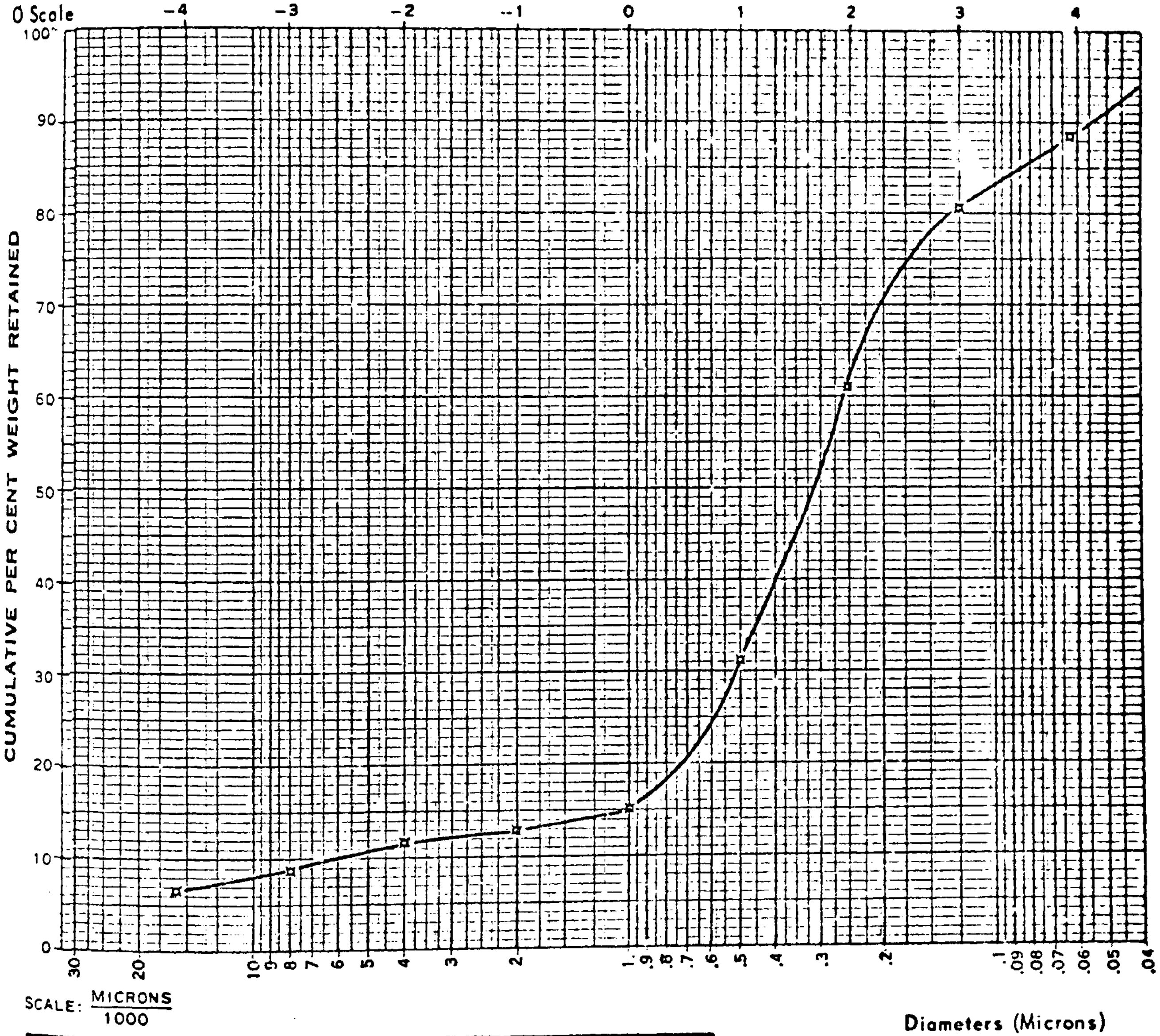
1% = 1,850
50% = 556
Modal Class (Ø Scale) = (0,1)



Sample No. S 1-8

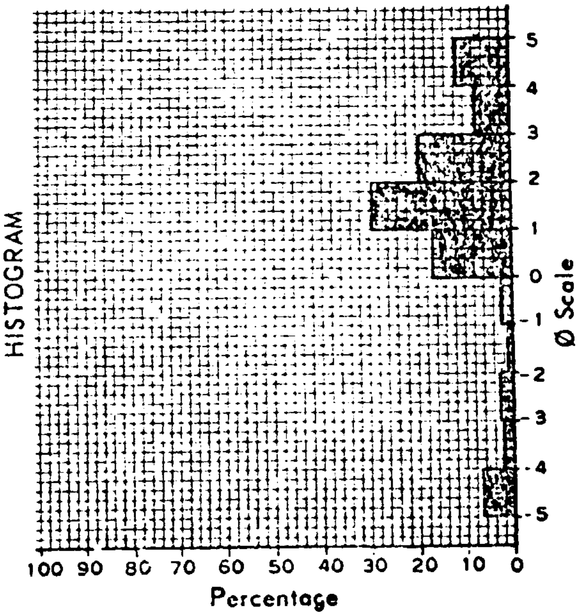
Screen Analysis

Gravelly Sand



Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4	4.80	6.6	4.30	6.6
8	-3	1.67	2.3	6.47	8.8
4	-2	2.22	3.0	8.69	11.9
2	-1	0.71	1.0	9.4	12.9
1.00	0.00	1.58	2.2	10.98	15.0
(1/2) 0.5	1.00	12.00	16.4	22.98	31.4
(1/4) 0.250	2.00	21.67	29.6	44.65	61.1
(1/8) 0.125	3.00	14.30	19.6	58.95	80.6
(1/16) 0.062	4.00	5.61	7.7	64.56	88.3
Pan		8.53	11.7	73.09	100.0
	TOTAL	73.09	100.1		
	Loss				

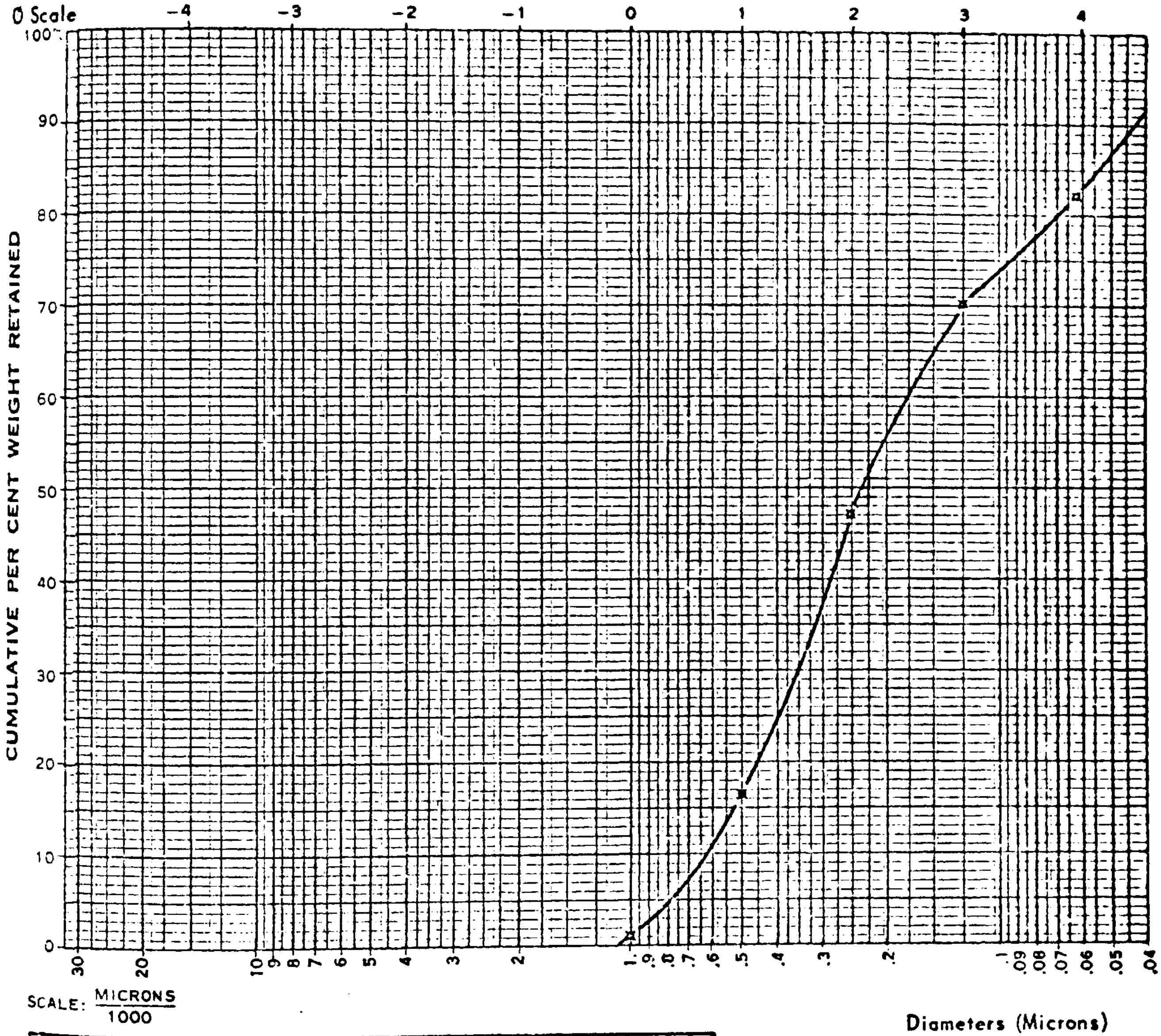
1% =
50% = 320
Modal Class (Ø Scale) = (1,2) (-5,-4)



Sample No. S 1-9

Screen Analysis

Muddy Sand

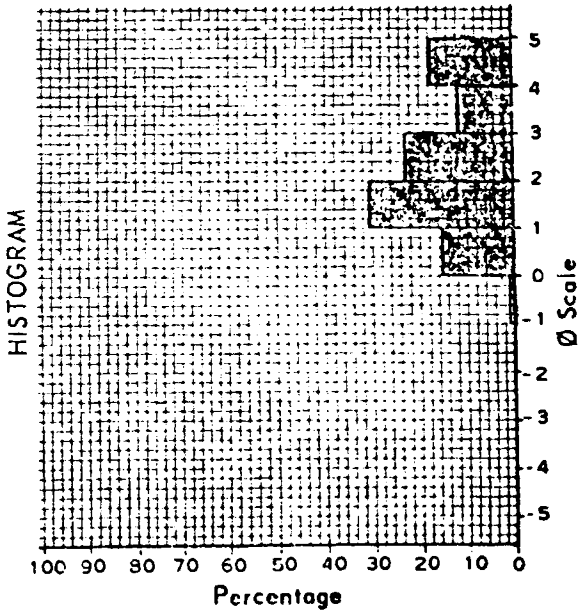


Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2				
2	-1				
1.00	0.00	0.49	1.0	0.49	1.0
(1/2) 0.5	1.00	8.00	15.7	8.49	16.6
(1/4) 0.250	2.00	15.50	30.4	23.99	47.0
(1/8) 0.125	3.00	11.86	23.3	35.85	70.3
(1/16) 0.062	4.00	6.00	11.8	41.85	82.1
Pan		9.14	17.9	50.99	100.
	TOTAL	50.99	100.1		
	Loss				

1% = 1,000

50% = 230

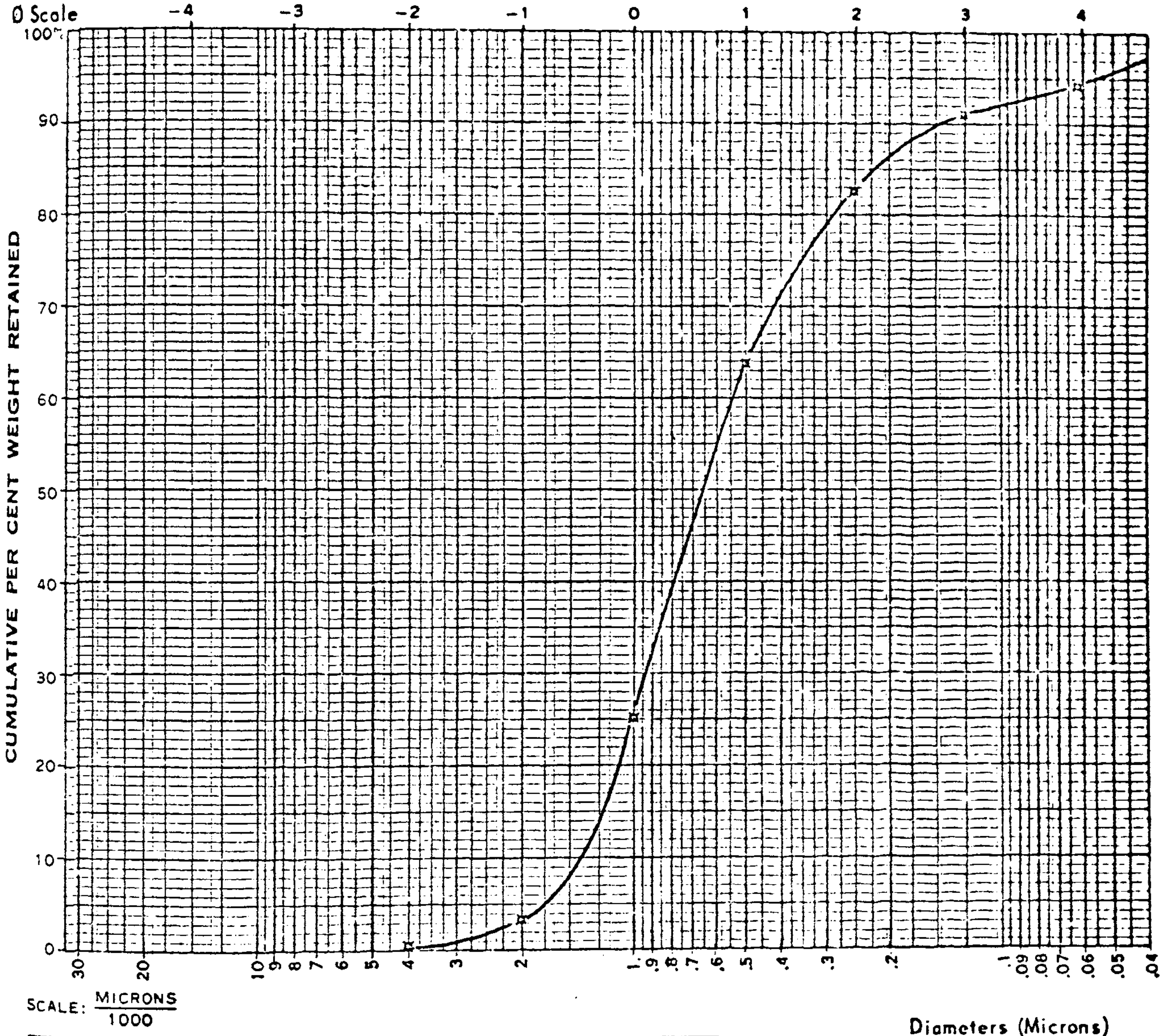
Modal Class (Ø Scale) = (1, 2)



Sand

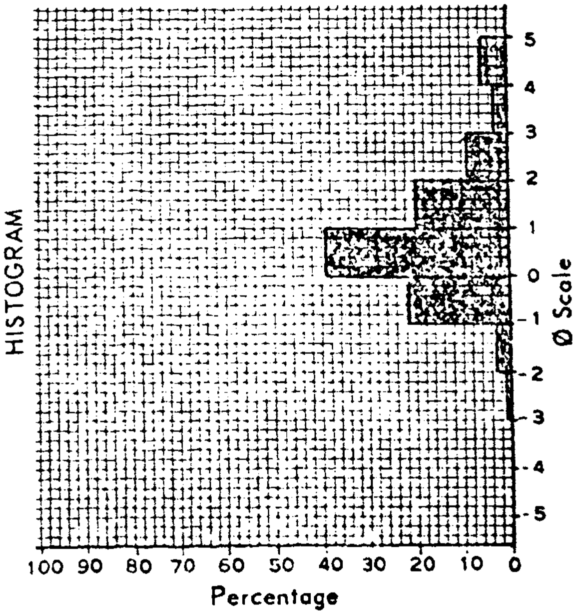
Sample No. S 2-2

Screen Analysis



Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2	0.40	0.5	0.40	0.5
2	-1	2.28	3.0	2.68	3.5
1.00	0.00	16.46	21.6	19.14	25.1
(1/2) 0.5	1.00	29.50	38.7	48.64	63.8
(1/4) 0.250	2.00	14.56	19.1	63.20	82.9
(1/8) 0.125	3.00	6.46	8.5	69.66	91.3
(1/16) 0.062	4.00	2.26	3.0	71.92	94.3
Pan		4.34	5.7	76.26	100.0
TOTAL		76.26	100.1		
Loss					

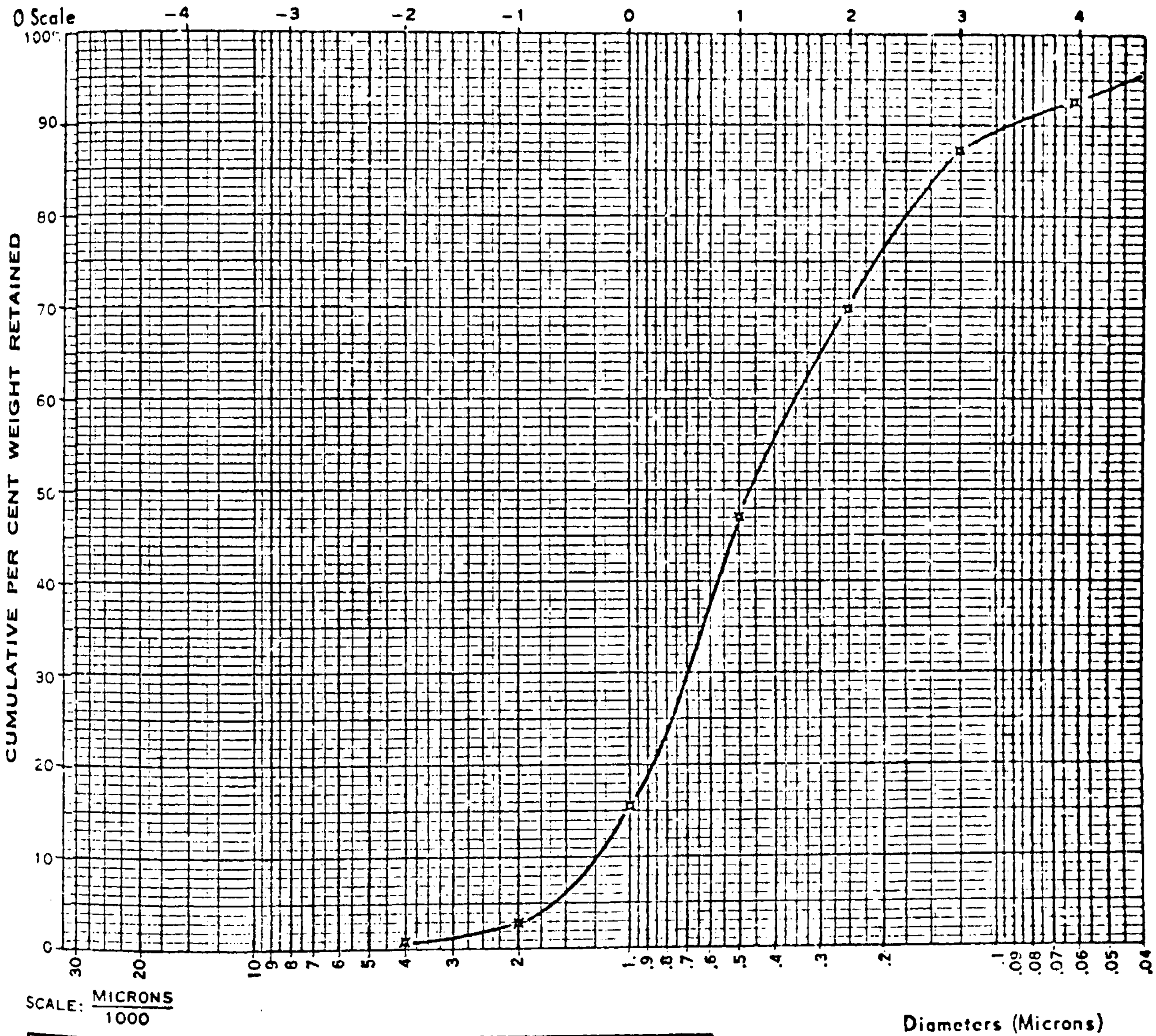
1% = 3,000
50% = 650
Modal Class (Ø Scale) = (0,1)



Sand

Sample No. S 2-3

Screen Analysis



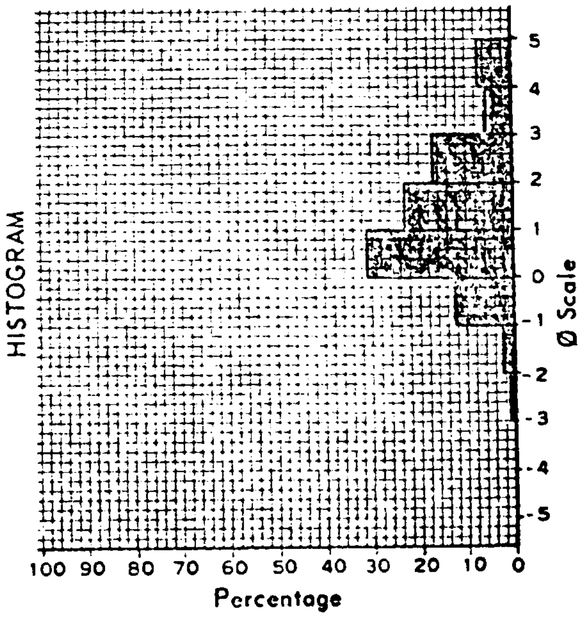
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2	0.60	0.8	0.60	0.8
2	-1	1.66	2.2	2.26	3.0
1.00	0.00	9.52	12.6	11.78	15.6
(1/2) 0.5	1.00	23.69	31.4	35.47	47.0
(1/4) 0.250	2.00	17.60	23.3	53.07	70.3
(1/8) 0.125	3.00	12.85	17.0	65.92	87.4
(1/16) 0.062	4.00	4.08	5.4	70.0	92.8
· Pan		5.44	7.2	75.44	100.0
	TOTAL	75.44	99.9		
	Loss				

Diameters (Microns)

1% = 3,250

50% = 456

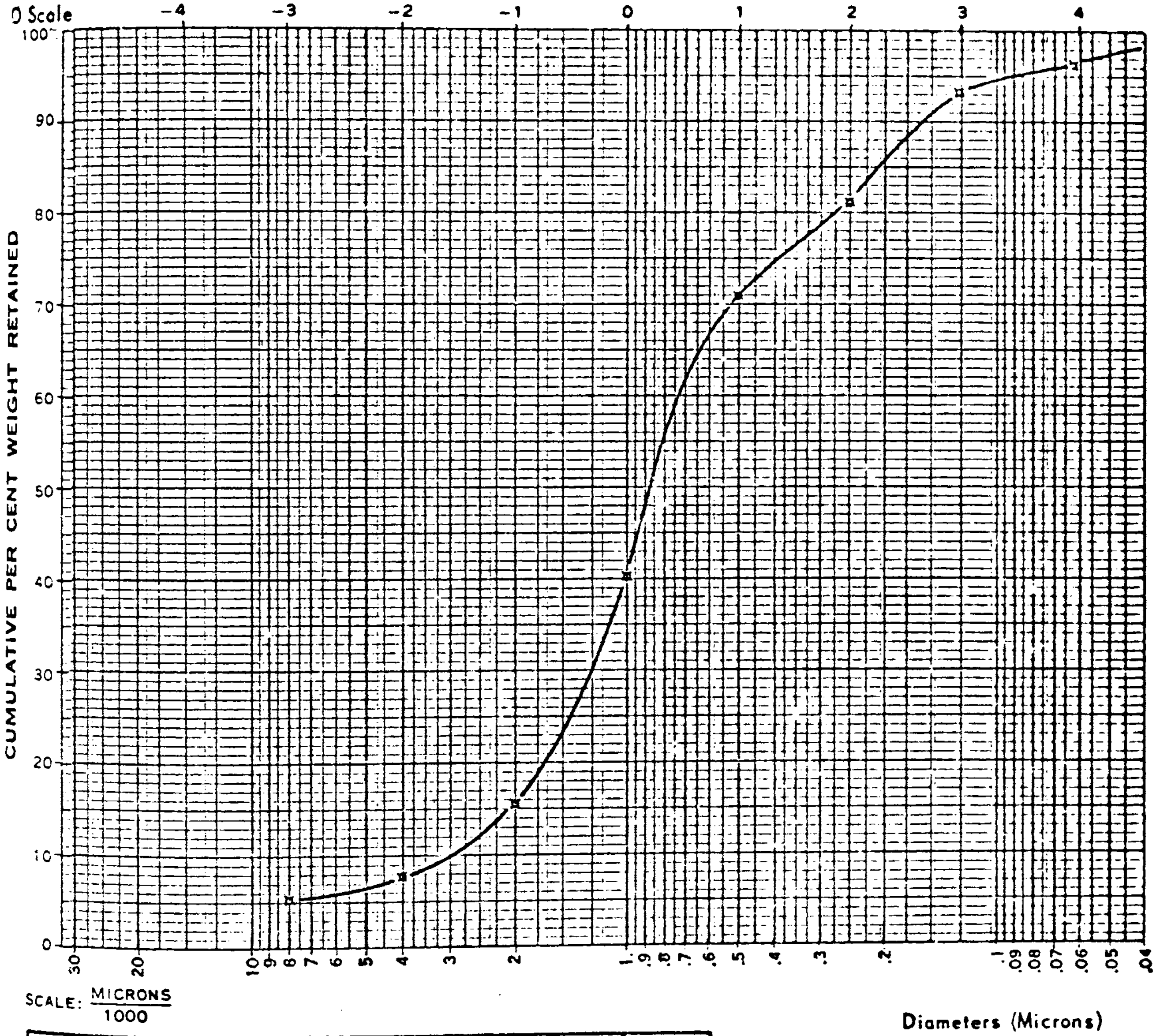
Modal Class (Ø Scale) = (0, 1)



Sample No. S 2-4

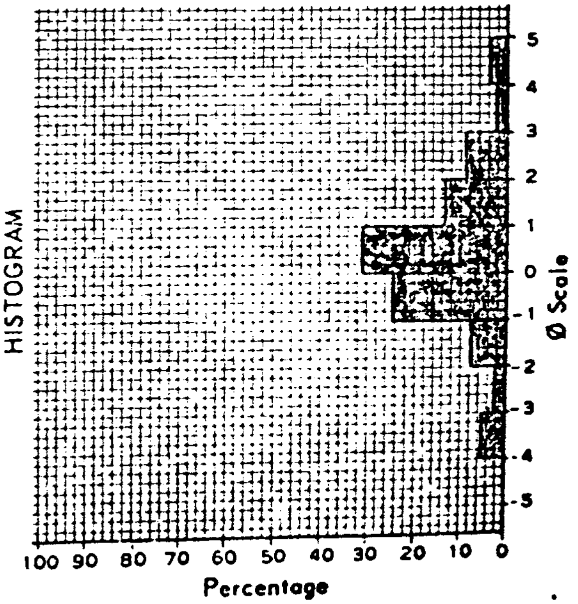
Screen Analysis

Gravelly Sand



Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3	3.92	5.4	3.92	5.4
4	-2	1.69	2.3	5.61	7.8
2	-1	5.70	7.9	11.31	15.7
1.00	0.00	17.66	24.5	28.97	40.2
(1/2) 0.5	1.00	22.48	31.2	51.45	71.4
(1/4) 0.250	2.00	9.88	13.7	61.33	81.1
(1/8) 0.125	3.00	6.19	8.6	67.52	93.7
(1/16) 0.062	4.00	1.71	2.4	69.23	96.1
Pan		2.80	3.9	72.03	100.0
	TOTAL	72.03	99.9		
	Loss				

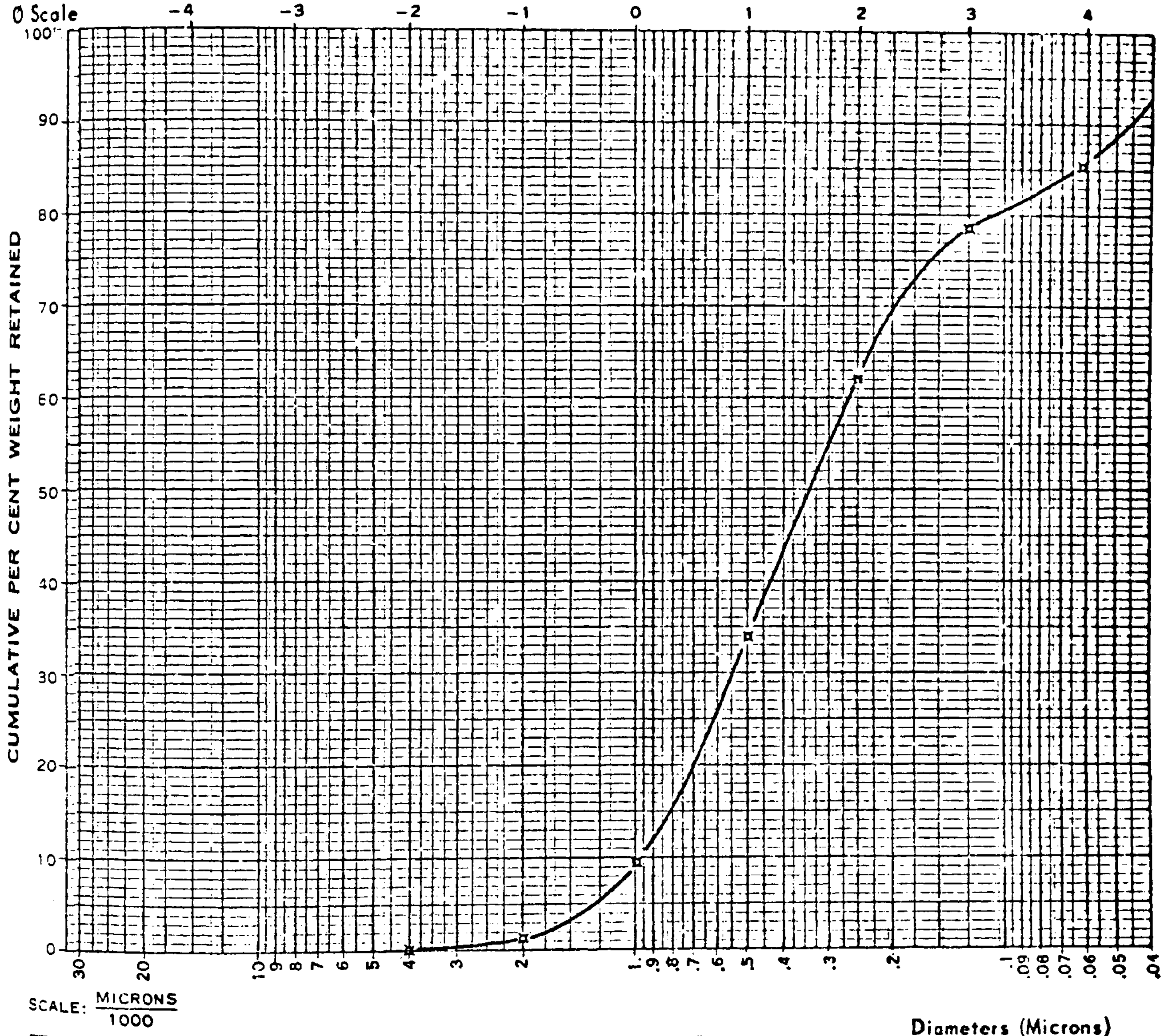
1% =
50% = 856
Modal Class (Ø Scale) = (0, 1)



Sample No. S 2-6

Screen Analysis

Sand



SCALE: MICRONS / 1000

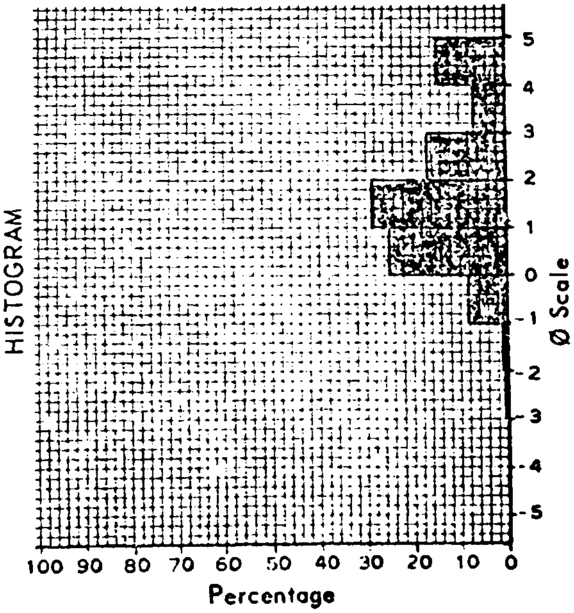
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2	0.05	0.1	0.05	0.1
2	-1	0.85	1.2	0.90	1.3
1.00	0.00	5.64	8.1	6.54	9.4
(1/2) 0.5	1.00	17.15	24.6	23.69	34.0
(1/4) 0.250	2.00	19.56	28.1	43.25	62.1
(1/8) 0.125	3.00	11.61	16.7	54.86	78.8
(1/16) 0.062	4.00	4.76	6.8	59.62	85.6
Pan		10.00	14.4	69.62	100.0
	TOTAL	69.62	100.0		
	Loss				

Diameters (Microns)

1% = 2,250

50% = 335

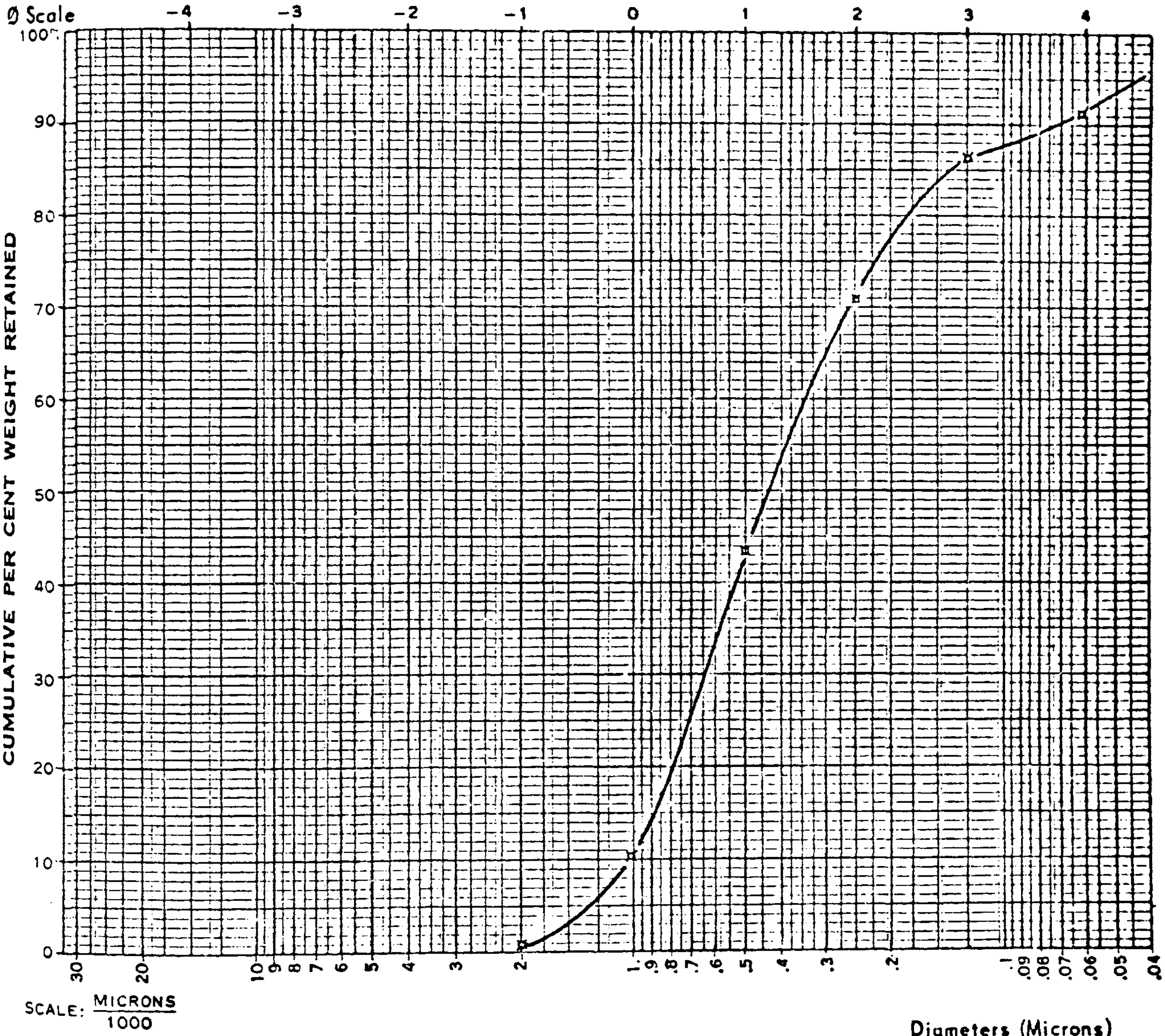
Modal Class (Ø Scale) = (1,2)



Sample No. S 2-8

Screen Analysis

Sand



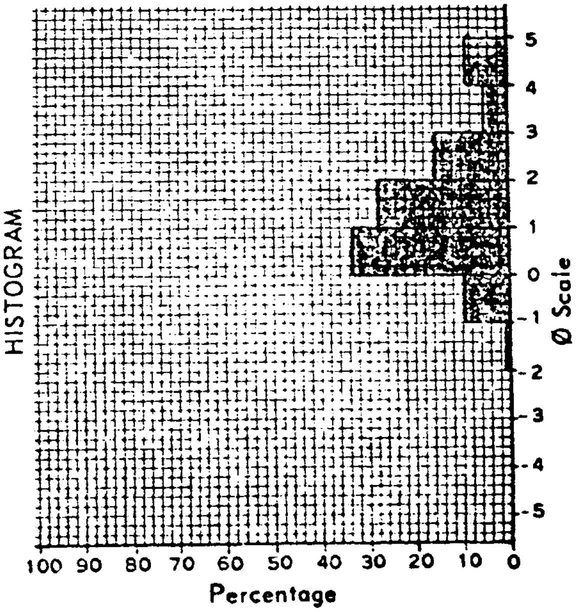
Diameters (Microns)

1% = 1,900

50% = 440

Modal Class (Ø Scale) = (0,1)

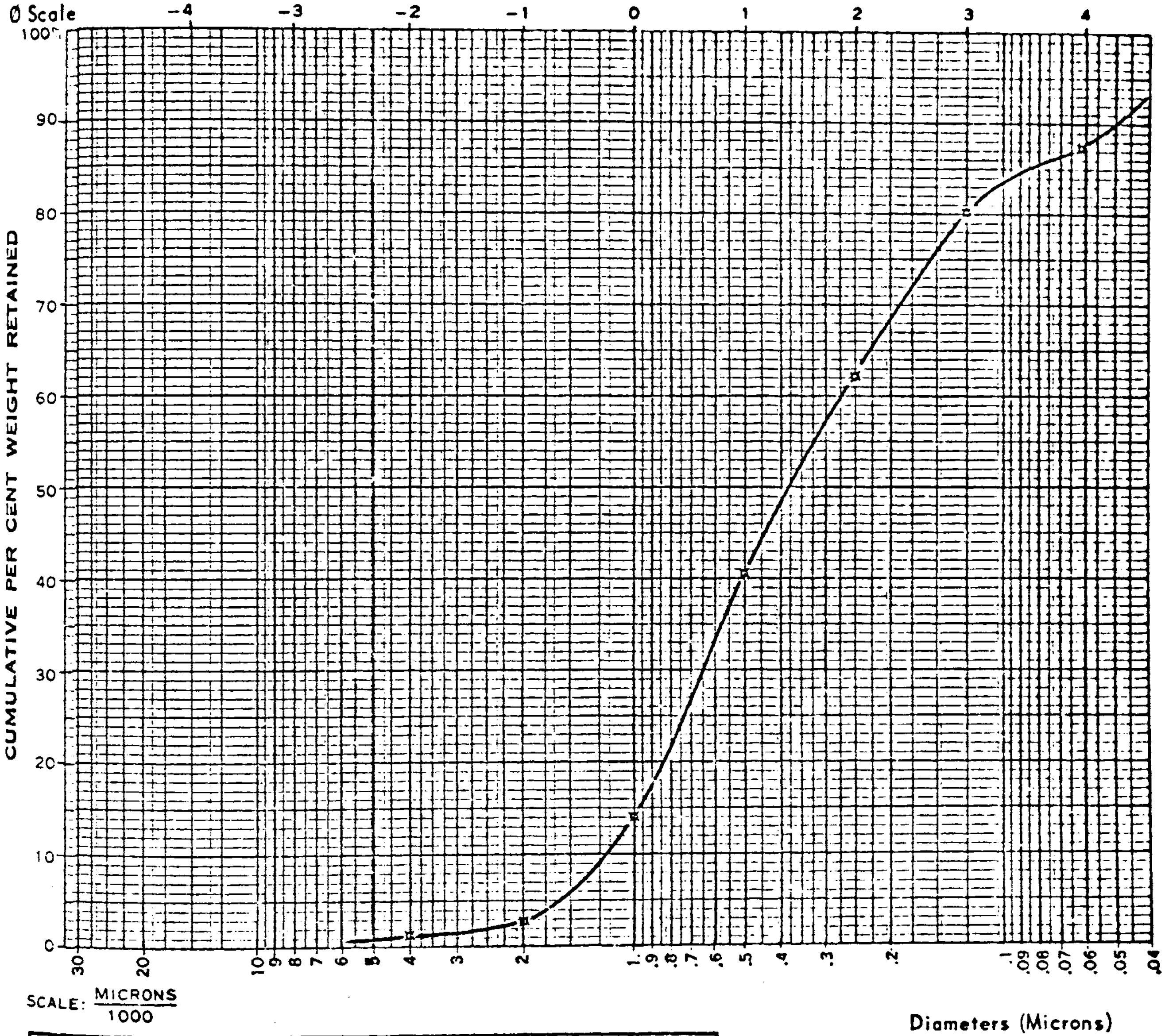
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2				
2	-1	0.55	0.8	0.55	0.8
1.00	0.00	6.60	9.6	7.15	10.4
(1/2) 0.5	1.00	22.87	33.2	30.02	43.6
(1/4) 0.250	2.00	18.90	27.5	48.92	71.1
(1/8) 0.125	3.00	10.73	15.6	59.65	86.6
(1/16) 0.062	4.00	3.19	4.6	62.84	91.3
Pan		6.00	8.7	68.84	100.
	TOTAL	68.84	100.0		
	Loss				



Sample No. S 2-9

Screen Analysis

Sand

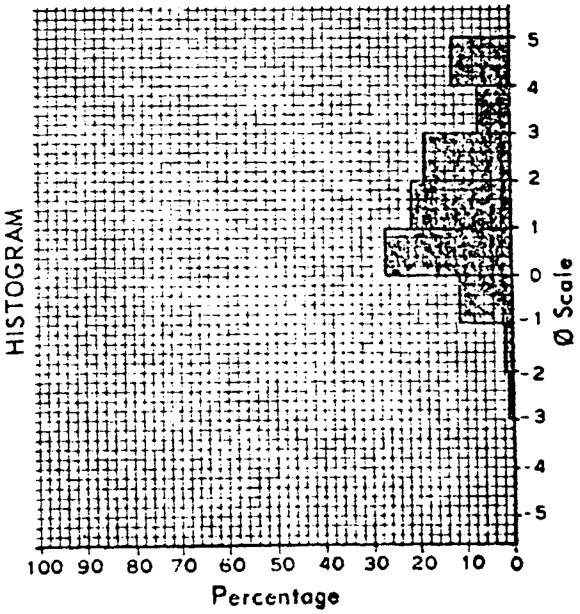


Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2	0.80	1.3	0.80	1.3
2	-1	1.02	1.6	1.82	2.9
1.00	0.00	7.12	11.3	8.94	14.1
(1/2) 0.5	1.00	16.84	26.6	25.78	40.8
(1/4) 0.250	2.00	13.48	21.3	39.26	62.1
(1/8) 0.125	3.00	11.60	18.3	50.86	80.4
(1/16) 0.062	4.00	4.25	6.7	55.11	87.2
Pan		8.11	12.8	63.22	100.0
	TOTAL	63.22	99.9		
	Loss				

1% = 4,500

50% = 375

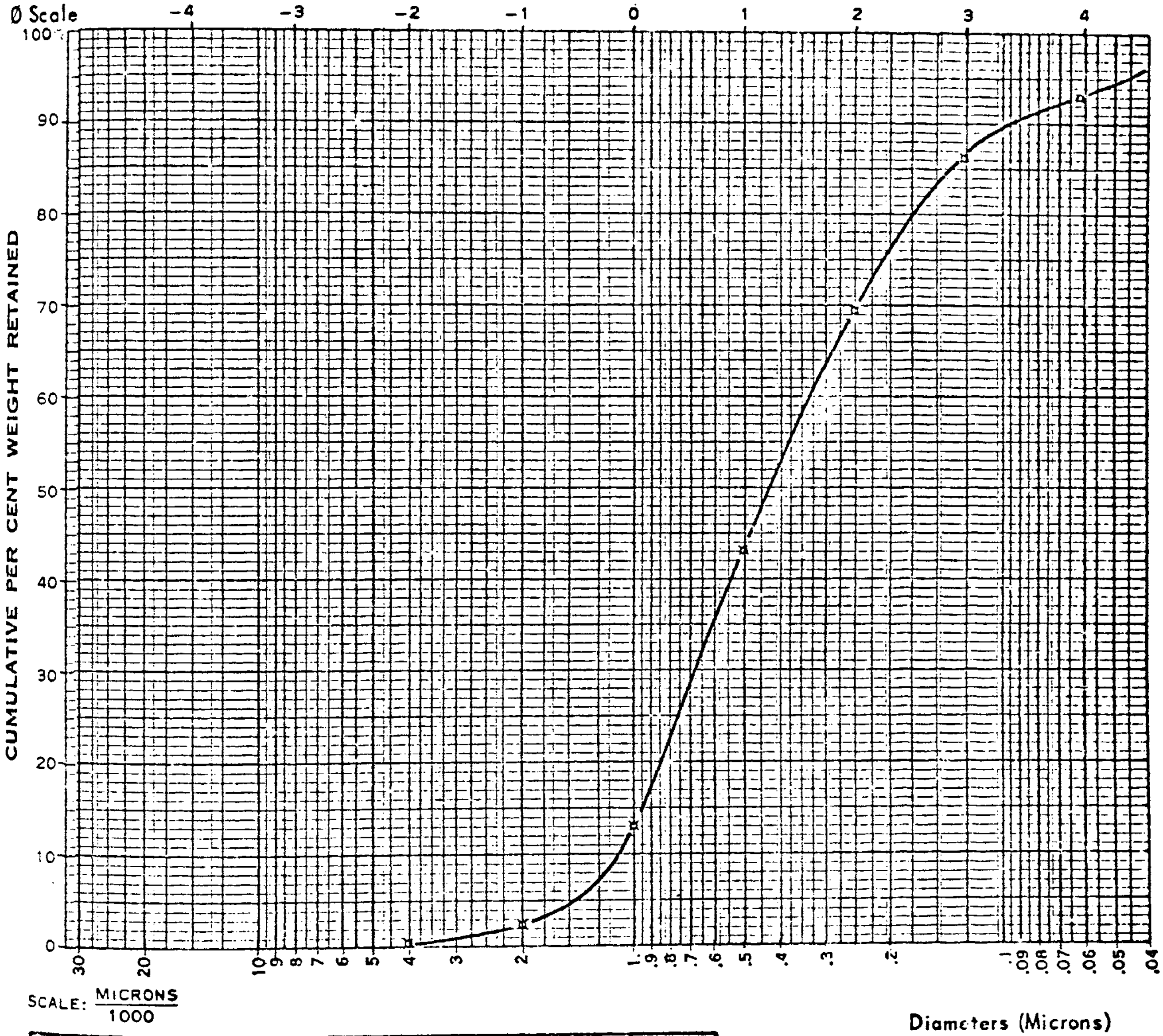
Modal Class (Ø Scale) = (0,1)



Sample No. S 2-10

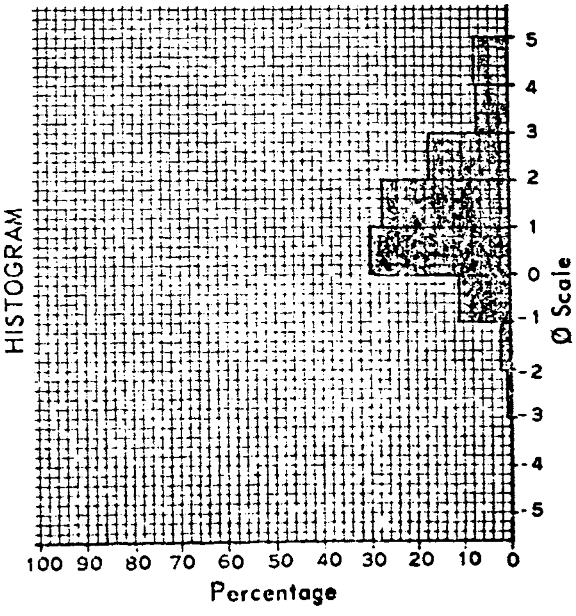
Screen Analysis

Sand



Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2	0.35	0.5	0.35	0.5
2	-1	1.44	2.0	1.79	2.5
1.00	0.00	7.72	10.7	9.51	13.2
(1/2) 0.5	1.00	21.56	29.9	31.07	43.1
(1/4) 0.250	2.00	19.16	26.6	50.23	69.7
(1/8) 0.125	3.00	12.03	16.7	62.26	86.4
(1/16) 0.062	4.00	4.80	6.7	67.06	93.1
Pan		4.96	6.9	72.02	100.0
	TOTAL	72.02	100.0		
	Loss				

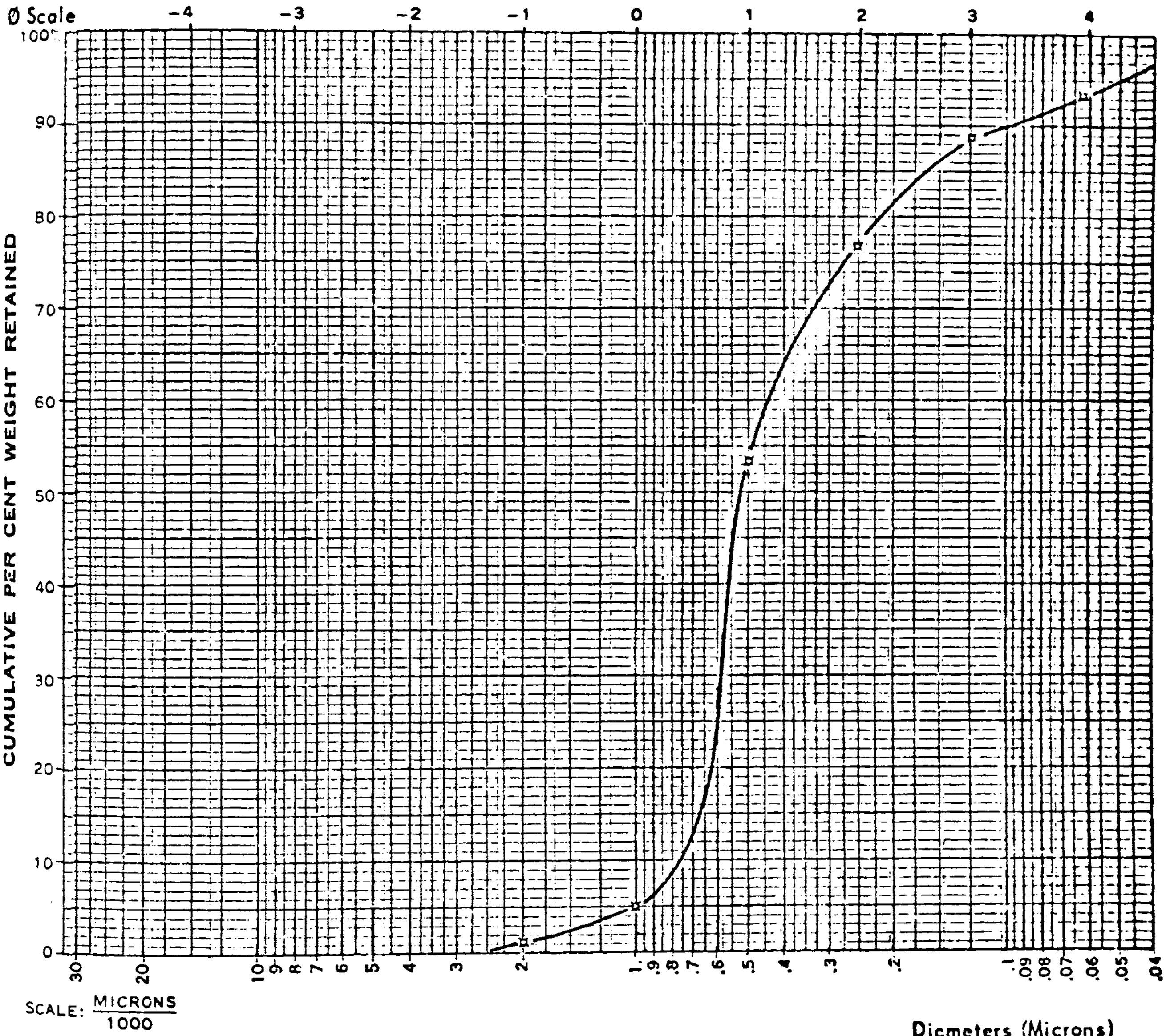
1% = 3,000
50% = 435
Modal Class (Ø Scale) = (0, 1)



Sand

Sample No. S 3-1

Screen Analysis



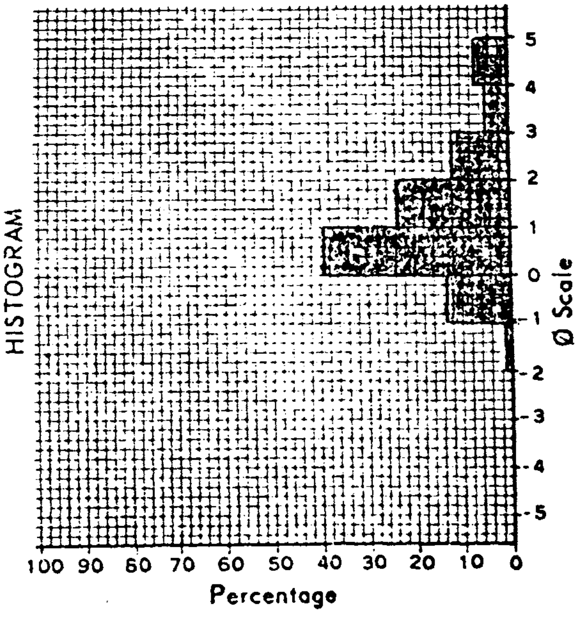
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2				
2	-1	1.10	1.4	1.10	1.4
1.00	0.00	10.72	13.7	11.82	5.1
(1/2) 0.5	1.00	29.80	38.2	41.62	53.3
(1/4) 0.250	2.00	18.38	23.5	60.00	76.9
(1/8) 0.125	3.00	9.38	12.0	69.33	88.9
(1/16) 0.062	4.00	3.41	4.4	72.79	93.3
Pan		5.24	6.7	78.03	100.0
	TOTAL	78.03	99.9		
	Loss				

Diameters (Microns)

1% = 2,100

50% = 530

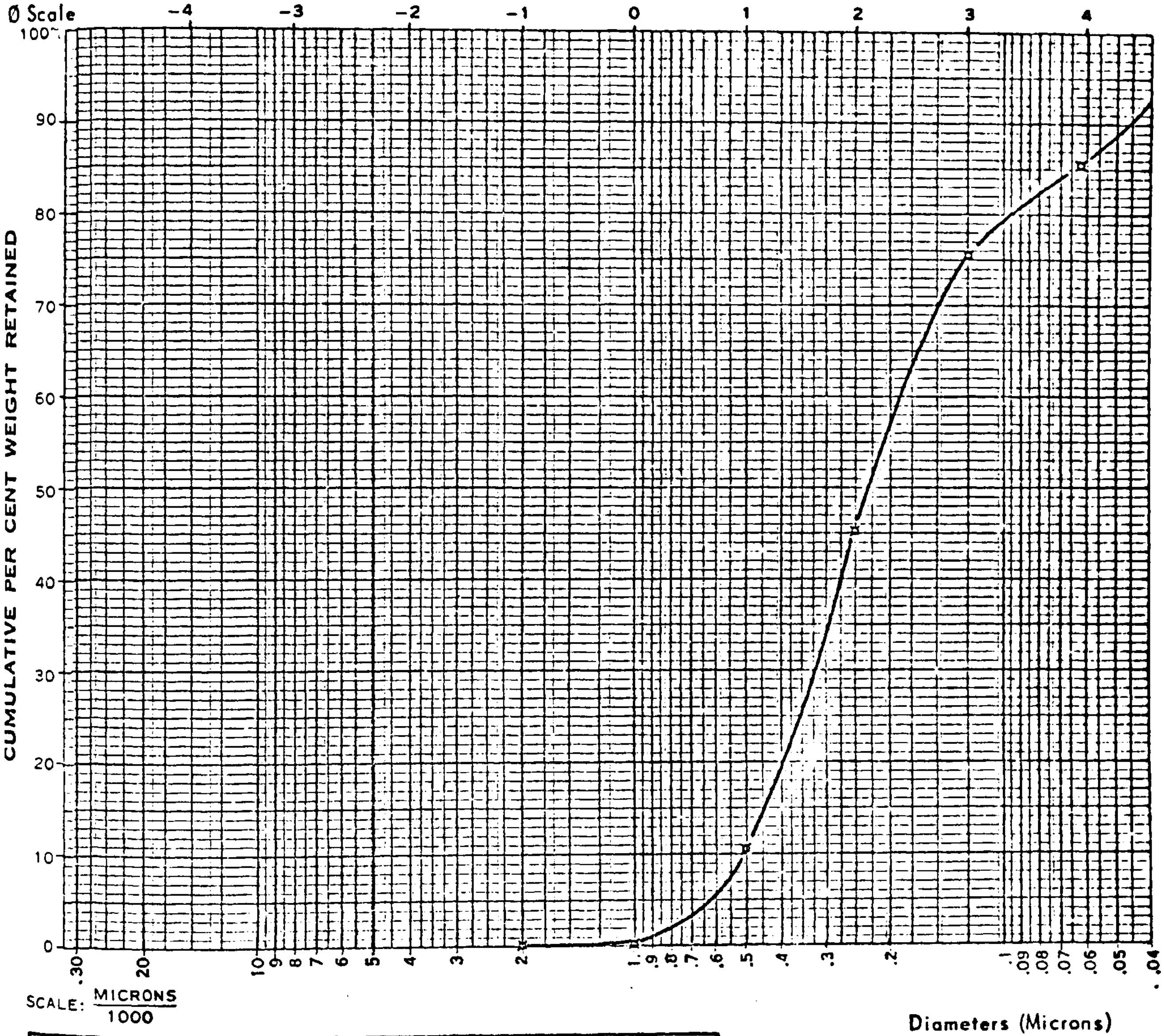
Modal Class (Ø Scale) = (0,1)



Sand

Sample No. S 3-2

Screen Analysis

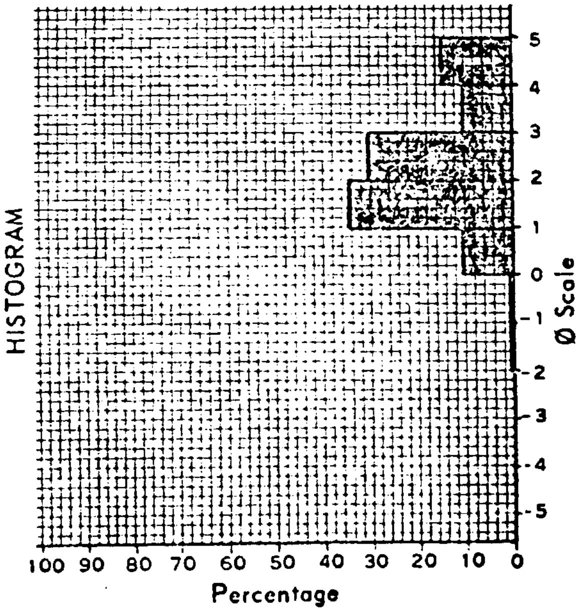


Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2				
2	-1	0.09	0.1	0.09	0.1
1.00	0.00	0.13	0.2	0.22	0.3
(1/2) 0.5	1.00	8.21	10.5	8.43	10.8
(1/4) 0.250	2.00	26.80	34.4	35.23	45.2
(1/8) 0.125	3.00	23.66	30.4	58.89	75.6
(1/16) 0.062	4.00	7.76	10.0	66.65	85.5
Pan		11.27	14.5	77.92	100.0
	TOTAL	77.92	100.1		
	Loss				

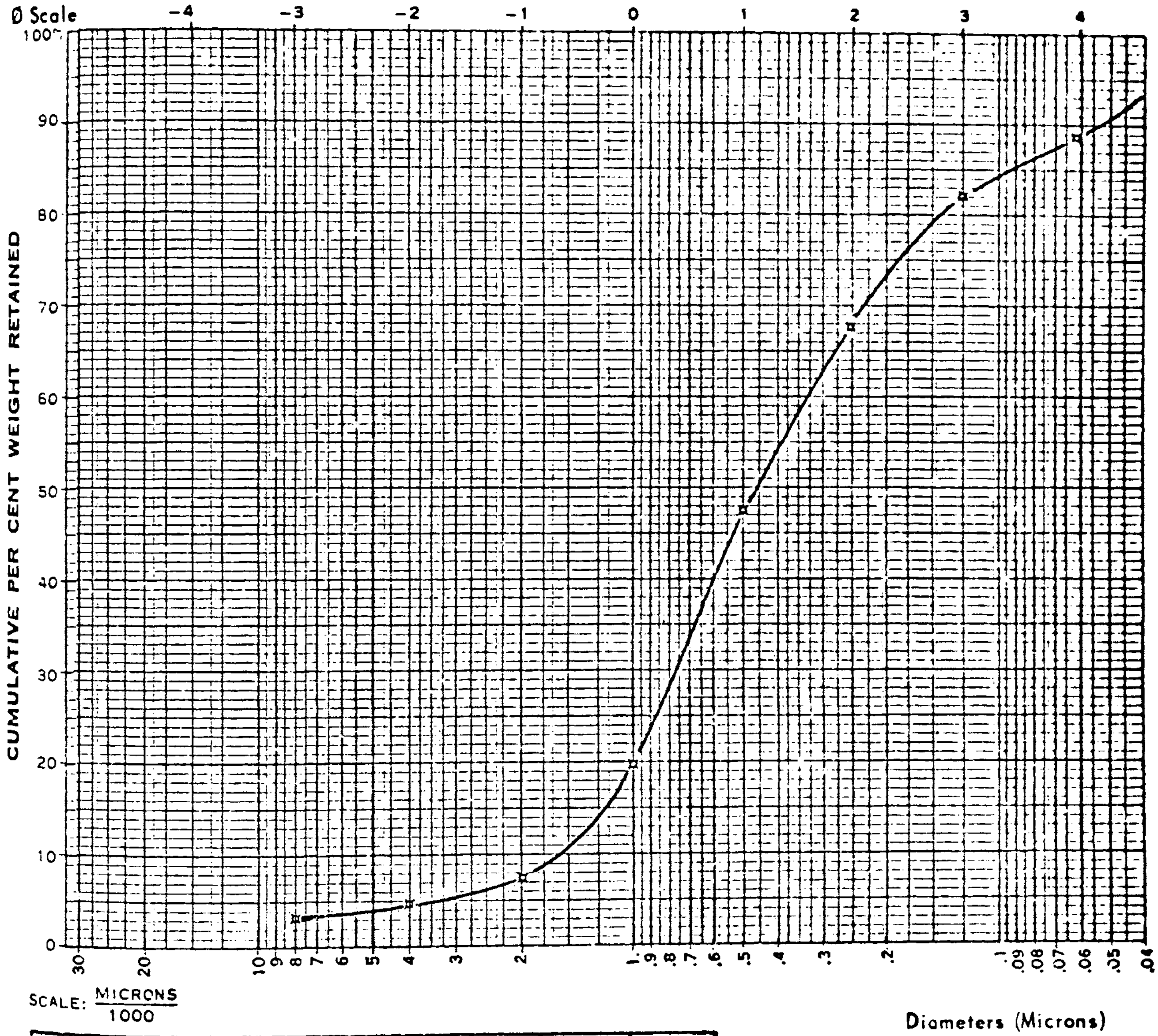
1% = 910

50% = 230

Modal Class (Ø Scale) = (1,2)

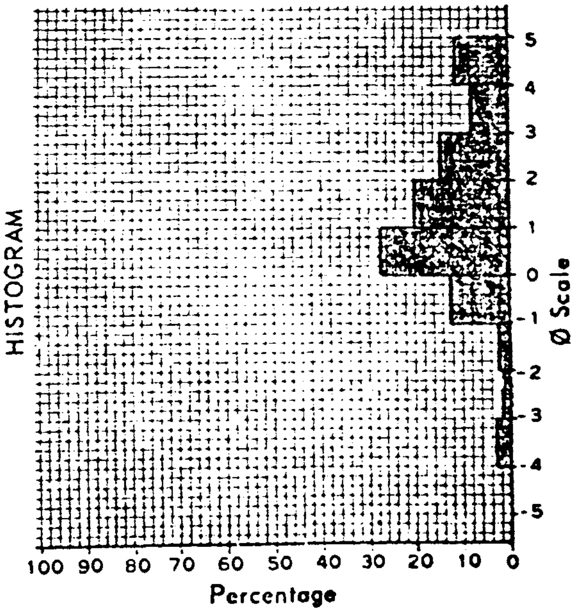


Sample No. S 3-5 **Screen Analysis** Gravelly Sand



Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3	2.26	3.2	2.26	3.2
4	-2	1.05	1.5	3.31	4.7
2	-1	1.92	2.7	5.23	7.5
1.00	0.00	8.67	12.4	13.90	19.9
(1/2) 0.5	1.00	19.35	27.7	33.25	47.6
(1/4) 0.250	2.00	14.03	20.0	47.28	67.7
(1/8) 0.125	3.00	10.02	14.3	57.30	82.1
(1/16) 0.062	4.00	4.78	6.8	62.08	88.9
Pan		7.73	11.1	69.81	100.0
	TOTAL	69.81	99.7		
	Loss				

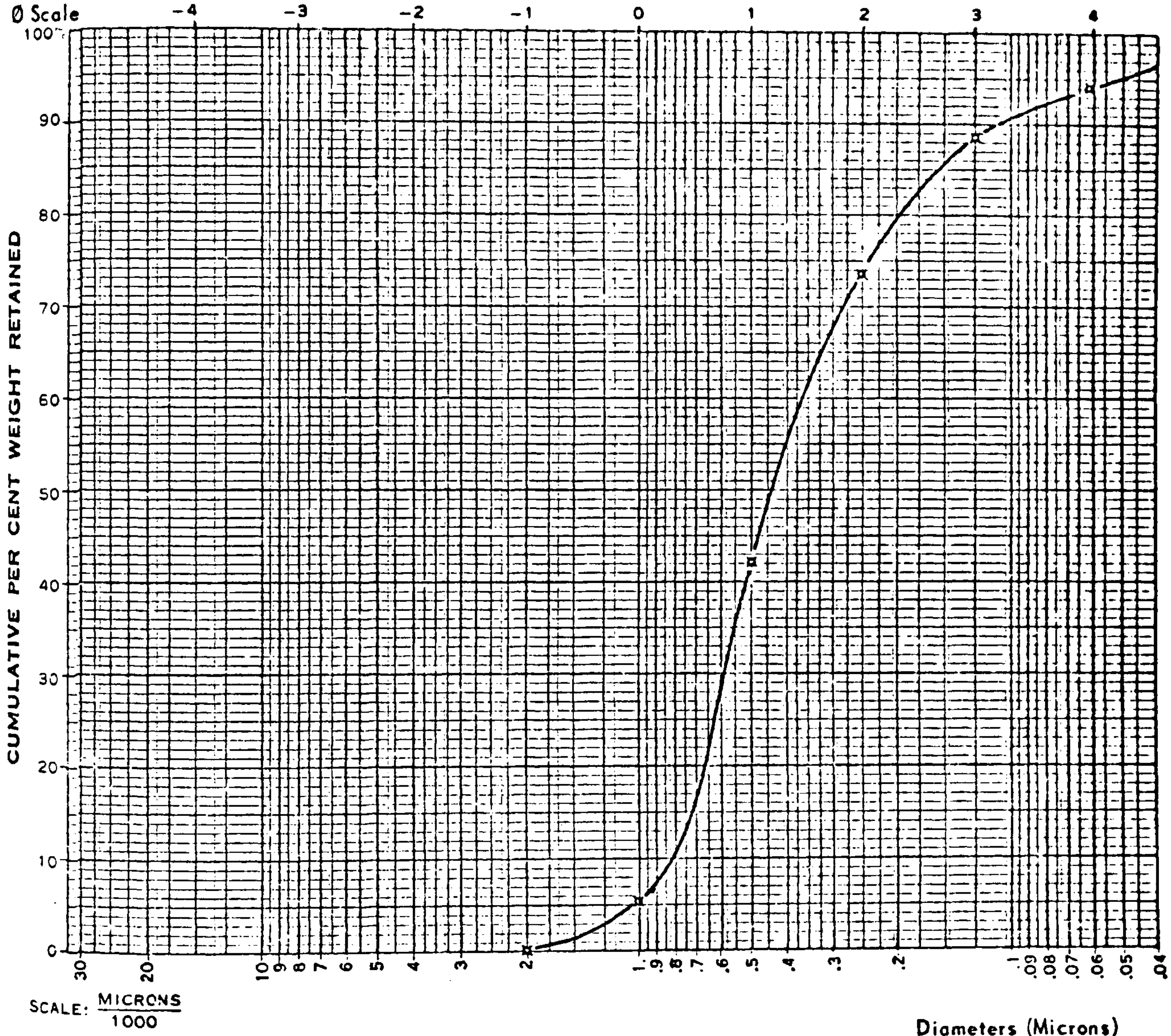
1% =
50% = 450
Modal Class (O Scale) = (0, 1)



Sand

Sample No. S 4-1

Screen Analysis



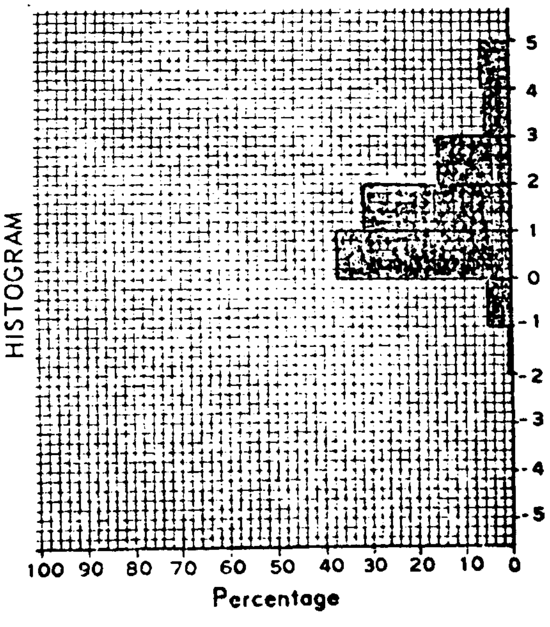
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2				
2	-1	0.20	0.3	0.20	0.3
1.00	0.00	4.04	5.2	4.24	5.4
(1/2) 0.5	1.00	28.57	36.7	32.81	42.1
(1/4) 0.250	2.00	24.59	31.6	57.40	73.6
(1/8) 0.125	3.00	11.72	15.0	69.12	88.7
(1/16) 0.062	4.00	4.10	5.3	73.22	94.0
Pan		4.71	6.0	77.93	100.0
	TOTAL	77.93	100.1		
	Loss				

Diameters (Microns)

1% = 1,700

50% = 440

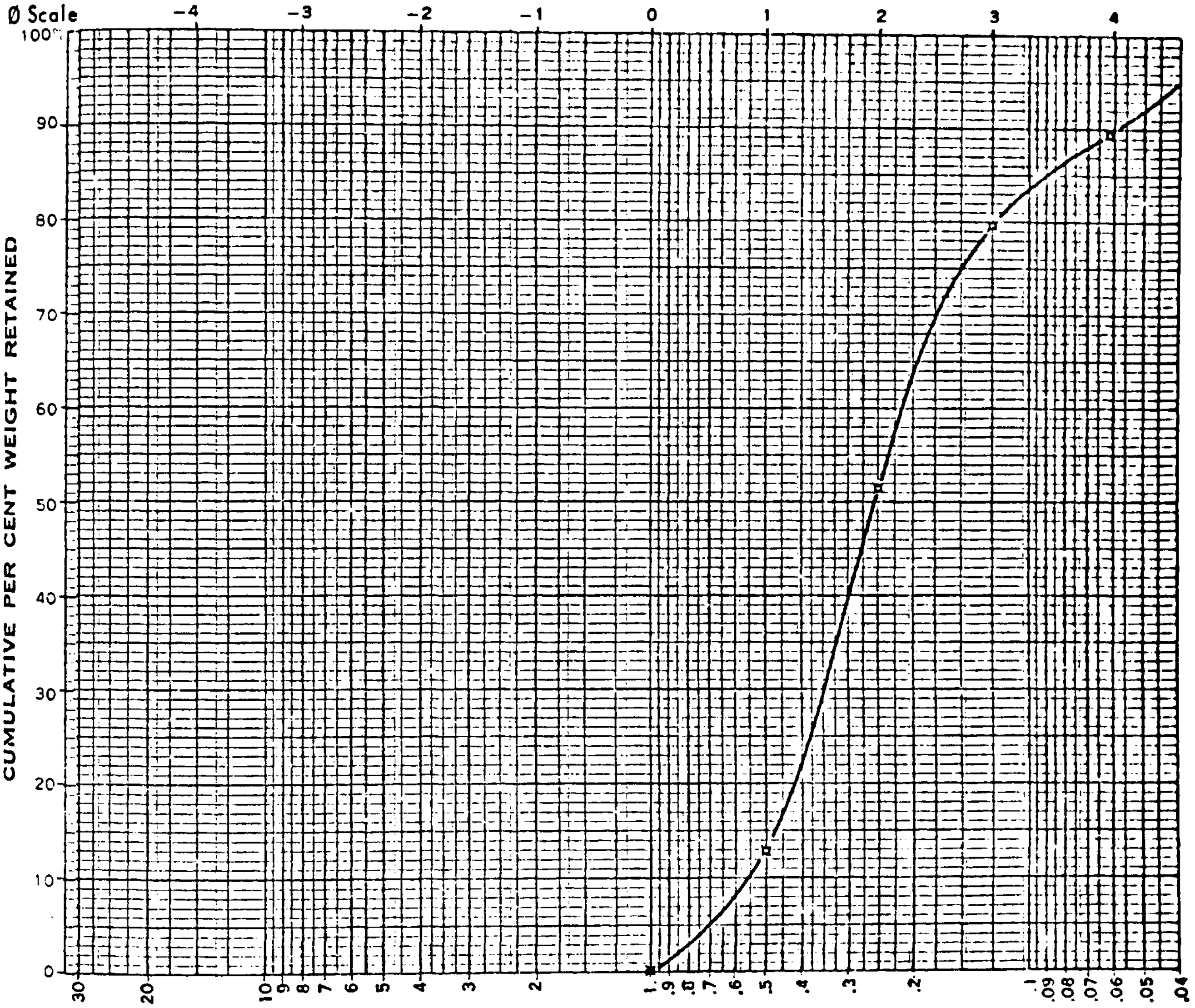
Modal Class (Ø Scale) = (0,1)



Sample No. S 4-3

Screen Analysis

Sand

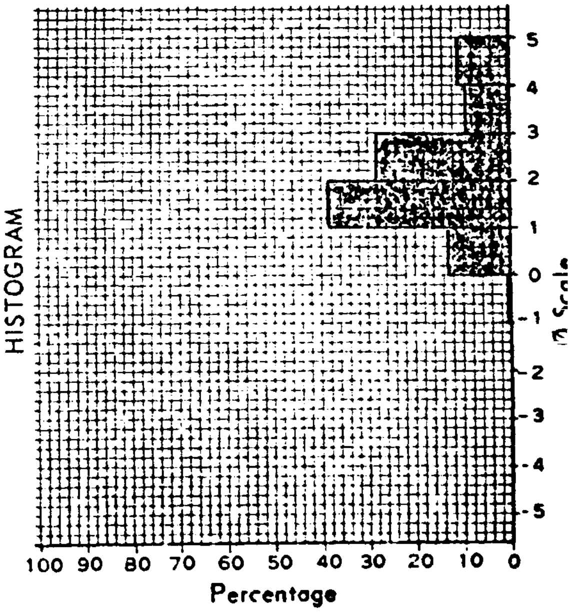


SCALE: $\frac{\text{MICRONS}}{1000}$

Diameters (Microns)

Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2				
2	-1	0.02	0.0	0.02	0.0
1.00	0.00	0.17	0.2	0.19	0.2
(1/2) 0.5	1.00	9.99	13.0	10.18	13.2
(1/4) 0.250	2.00	29.71	38.6	39.89	51.8
(1/8) 0.125	3.00	21.57	28.0	61.46	79.9
(1/16) 0.062	4.00	7.36	9.6	68.82	89.4
Pan		8.13	10.6	76.95	100.0
	TOTAL	76.95	100.0		
	Loss				

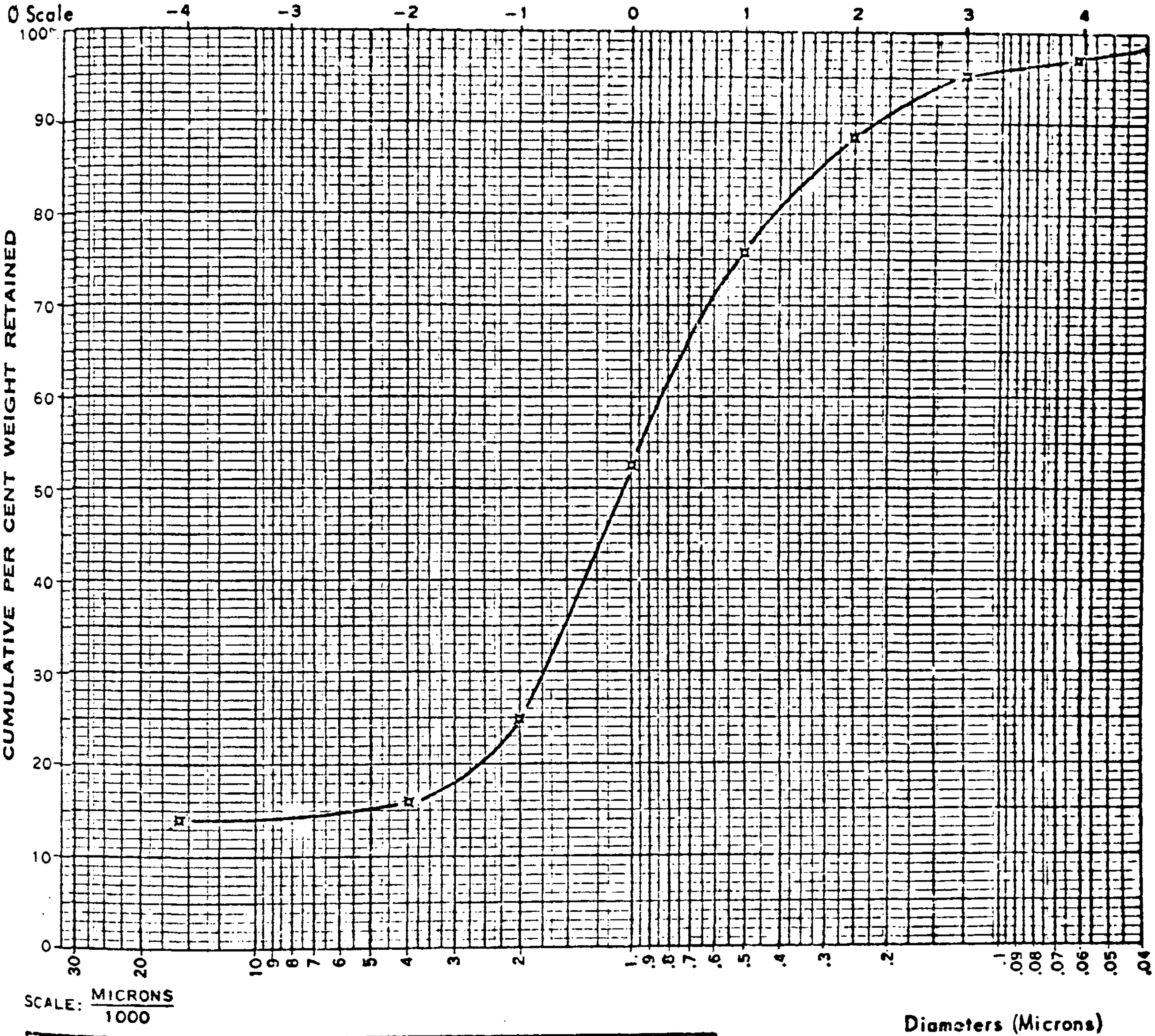
1% = 900
50% = 260
Modal Class (Ø Scale) = (1,2)



Sample No. S 4-4

Screen Analysis

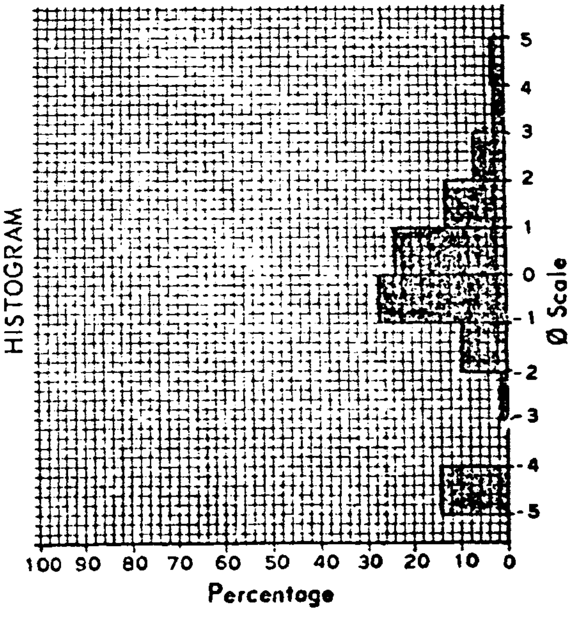
Gravelly Sand



Diameters (Microns)

Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4	10.77	14.1	10.77	14.0
8	-3	----	----	----	----
4	-2	1.25	1.6	12.02	15.7
2	-1	7.00	9.1	19.02	24.8
1.00	0.00	21.21	27.7	40.23	52.5
(1/2) 0.5	1.00	17.77	23.2	58.00	75.8
(1/4) 0.250	2.00	9.70	12.7	67.70	88.4
(1/8) 0.125	3.00	5.08	6.6	72.78	95.1
(1/16) 0.062	4.00	1.67	2.2	74.45	97.2
Pan		2.11	2.8	76.56	100.0
TOTAL		76.56	100.0		
Loss					

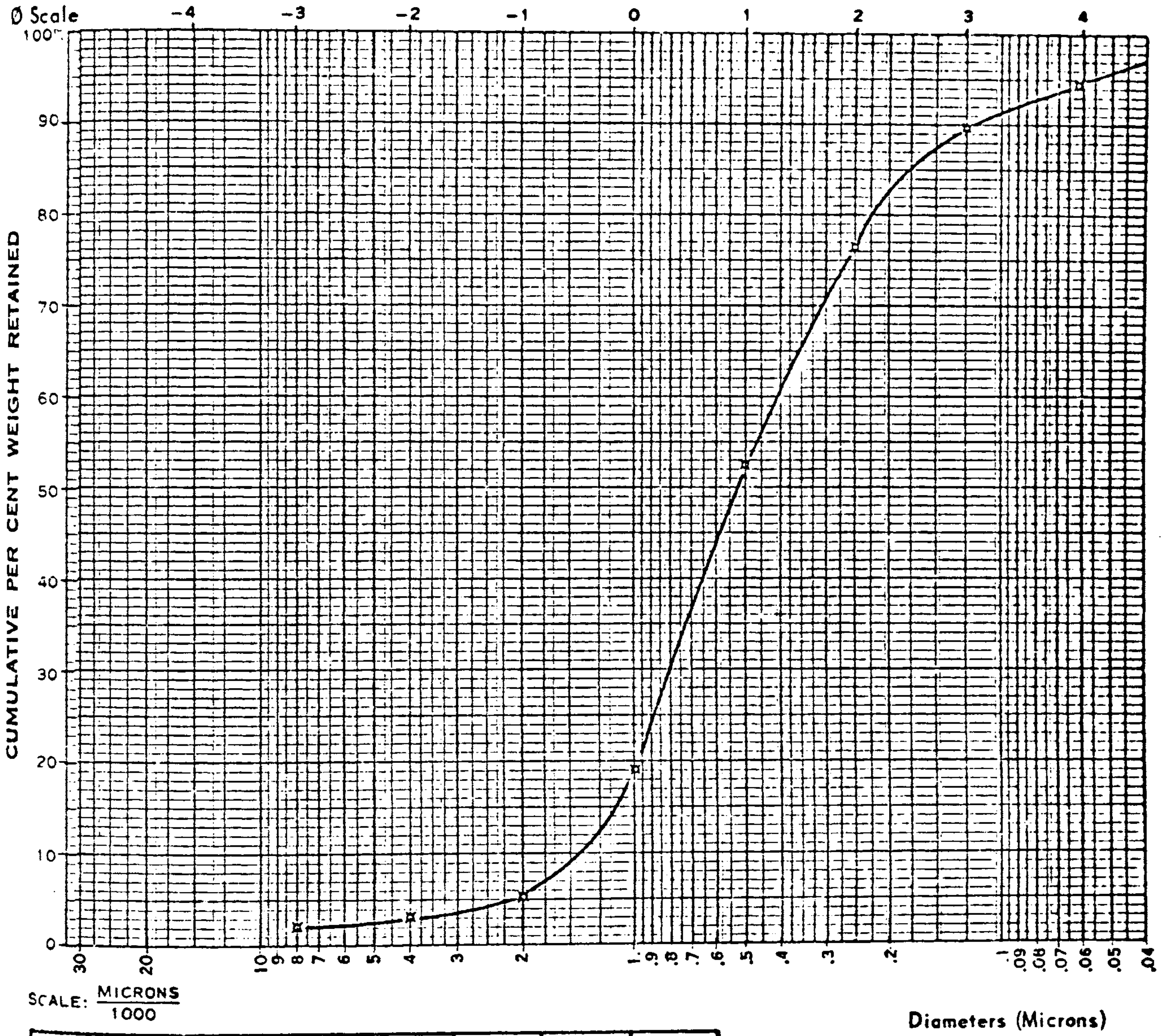
1% =
50% = 1,100
Modal Class (Ø Scale) = (−1,0)(−5,−4)



Sample No. S 4-5

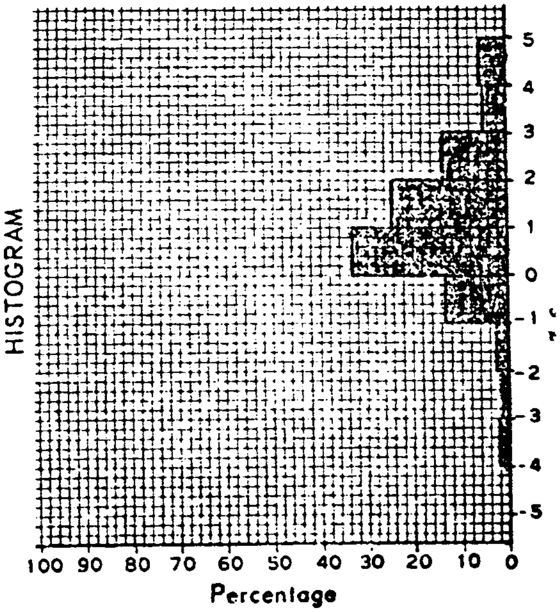
Screen Analysis

Gravelly Sand



1% =
50% = 510
Modal Class (Ø Scale) = (0, 1)

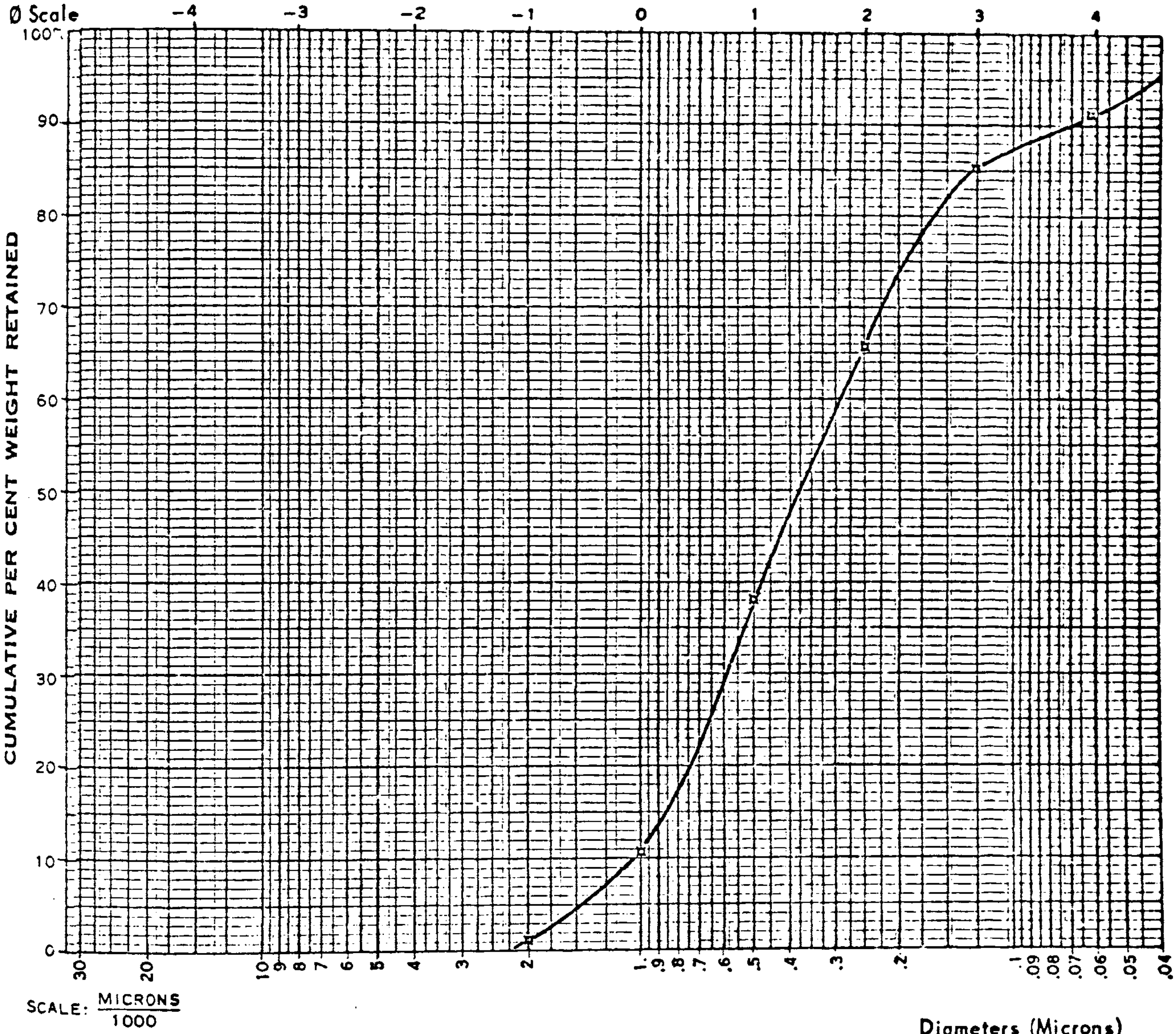
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3	1.51	2.1	1.51	2.1
4	-2	0.70	1.0	2.21	3.1
2	-1	1.53	2.2	3.74	5.3
1.00	0.00	9.77	13.8	13.51	19.0
(1/2) 0.5	1.00	23.58	33.2	37.09	52.3
(1/4) 0.250	2.00	17.16	24.2	54.25	76.4
(1/8) 0.125	3.00	9.54	13.4	63.79	89.9
(1/16) 0.062	4.00	3.33	4.7	67.12	94.6
Pan		3.85	5.4	70.97	100.0
	TOTAL	70.97	100.0		
	Loss				



Sand

Sample No. S 5-1

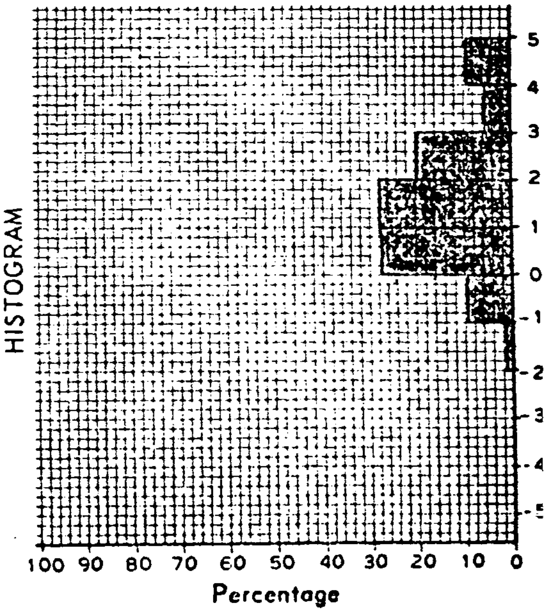
Screen Analysis



Diameters (Microns)

1% = 2,100
50% = 375
Modal Class (Ø Scale) = (1,2)(0,1)

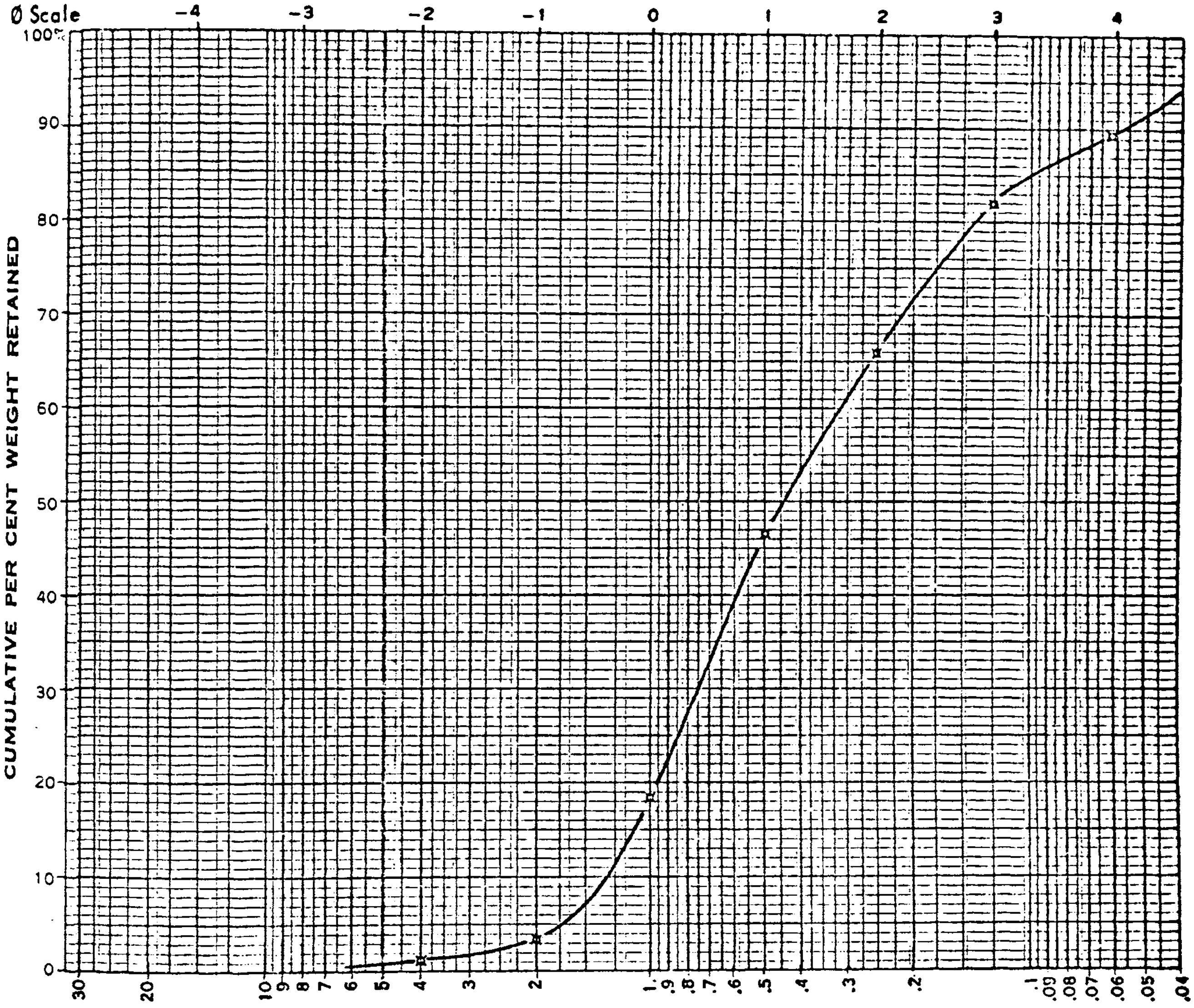
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2				
2	-1	1.00	1.3	1.00	1.3
1.00	0.00	7.68	9.6	8.68	10.9
(1/2) 0.5	1.00	21.67	27.2	30.35	38.1
(1/4) 0.250	2.00	22.15	27.8	52.50	65.9
(1/8) 0.125	3.00	15.64	19.6	68.14	85.6
(1/16) 0.062	4.00	4.57	5.7	72.71	91.3
Pan		6.89	8.7	79.60	100.0
	TOTAL	79.60	99.9		
	Loss				



Sample No. S 5-2

Screen Analysis

Sand

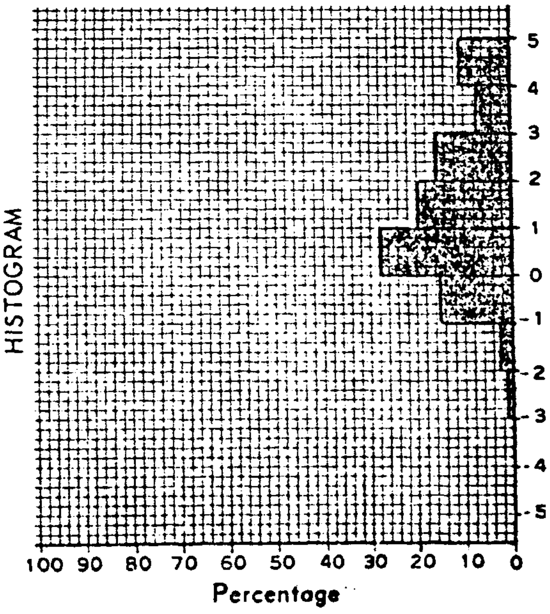


SCALE: MICRONS/1000

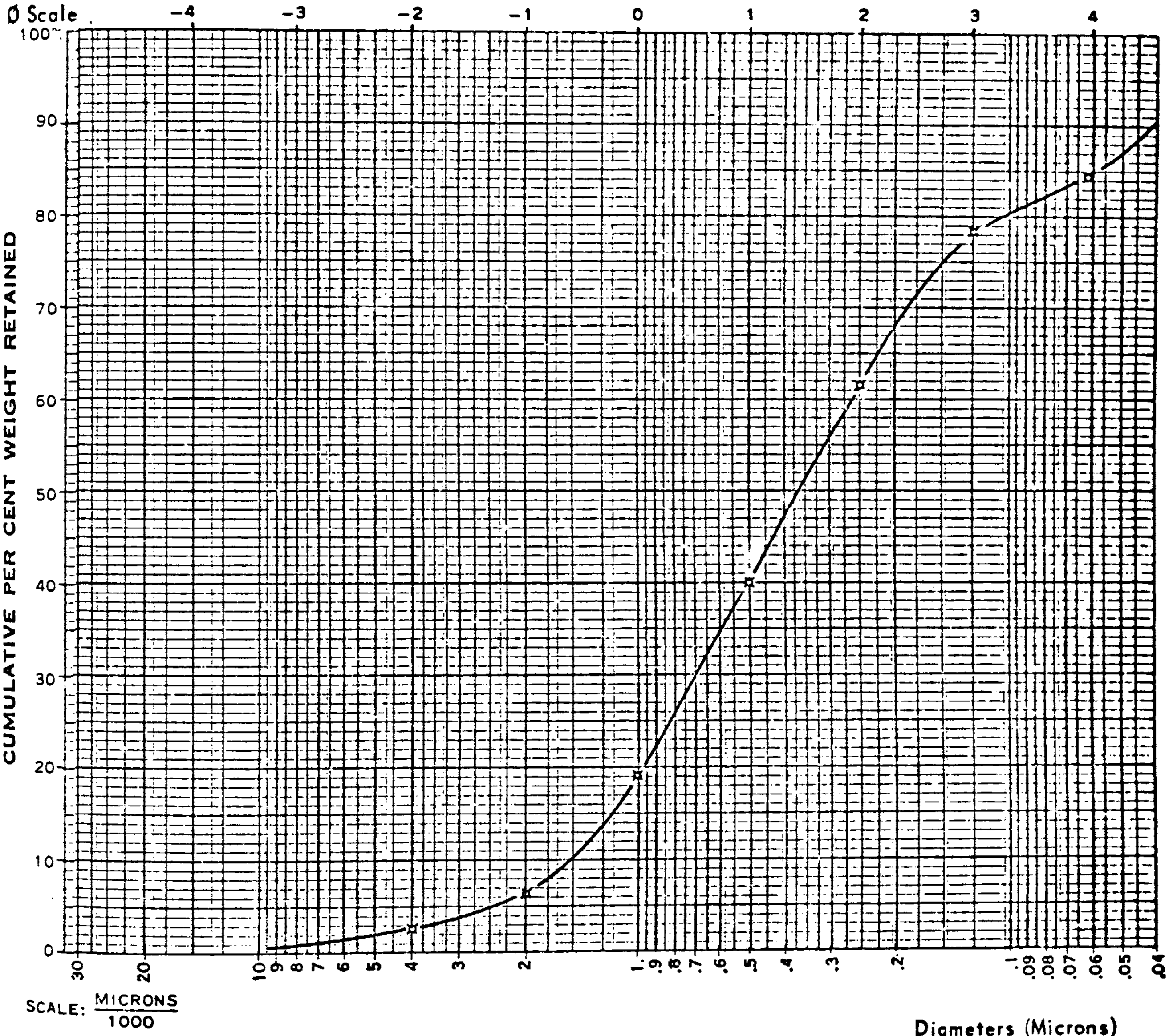
Diameters (Microns)

Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2	1.00	1.3	1.00	1.3
2	-1	1.85	2.4	2.85	3.8
1.00	0.00	11.30	14.9	14.15	18.7
(1/2) 0.5	1.00	21.16	27.9	35.31	46.6
(1/4) 0.250	2.00	14.81	19.5	50.12	66.2
(1/8) 0.125	3.00	12.07	15.9	62.19	82.1
(1/16) 0.062	4.00	5.43	7.2	67.62	89.3
Pan		8.13	10.7	75.75	100.0
	TOTAL	75.75	99.8		
	Loss				

1% = 5,000
50% = 450
Modal Class (Ø Scale) = (0,1)



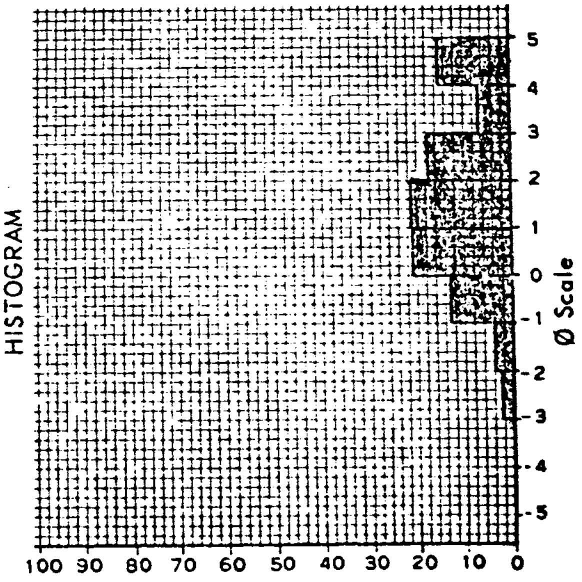
Sample No. S 5-3 **Screen Analysis** Gravelly Muddy Sand



Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2	2.09	2.6	2.09	2.6
2	-1	3.05	3.9	5.14	6.5
1.00	0.00	10.20	12.9	15.34	19.4
(1/2) 0.5	1.00	16.40	20.8	31.74	40.2
(1/4) 0.250	2.00	17.00	21.5	48.74	61.8
(1/8) 0.125	3.00	13.22	16.8	61.96	78.5
(1/16) 0.062	4.00	5.00	6.3	66.96	84.9
Pan		11.95	15.1	78.91	100.0
	TOTAL	78.91	99.9		
	Loss				

Diameters (Microns)

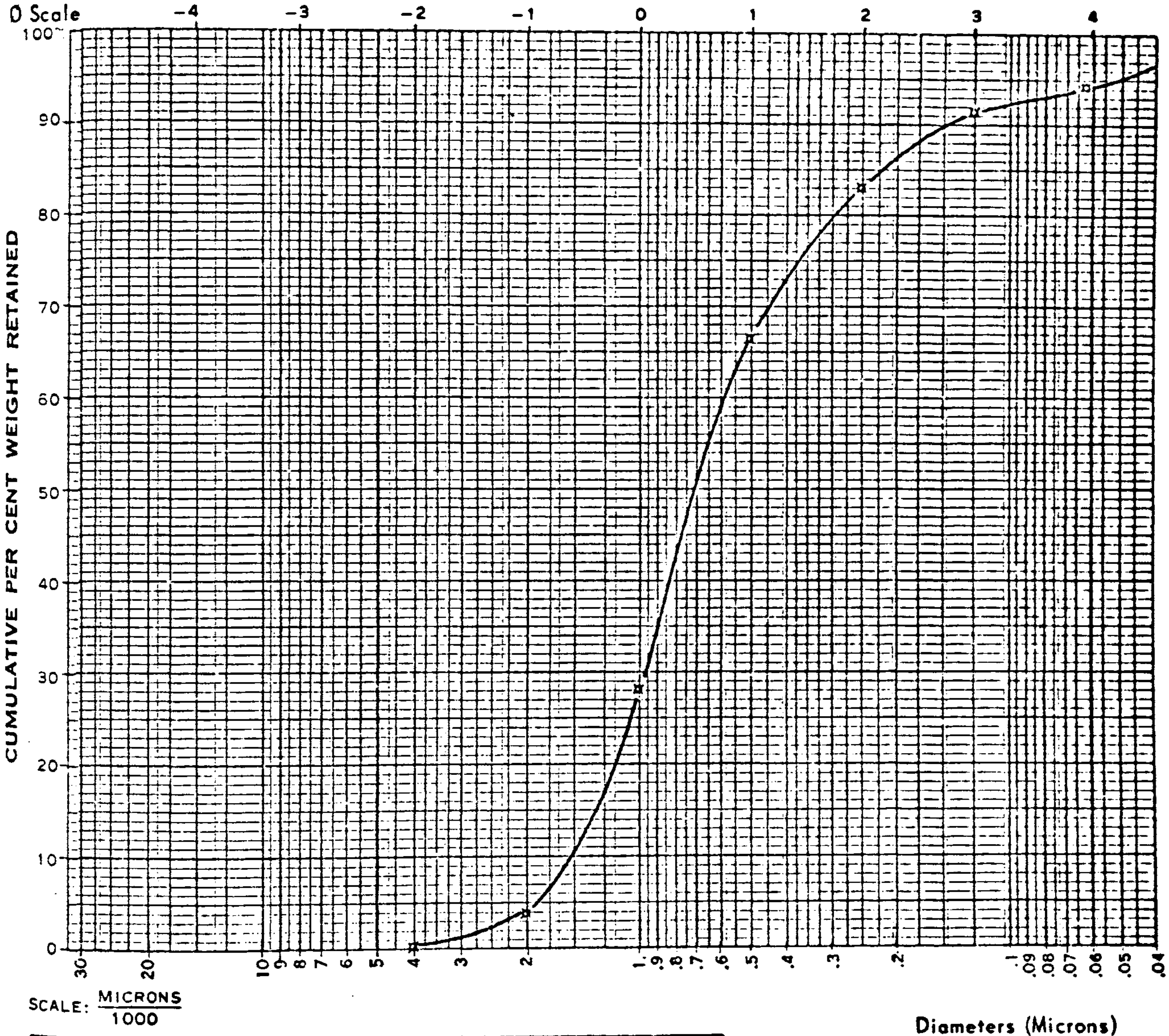
1% = 7,000
50% = 370
Modal Class (Ø Scale) = (1,2)(0,1)



Sample No. S 5-4

Screen Analysis

Sand



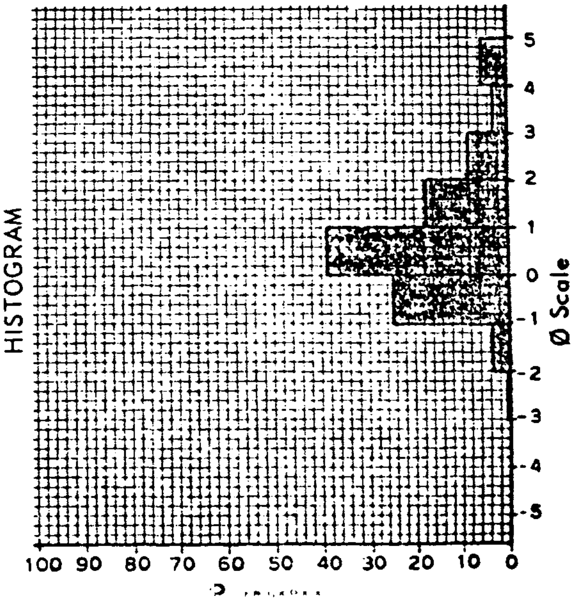
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2	0.32	0.4	0.32	0.4
2	-1	2.70	3.6	3.02	4.0
1.00	0.00	18.24	24.3	21.26	28.3
(1/2) 0.5	1.00	28.88	38.4	50.14	66.7
(1/4) 0.250	2.00	12.51	16.6	62.65	83.3
(1/8) 0.125	3.00	6.09	8.1	68.74	91.4
(1/16) 0.062	4.00	2.46	3.3	71.20	94.7
Pan		4.00	5.3	75.20	100.0
TOTAL		75.20	100.0		
Loss					

Diameters (Microns)

1% = 3,250

50% = 700

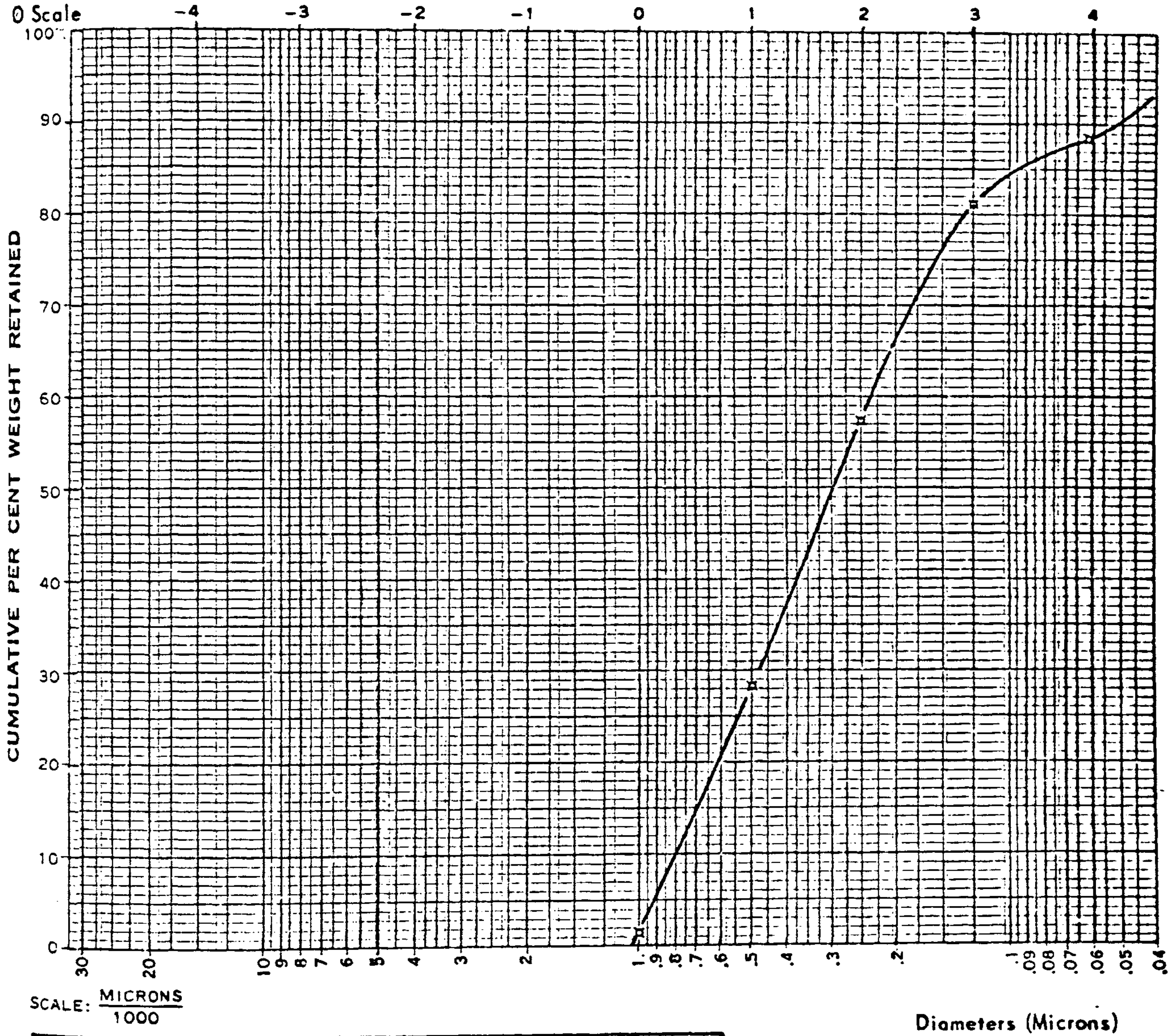
Modal Class (Ø Scale) = (0, 1)



Sand

Sample No. S 5-5

Screen Analysis

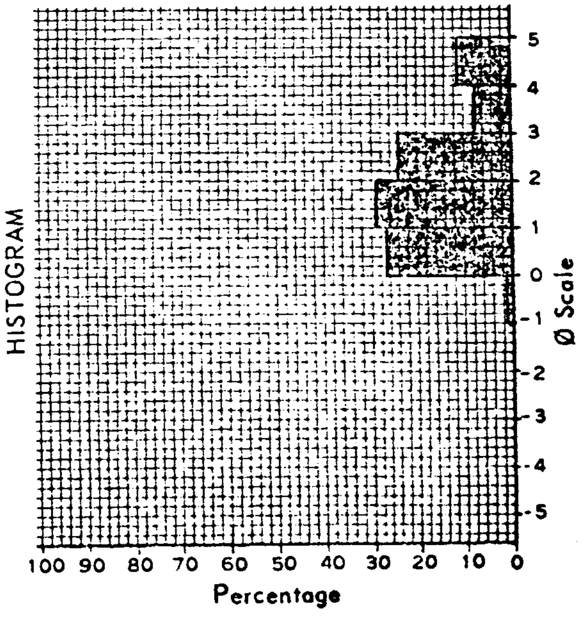


SCALE: MICRONS / 1000

Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2				
2	-1				
1.00	0.00	1.12	1.5	1.12	1.5
(1/2) 0.5	1.00	20.58	26.7	21.70	28.2
(1/4) 0.250	2.00	22.26	28.9	43.96	57.1
(1/8) 0.125	3.00	18.52	24.0	62.48	81.1
(1/16) 0.062	4.00	5.95	7.7	68.43	88.8
Pan		8.67	11.2	77.10	100.0
	TOTAL	77.10	100.0		
	Loss				

Diameters (Microns)

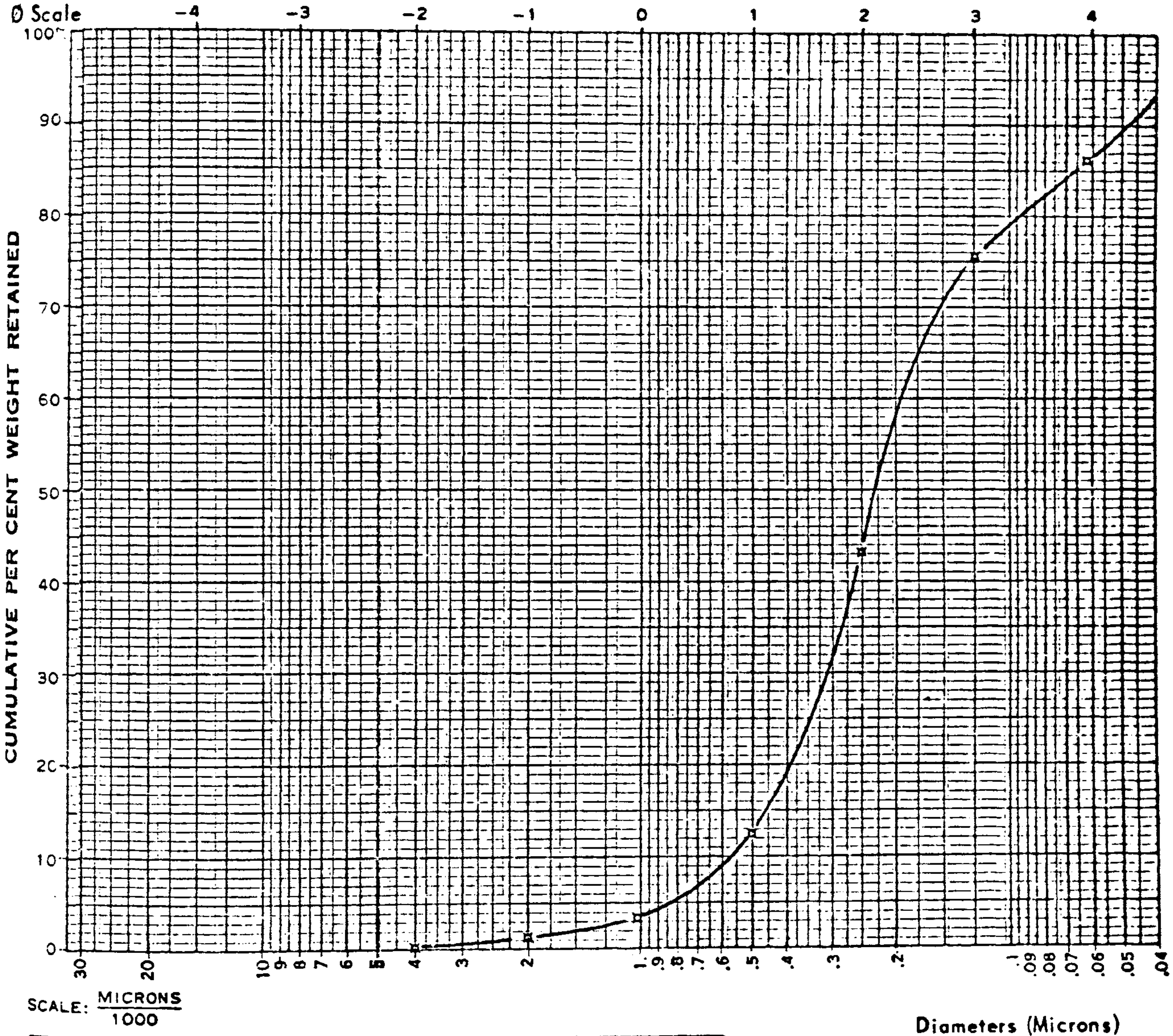
1% = 1,020
50% = 300
Modal Class (Ø Scale) = (1,2)



Sample No. S 5-6

Screen Analysis

Sand



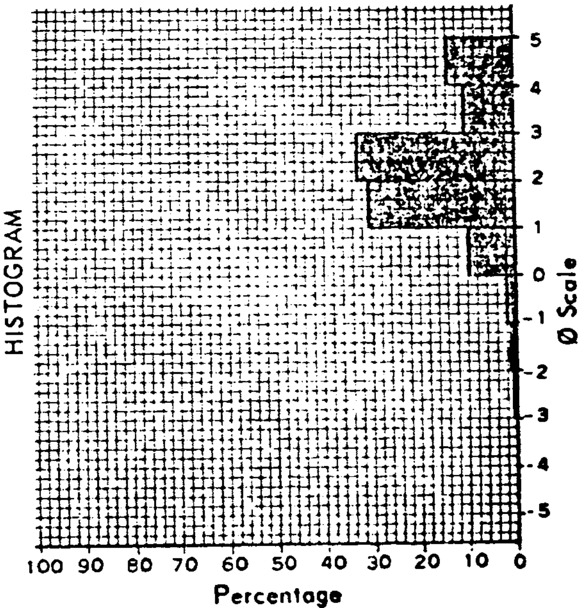
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2	0.15	0.2	0.15	0.2
2	-1	0.93	1.2	1.08	1.4
1.00	0.00	1.58	2.0	2.66	3.4
(1/2) 0.5	1.00	7.34	9.3	10.00	12.7
(1/4) 0.250	2.00	23.91	30.4	33.91	43.1
(1/8) 0.125	3.00	25.86	32.8	59.77	75.9
(1/16) 0.062	4.00	8.06	10.2	67.83	86.1
Pan		10.91	13.9	78.74	100.0
TOTAL		78.74	100.0		
Loss					

Diameters (Microns)

1% = 2,300

50% = 230

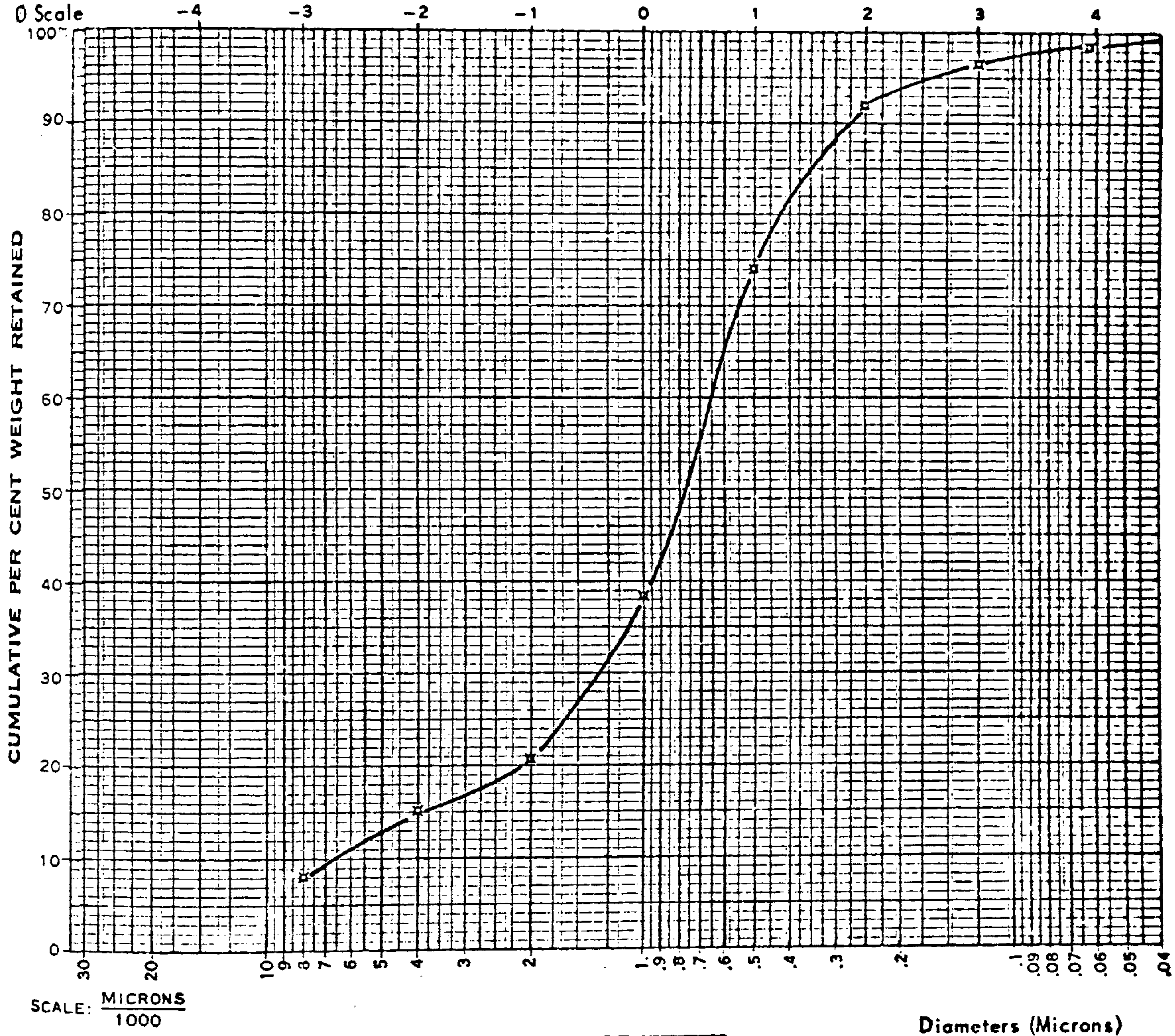
Modal Class (Ø Scale) = (2,3)



Sample No. S 10-1

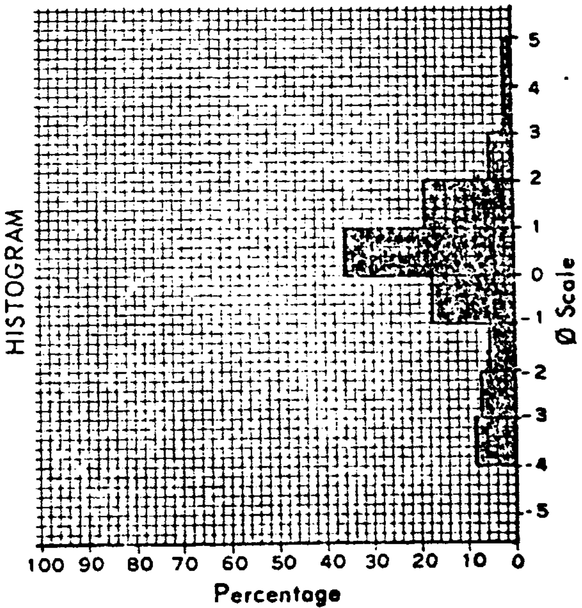
Screen Analysis

Gravelly Sand



Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3	6.55	8.2	6.55	8.2
4	-2	5.65	7.1	12.20	15.3
2	-1	4.48	5.6	16.68	20.9
1.00	0.00	13.95	17.5	30.63	38.4
(1/2) 0.5	1.00	28.27	35.4	58.90	73.8
(1/4) 0.250	2.00	14.50	18.2	73.40	92.0
(1/8) 0.125	3.00	3.80	4.8	77.20	96.8
(1/16) 0.062	4.00	1.30	1.6	78.50	98.4
Pan		1.28	1.6	79.78	100.0
	TOTAL	79.78	100.0		
	Loss				

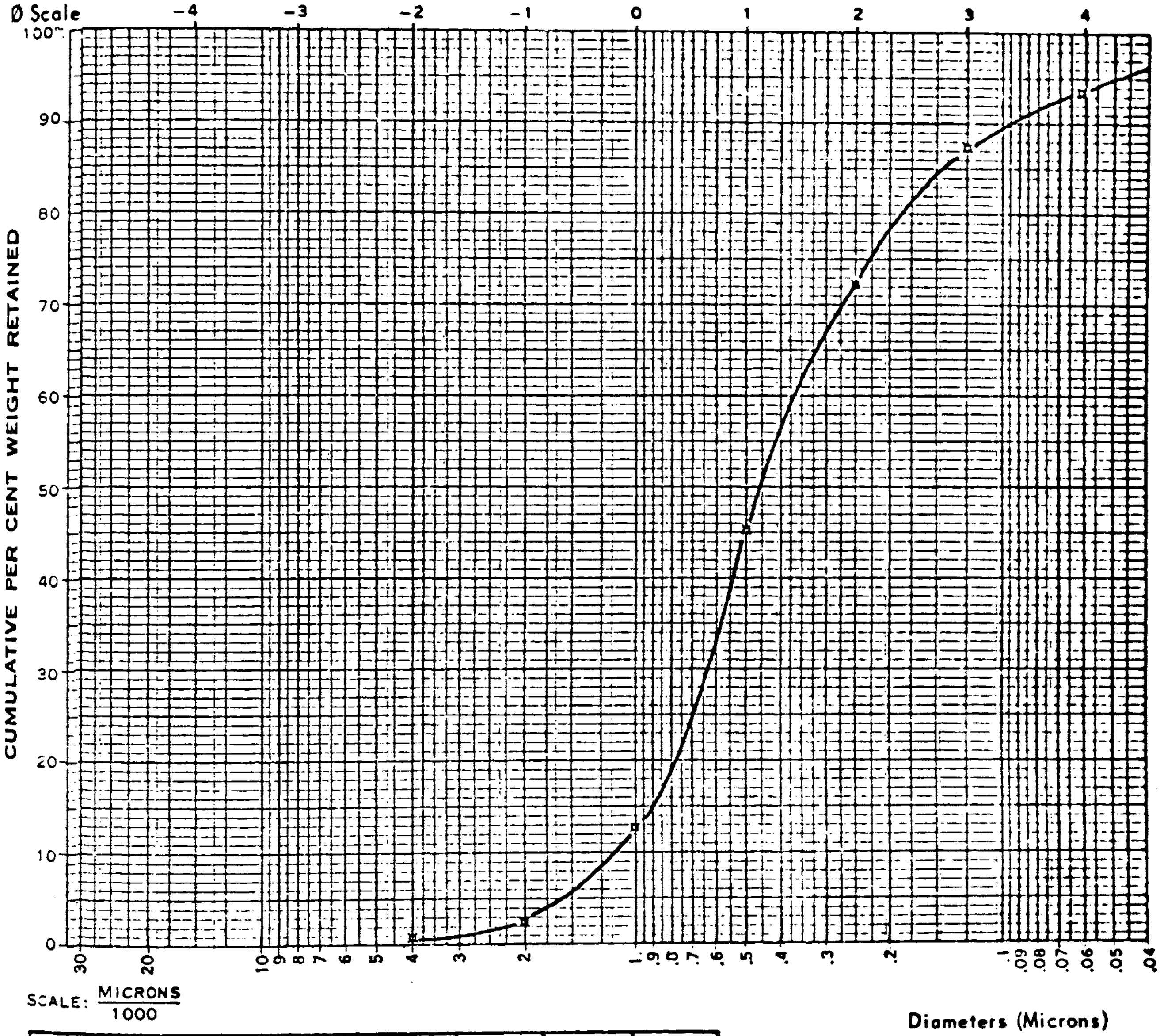
1% =
50% = 760
Modal Class (Ø Scale) = (0, 1)



Sand

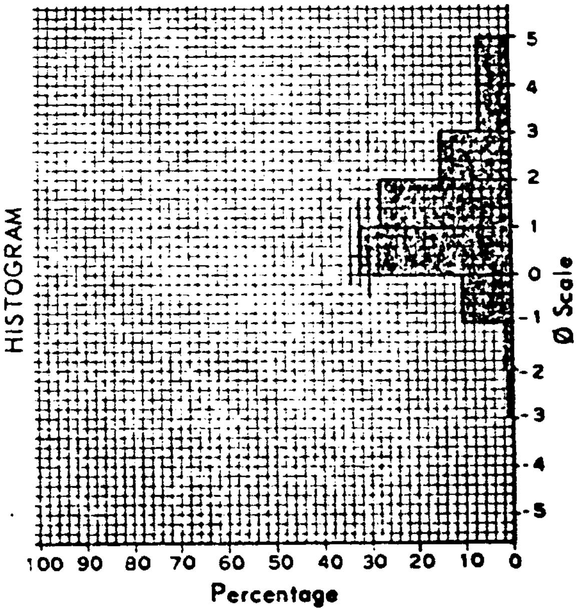
Sample No. S 10-2

Screen Analysis



1% = 3,000
50% = 450
Modal Class (Ø Scale) = (0, 1)

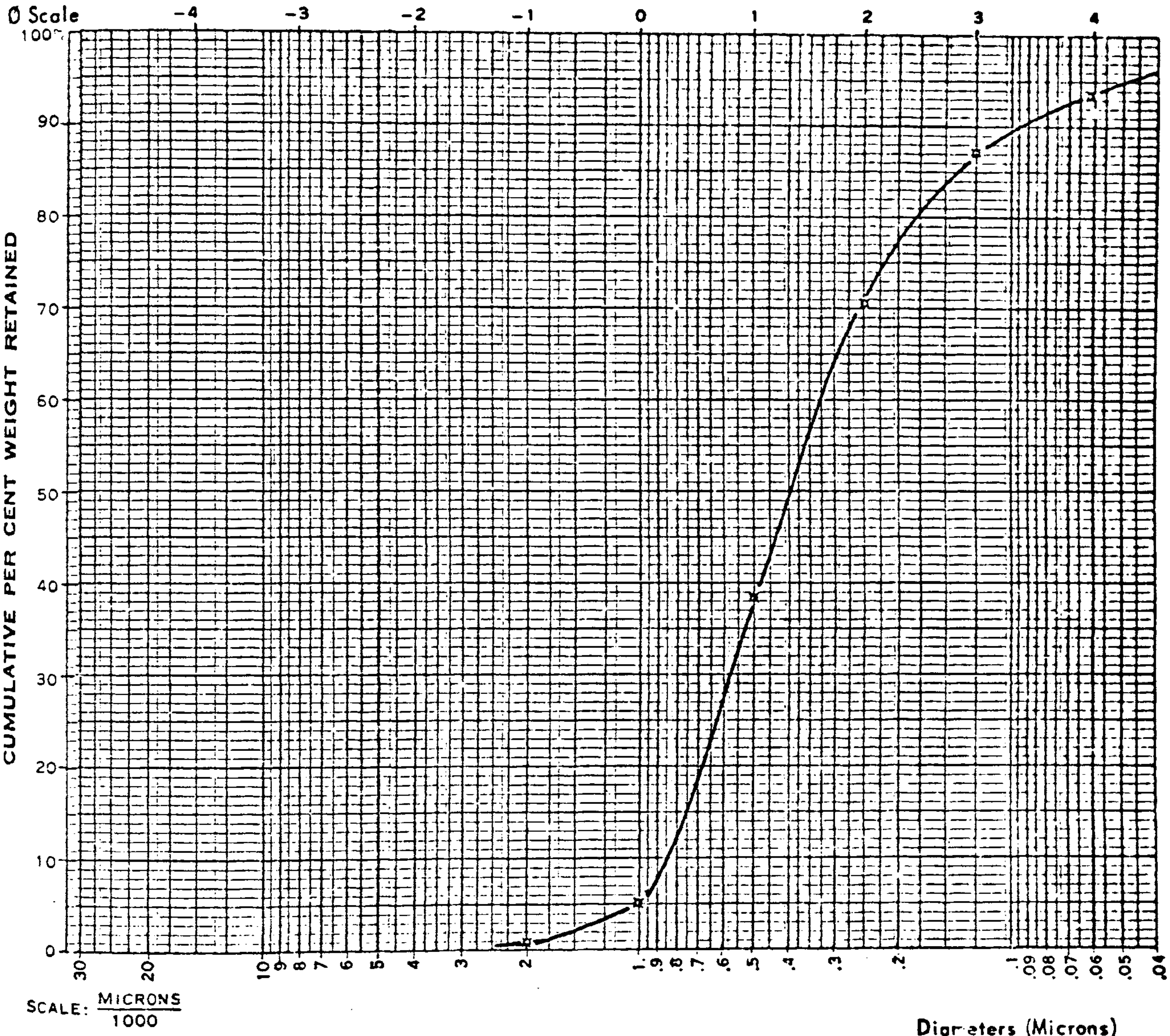
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2	0.60	0.8	0.60	0.8
2	-1	1.32	1.7	1.92	2.5
1.00	0.00	7.89	10.4	9.81	12.9
(1/2) 0.5	1.00	24.55	32.2	34.36	45.1
(1/4) 0.250	2.00	20.75	27.3	55.11	72.4
(1/8) 0.125	3.00	11.23	14.7	66.34	87.1
(1/16) 0.062	4.00	4.91	6.4	71.25	93.6
Pan		4.88	6.4	76.13	100.0
TOTAL		76.13	99.9		
Loss					



Sand

Sample No. S 10-3

Screen Analysis

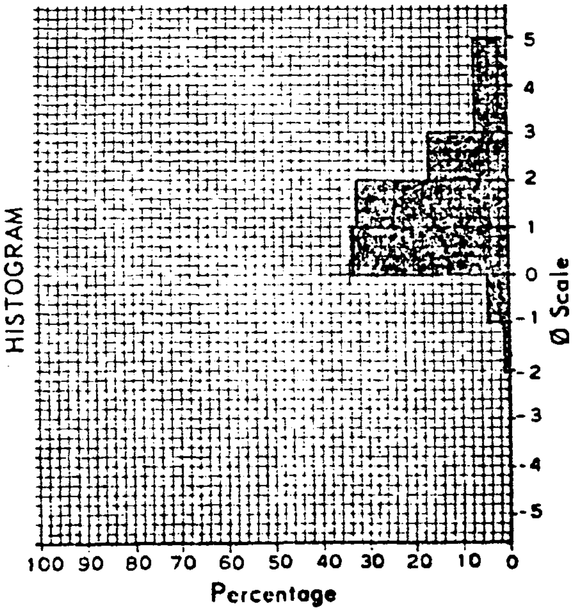


1% = 1,750

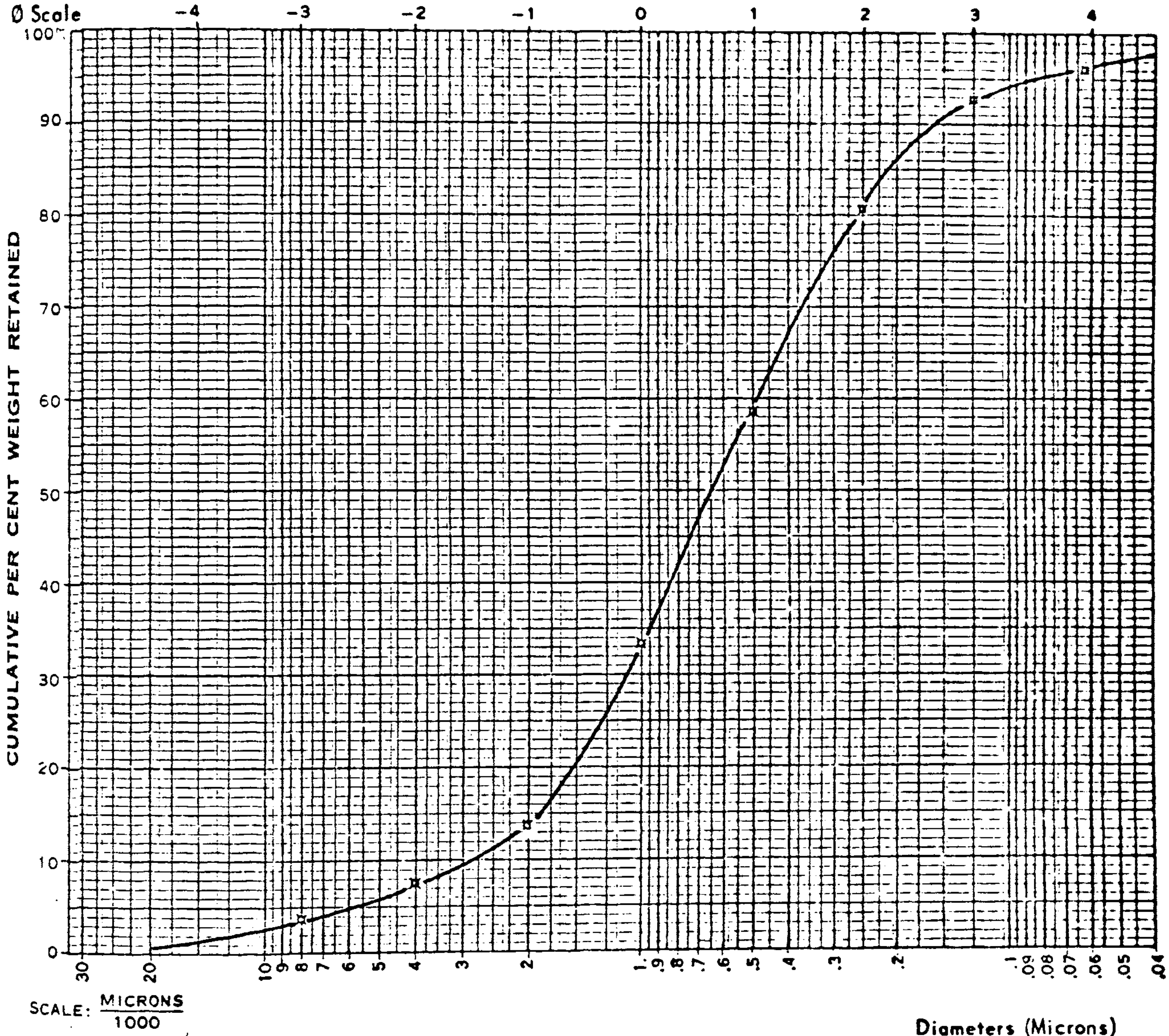
50% = 395

Modal Class (Ø Scale) = (0, 1) (1, 2)

Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2				
2	-1	0.62	0.8	0.62	0.8
1.00	0.00	3.41	4.4	4.03	5.1
(1/2) 0.5	1.00	25.82	33.0	29.85	38.2
(1/4) 0.250	2.00	25.59	32.7	55.44	70.9
(1/8) 0.125	3.00	12.65	16.2	68.09	87.0
(1/16) 0.062	4.00	5.04	6.4	73.13	93.5
Pan		5.10	6.5	78.23	100.0
TOTAL		78.23	100.0		
Loss					



Sample No. S 10-5 **Screen Analysis** Gravelly Sand



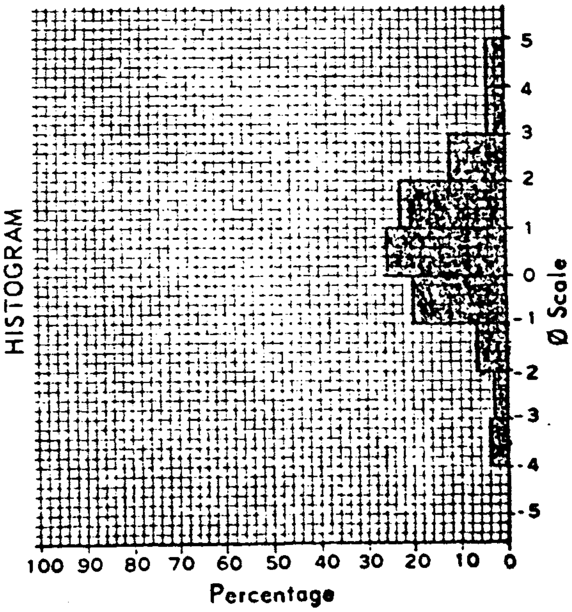
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3	2.93	3.9	2.93	3.9
4	-2	2.82	3.7	5.75	7.6
2	-1	4.73	6.3	10.48	13.9
1.00	0.00	14.69	19.5	25.17	33.4
(1/2) 0.5	1.00	18.96	25.2	44.13	58.6
(1/4) 0.250	2.00	16.78	22.3	60.91	80.8
(1/8) 0.125	3.00	8.95	11.9	69.86	92.7
(1/16) 0.062	4.00	2.62	3.5	72.48	96.2
Pan		2.88	3.8	75.36	100.0
	TOTAL	75.36	100.1		
	Loss				

Diameters (Microns)

1% = 17,500

50% = 650

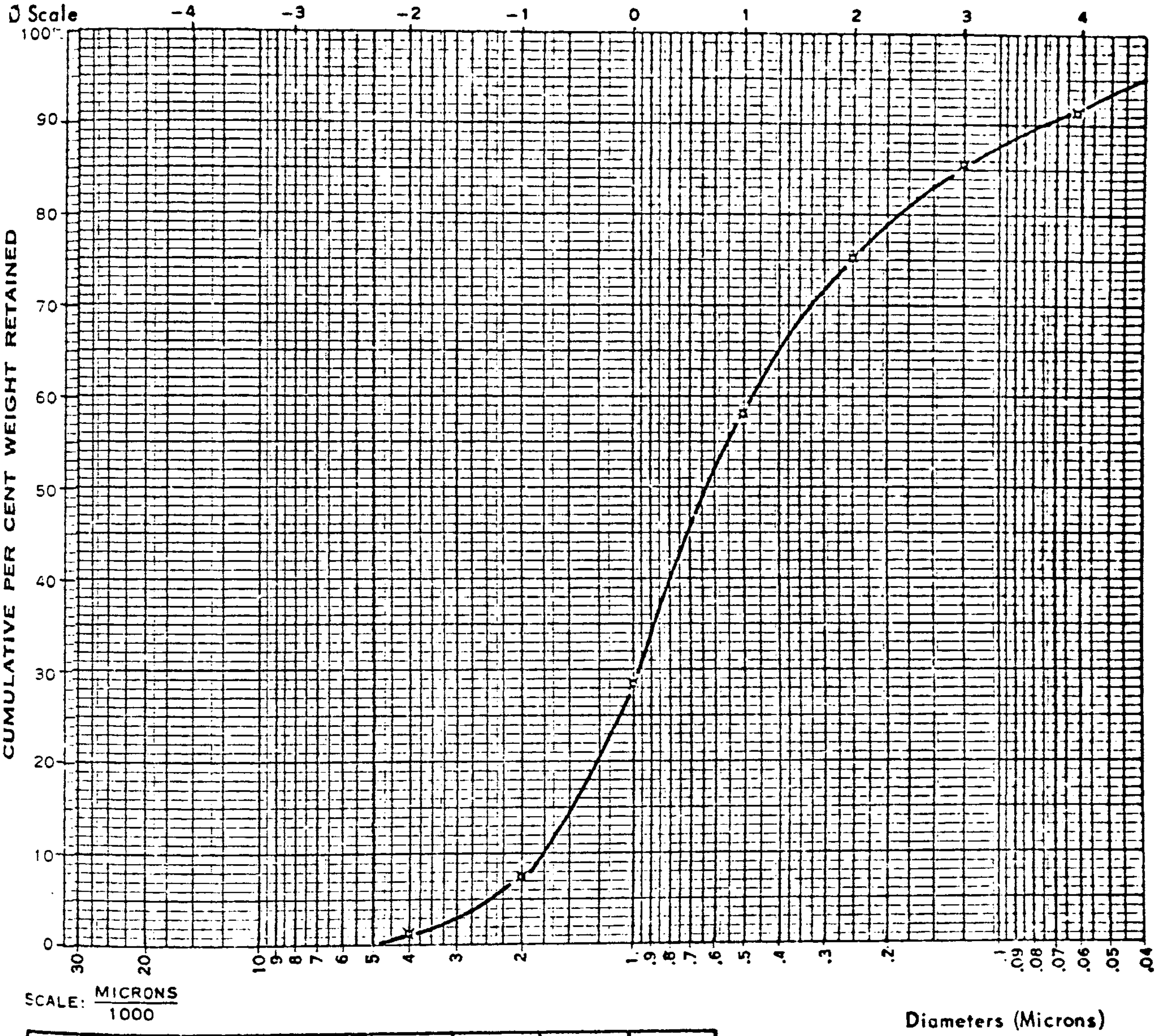
Modal Class (Ø Scale) = (0, 1)



Sample No. S 11-1

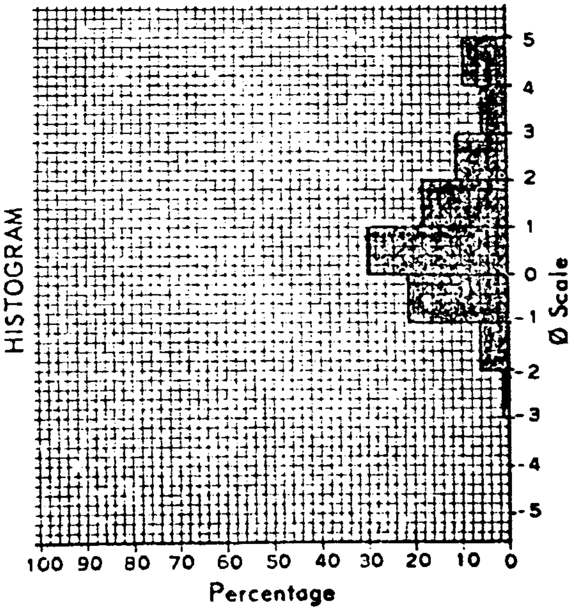
Screen Analysis

Gravelly Sand

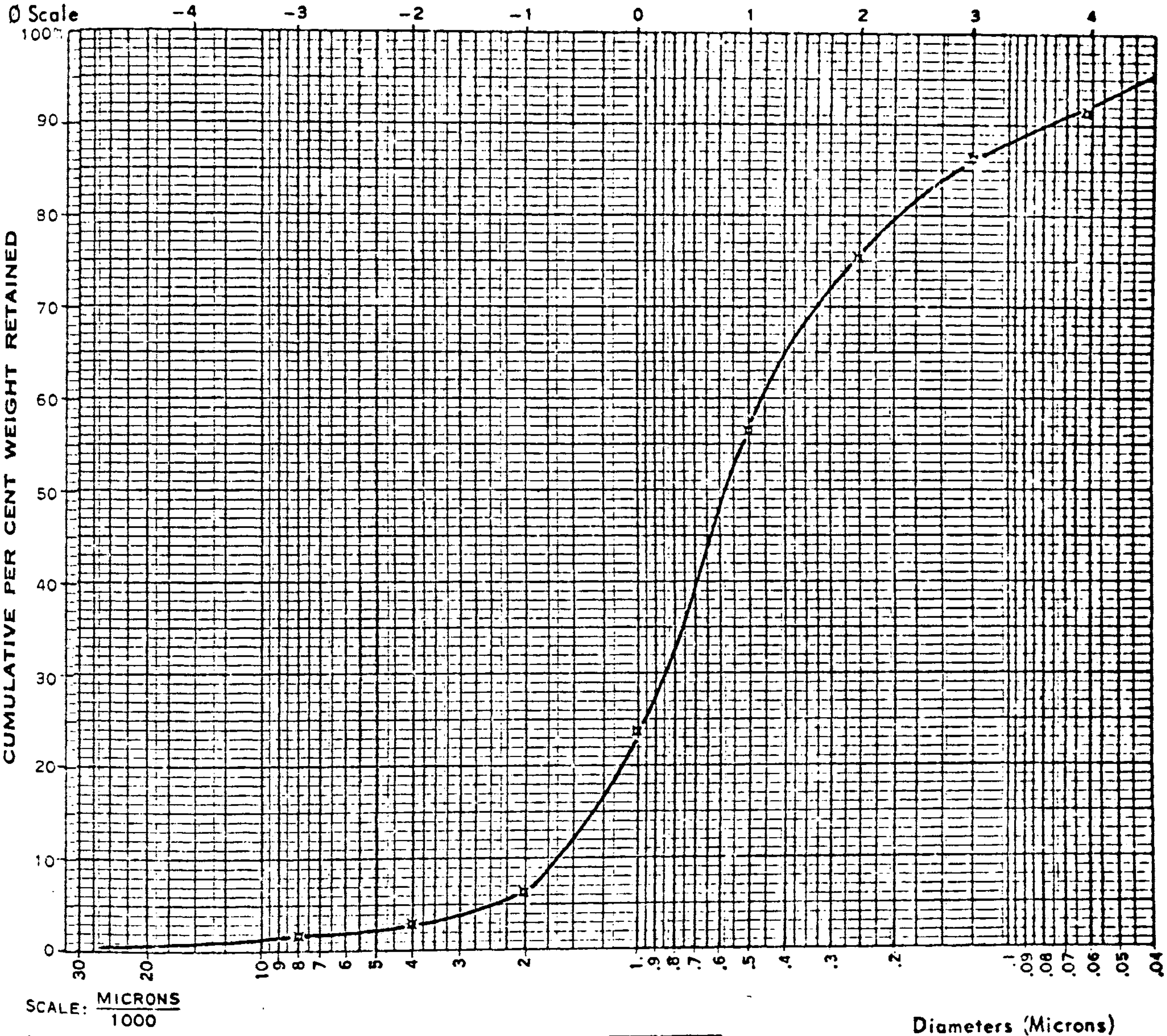


Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2	1.10	1.4	1.10	1.4
2	-1	4.70	6.1	5.80	7.5
1.00	0.00	16.30	21.1	22.10	28.6
(1/2) 0.5	1.00	22.80	29.5	44.90	58.0
(1/4) 0.250	2.00	13.39	17.3	58.29	75.3
(1/8) 0.125	3.00	8.11	10.5	66.40	85.8
(1/16) 0.062	4.00	4.11	5.3	70.51	91.1
Pan		6.85	8.8	77.36	100.0
	TOTAL	77.36	100.0		
	Loss				

1% = 4,100
50% = 640
Modal Class (Ø Scale) = (0,1)



Sample No. S 11-2 **Screen Analysis** Gravelly Sand



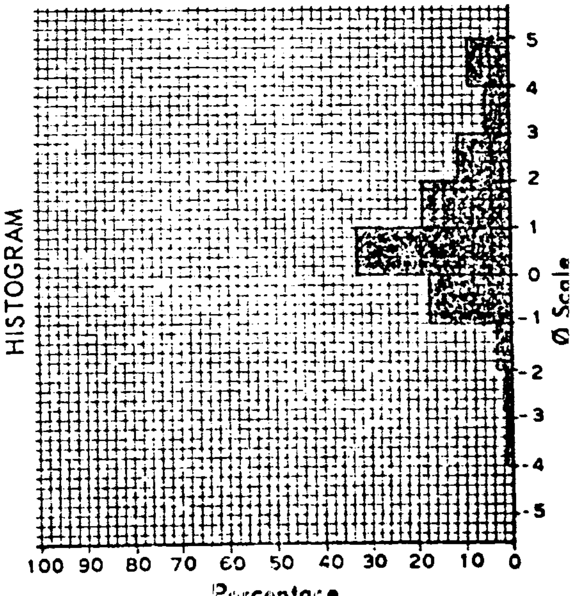
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3	1.24	1.6	1.24	1.6
4	-2	1.10	1.4	2.34	2.9
2	-1	2.66	3.4	5.00	6.3
1.00	0.00	13.75	17.3	18.75	23.7
(1/2) 0.5	1.00	26.03	32.8	44.78	56.5
(1/4) 0.250	2.00	14.76	18.6	59.54	75.1
(1/8) 0.125	3.00	8.72	11.0	68.26	86.1
(1/16) 0.062	4.00	4.32	5.4	72.58	91.6
Pan		6.65	8.4	79.23	100.0
TOTAL		79.23	99.9		
Loss					

Diameters (Microns)

1% = 12,500

50% = 580

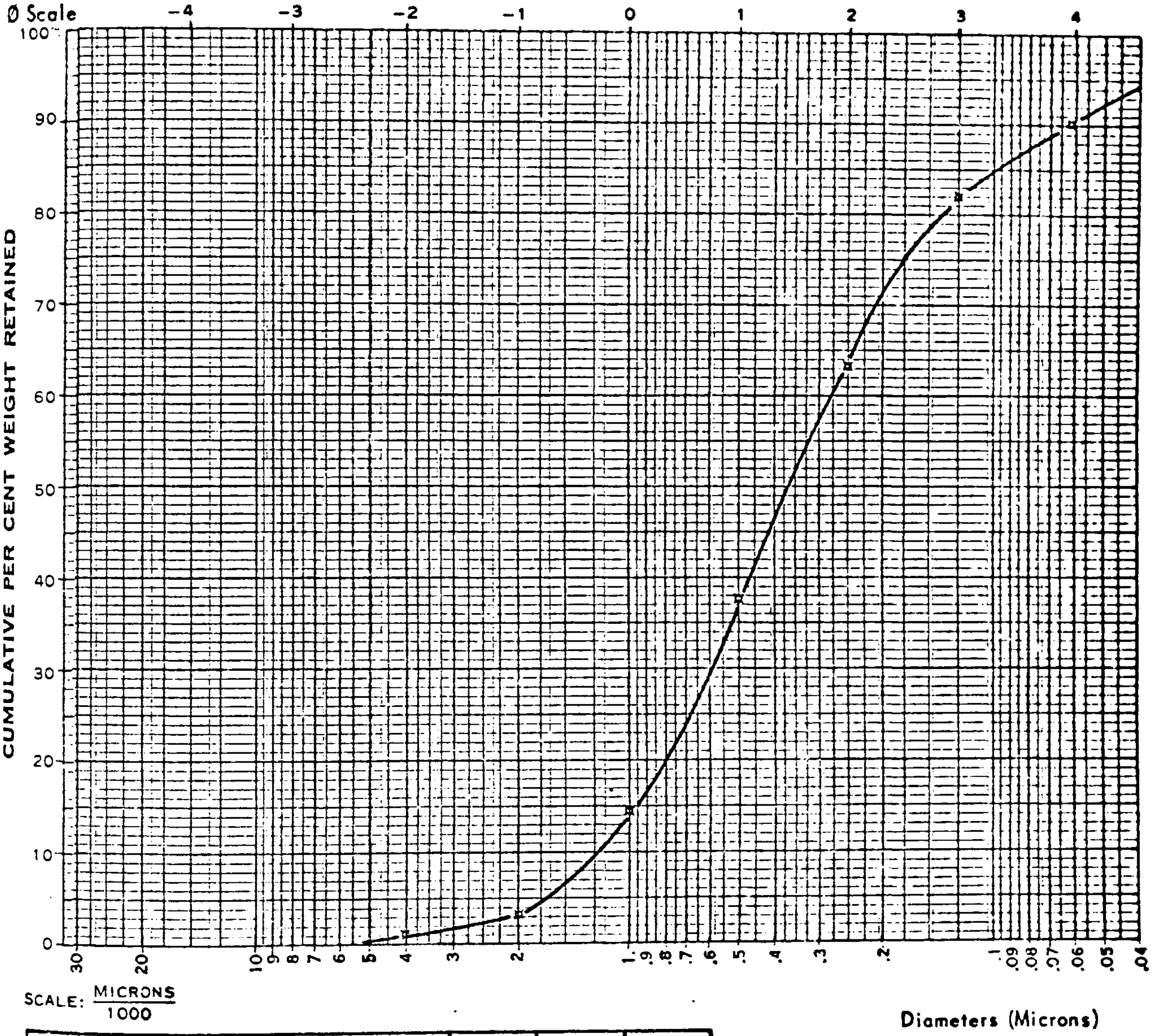
Modal Class (Ø Scale) = (0,1)



Sand

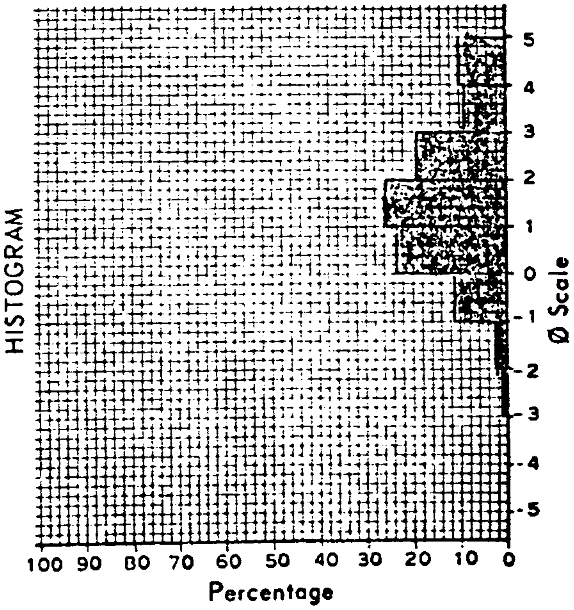
Sample No. S 11-4

Screen Analysis



Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2	0.84	1.1	0.84	1.1
2	-1	1.69	2.2	2.53	3.3
1.00	0.00	8.82	11.4	11.35	14.7
(1/2) 0.5	1.00	17.82	23.1	29.17	37.8
(1/4) 0.250	2.00	19.59	25.4	48.76	63.2
(1/8) 0.125	3.00	14.53	18.8	63.29	82.0
(1/16) 0.062	4.00	6.36	8.2	69.65	90.2
Pan		7.55	9.8	77.20	100.0
	TOTAL	77.20	100.0		
	Loss				

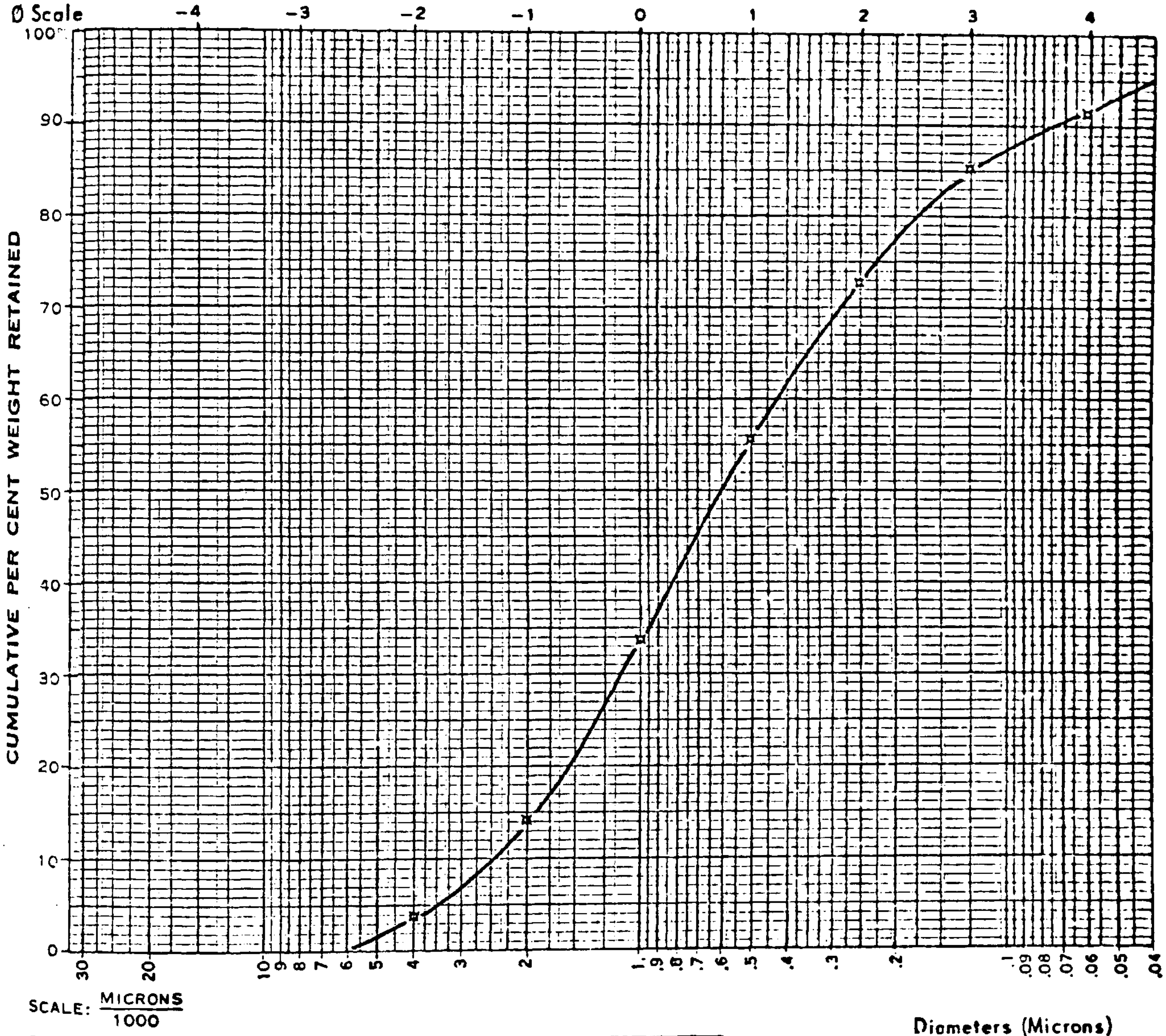
1% = 4,100
50% = 370
Modal Class (Ø Scale) = (1,2)



Sample No. S 12-1

Screen Analysis

Gravelly Sand



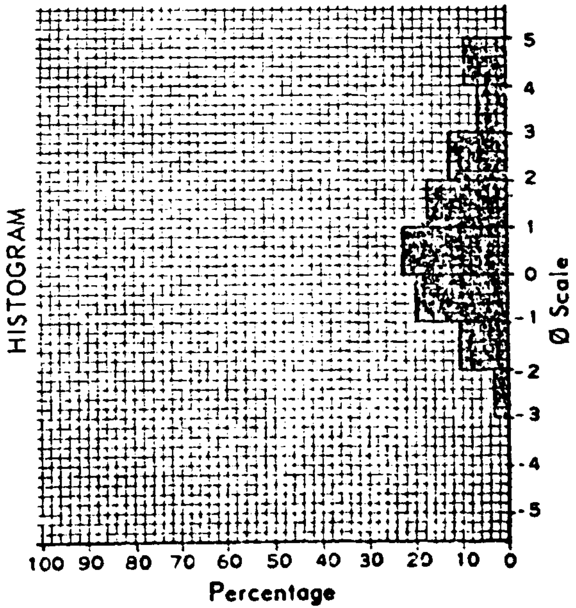
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2	2.90	3.7	2.90	3.7
2	-1	8.09	10.4	10.99	14.2
1.00	0.00	15.21	19.6	26.20	33.8
(1/2) 0.5	1.00	17.11	22.1	43.31	55.9
(1/4) 0.250	2.00	13.9	16.9	56.40	72.8
(1/8) 0.125	3.00	9.61	12.4	66.01	85.2
(1/16) 0.062	4.00	4.67	6.0	70.68	91.3
Pan		6.75	8.7	77.43	100.0
	TOTAL	77.43	99.8		
	Loss				

Diameters (Microns)

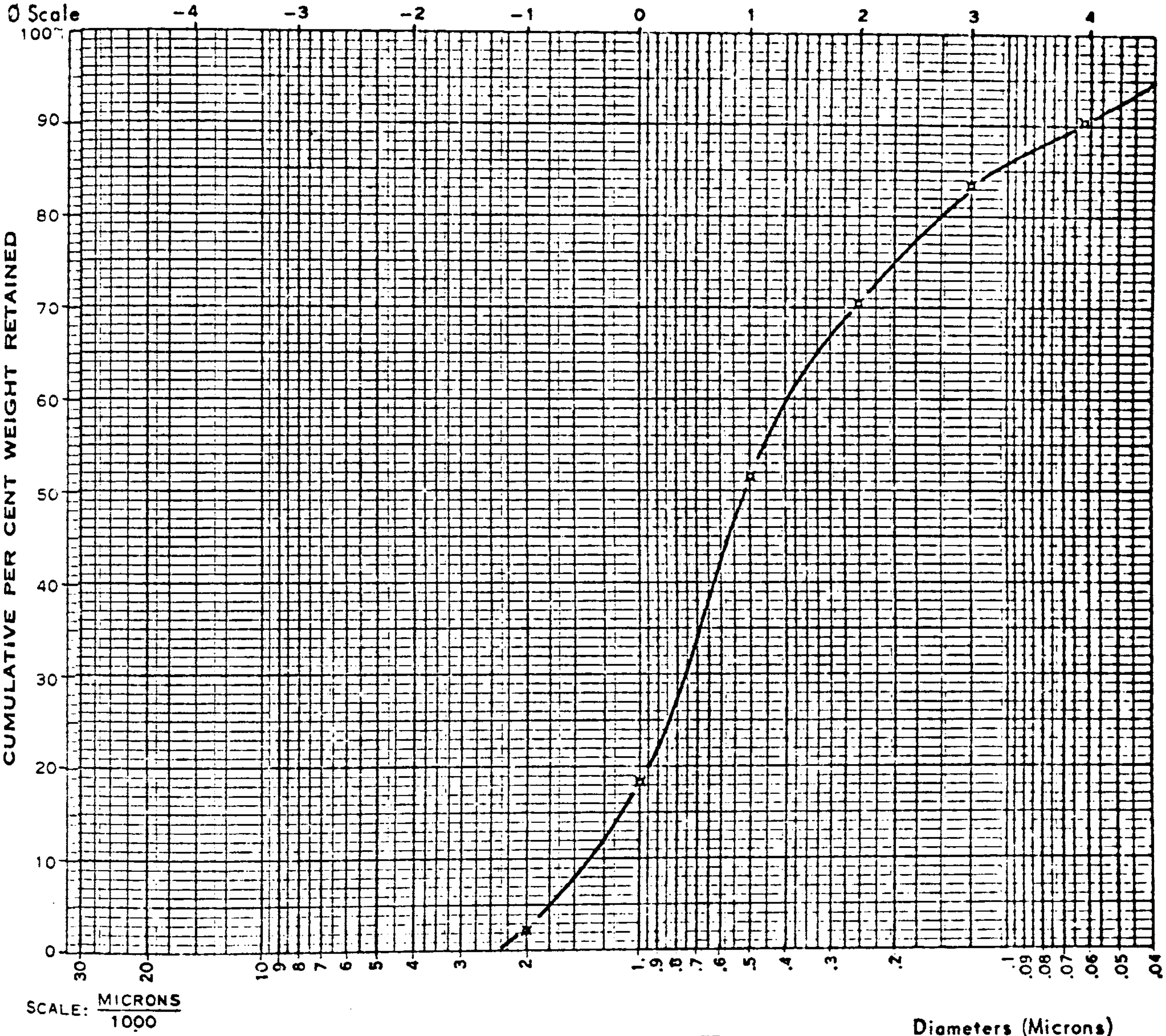
1% = 5,300

50% = 600

Modal Class (Ø Scale) = (0, 1)



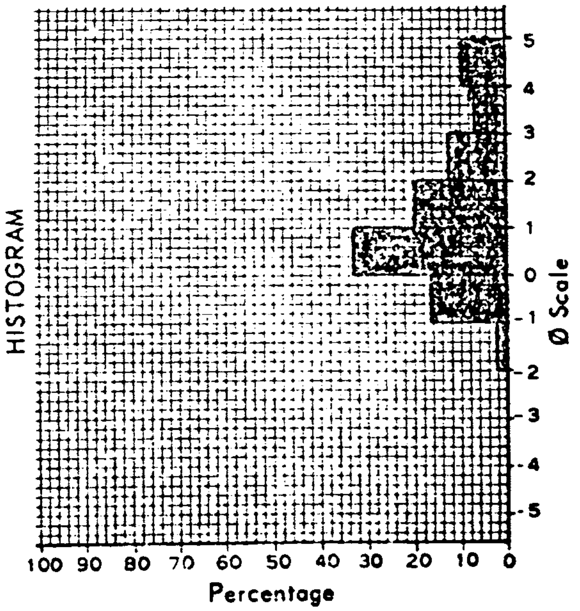
Sample No. S 12-2 **Screen Analysis** Sand



Diameters (Microns)

1% = 2,250
50% = 510
Modal Class (Ø Scale) = (0,1)

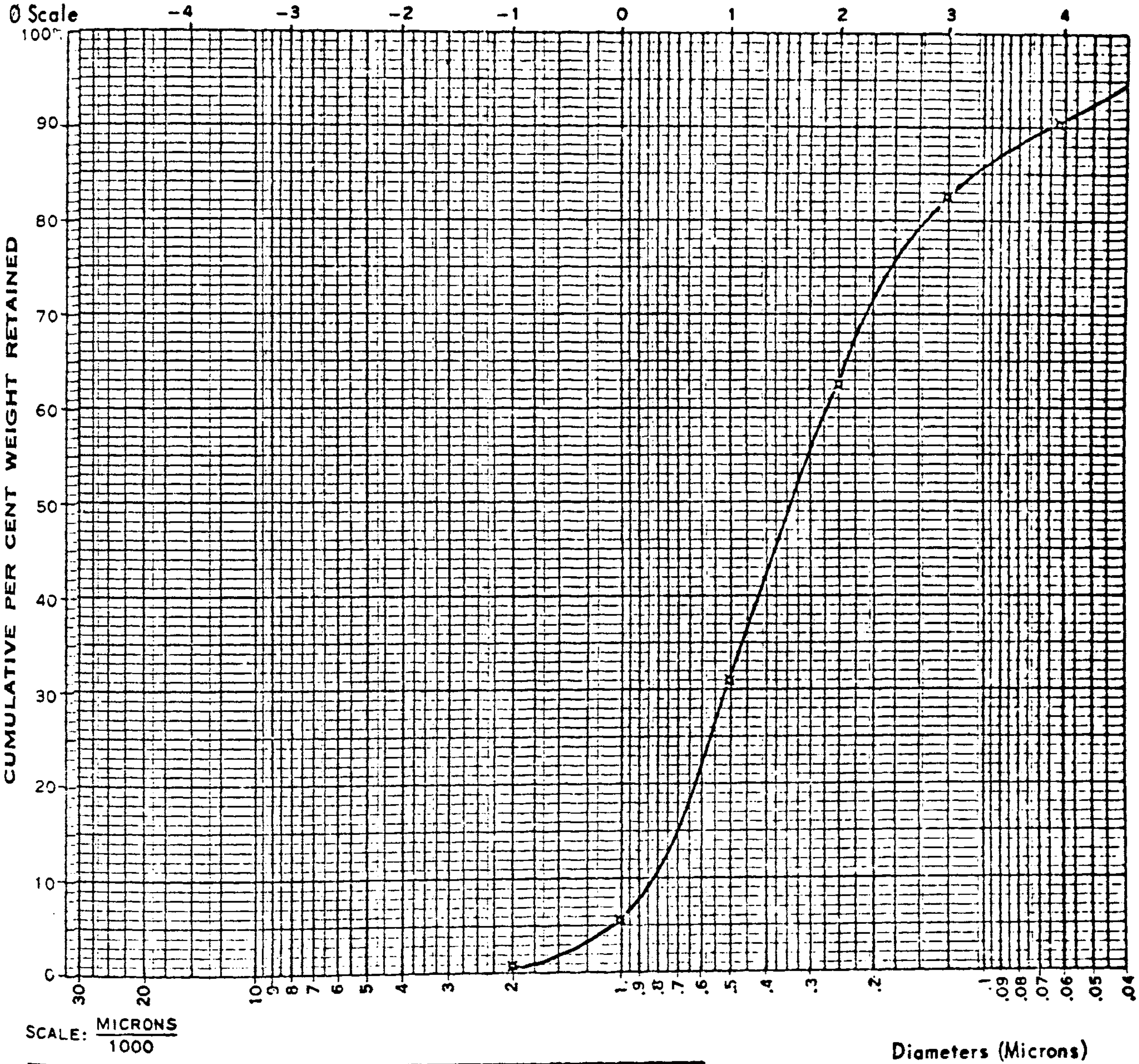
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2				
2	-1	1.60	2.1	1.60	2.1
1.00	0.00	12.48	16.3	14.08	18.4
(1/2) 0.5	1.00	25.31	33.0	39.39	51.4
(1/4) 0.250	2.00	15.20	19.8	54.59	71.2
(1/8) 0.125	3.00	9.60	12.5	64.19	83.7
(1/16) 0.062	4.00	5.07	6.6	69.26	90.3
Pan		7.41	9.7	76.67	100.0
	TOTAL	76.67	100.0		
	Loss				



Sample No. S 12-3

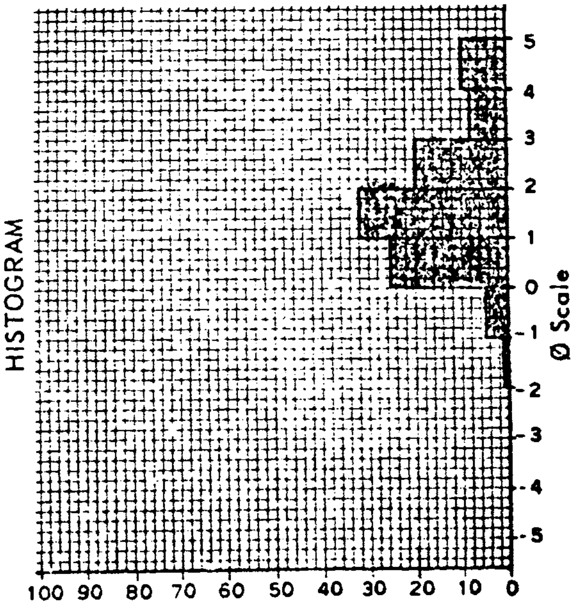
Screen Analysis

Sand



1% = 1,750
50% = 335
Modal Class (Ø Scale) = (1,2)

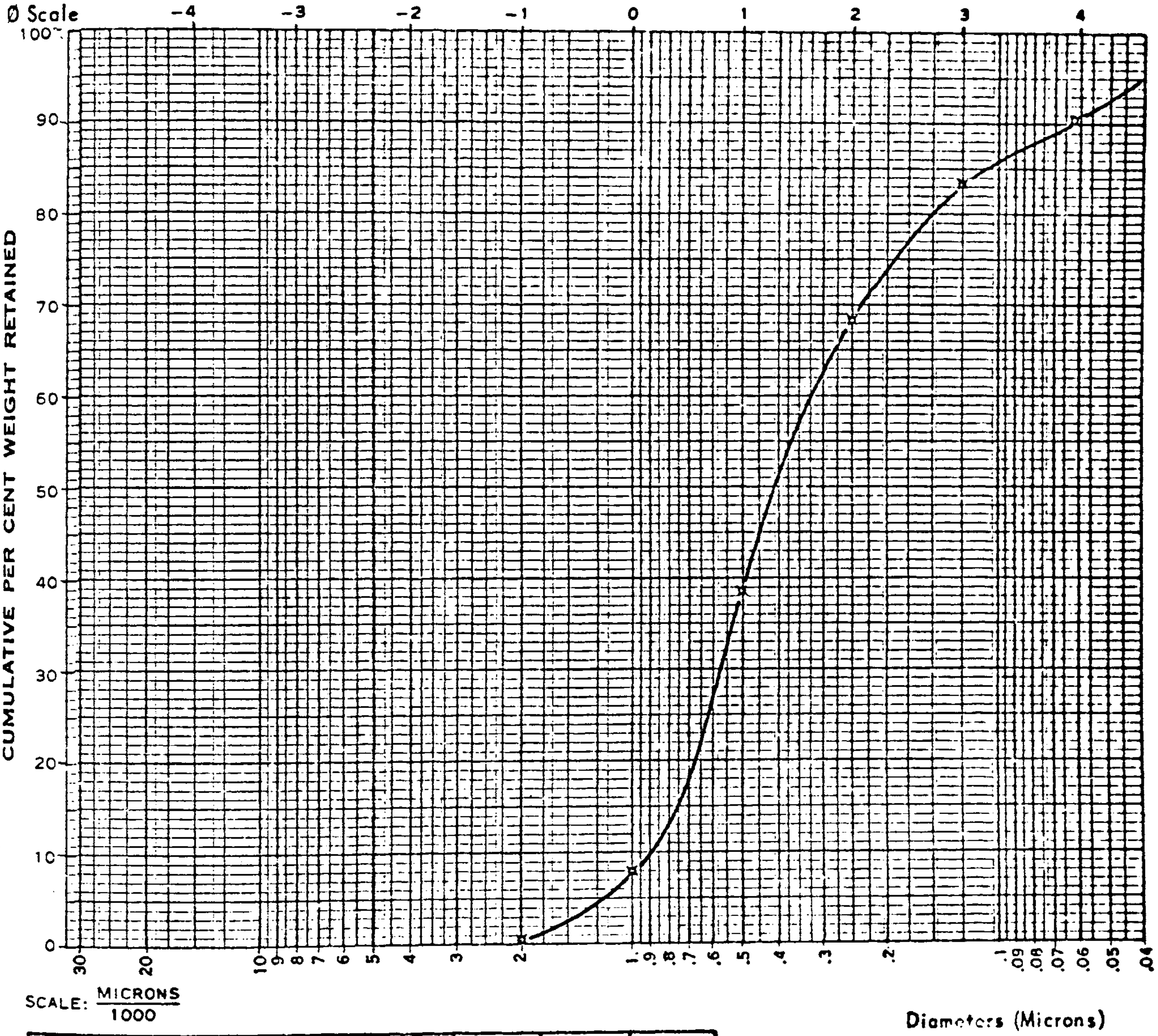
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2				
2	-1	0.62	0.8	0.62	0.8
1.00	0.00	3.70	4.8	4.32	5.7
(1/2) 0.5	1.00	19.29	25.3	23.61	31.0
(1/4) 0.250	2.00	24.31	31.9	47.92	62.8
(1/8) 0.125	3.00	15.05	19.7	62.97	82.6
(1/16) 0.062	4.00	6.08	8.0	69.05	90.6
Pan		7.20	9.4	76.25	100.0
	TOTAL	76.25	99.9		
	Loss				



Sample No. S 12-5

Screen Analysis

Sand

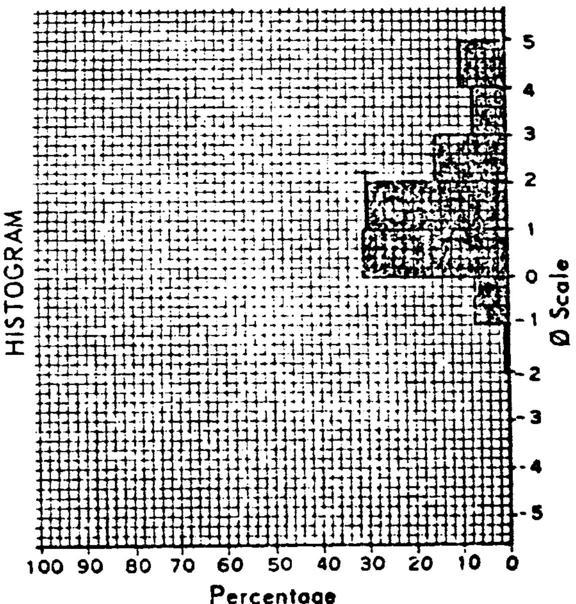


Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2				
2	-1	0.40	0.5	0.40	0.5
1.00	0.00	5.69	7.4	6.09	7.9
(1/2) 0.5	1.00	23.57	30.7	29.66	38.6
(1/4) 0.250	2.00	22.80	29.7	52.46	68.3
(1/8) 0.125	3.00	11.60	15.1	64.06	83.4
(1/16) 0.062	4.00	5.44	7.1	69.50	90.5
Pan		7.28	9.5	76.78	100.0
	TOTAL	76.78	100.0		
	Loss				

1% = 1,750

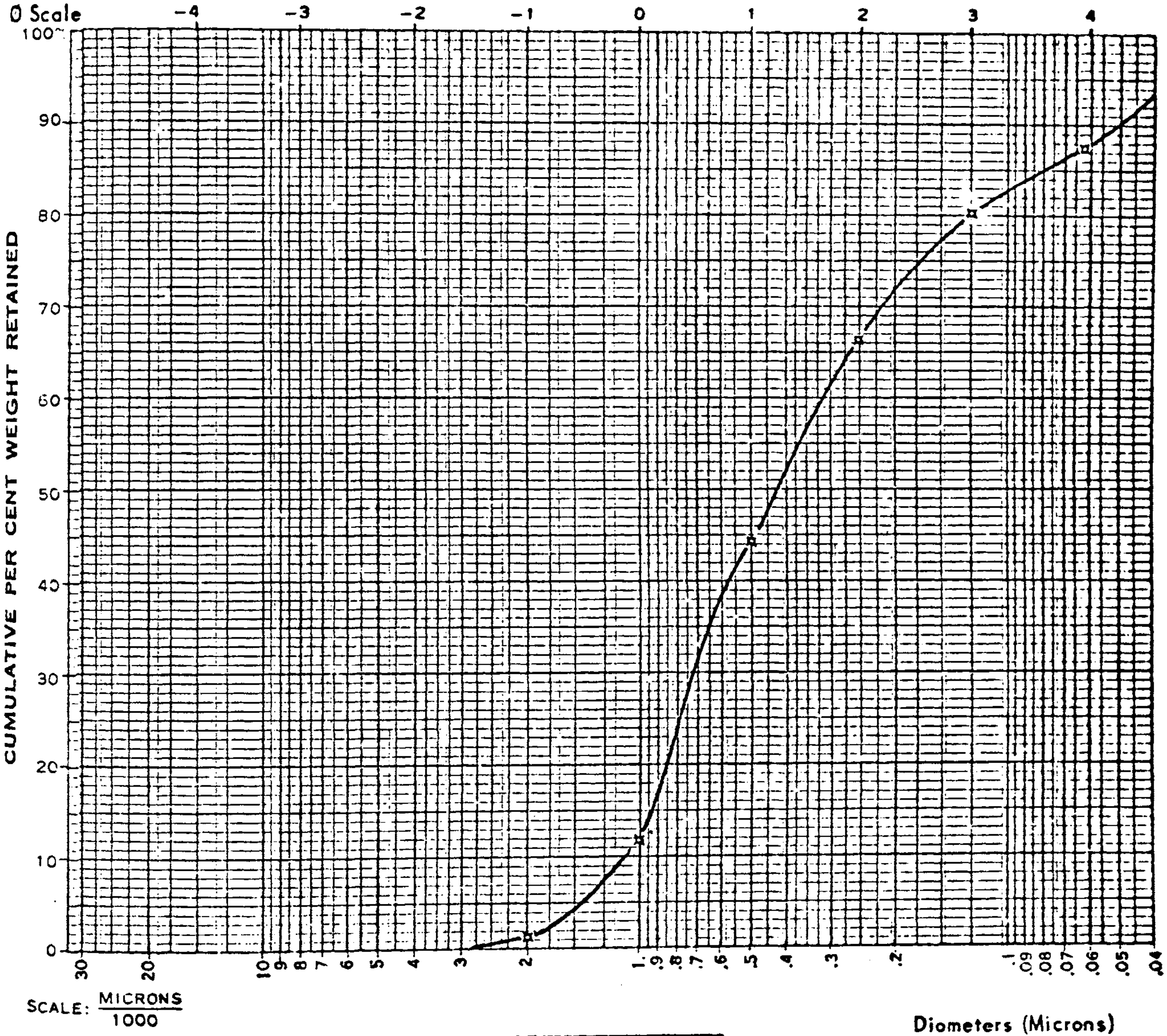
50% = 405

Modal Class (Ø Scale) = (0,1)



Sample No. S 12-6

Screen Analysis



SCALE: $\frac{\text{MICRONS}}{1000}$

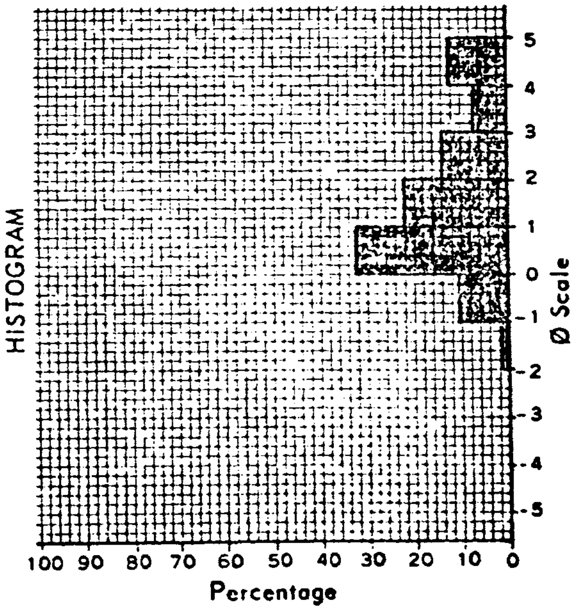
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2				
2	-1	1.03	1.4	1.03	1.4
1.00	0.00	7.45	10.3	8.48	11.7
(1/2) 0.5	1.00	23.47	32.4	31.95	44.1
(1/4) 0.250	2.00	16.08	22.2	48.03	66.3
(1/8) 0.125	3.00	10.16	14.0	58.19	80.3
(1/16) 0.062	4.00	5.30	7.3	63.49	87.6
Pan		8.95	12.3	72.44	100.0
	TOTAL	72.44	99.9		
	Loss				

Diameters (Microns)

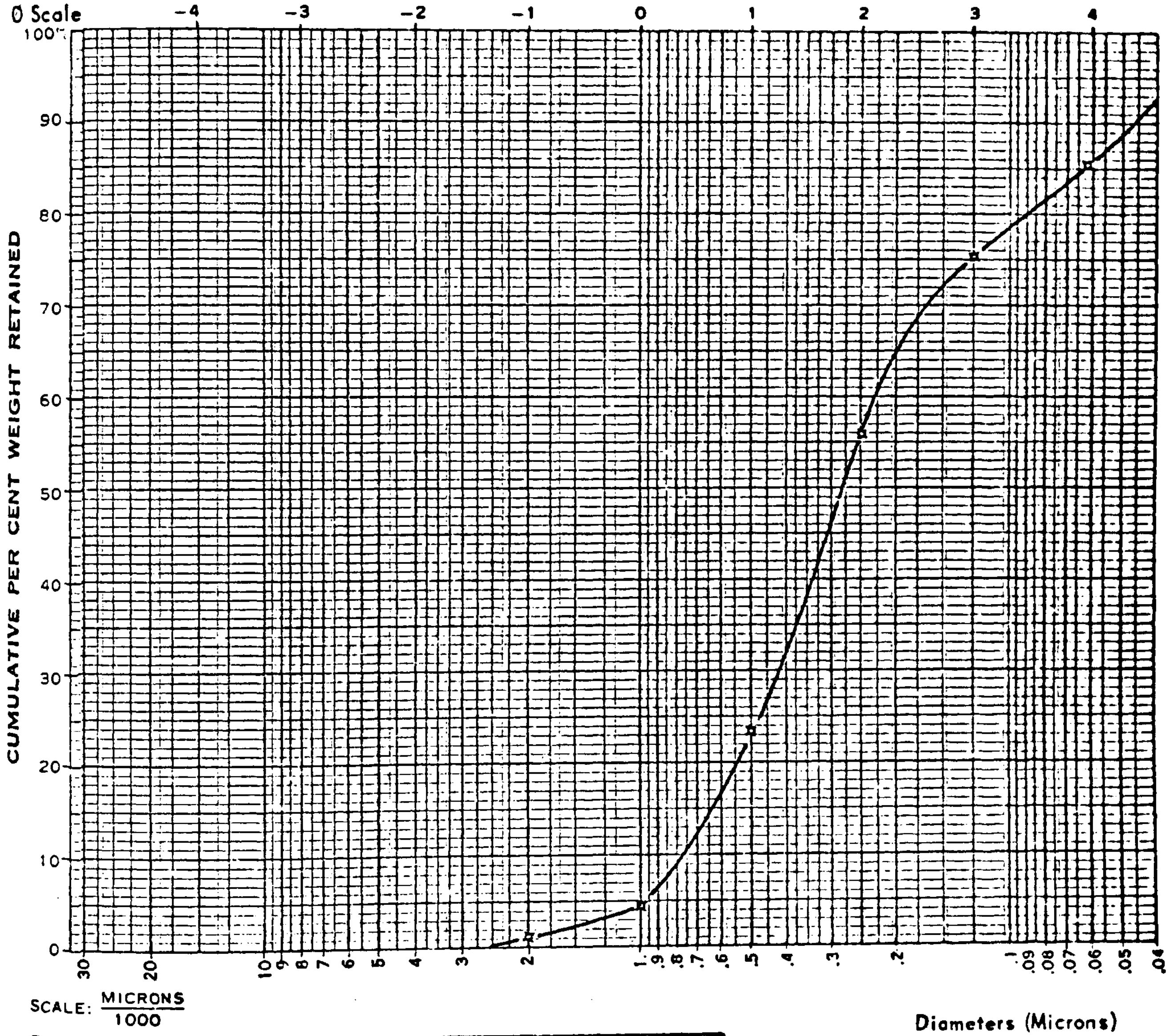
1% = 2,250

50% = 420

Modal Class (Ø Scale) = (0,1)



Sample No. S 12-7 **Screen Analysis** Muddy Sand



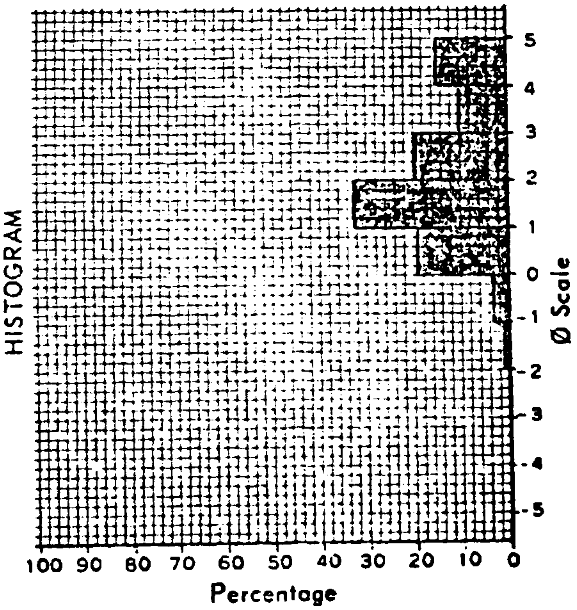
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2				
2	-1	0.98	1.3	0.98	1.3
1.00	0.00	2.52	3.3	3.50	4.5
(1/2) 0.5	1.00	14.65	19.0	18.15	23.6
(1/4) 0.250	2.00	24.91	32.4	43.06	56.0
(1/8) 0.125	3.00	14.84	19.3	57.90	75.2
(1/16) 0.062	4.00	7.72	10.0	65.62	85.3
Pan		11.32	14.7	76.94	100.0
	TOTAL	76.94	100.0		
	Loss				

Diameters (Microns)

1% = 2,100

50% = 280

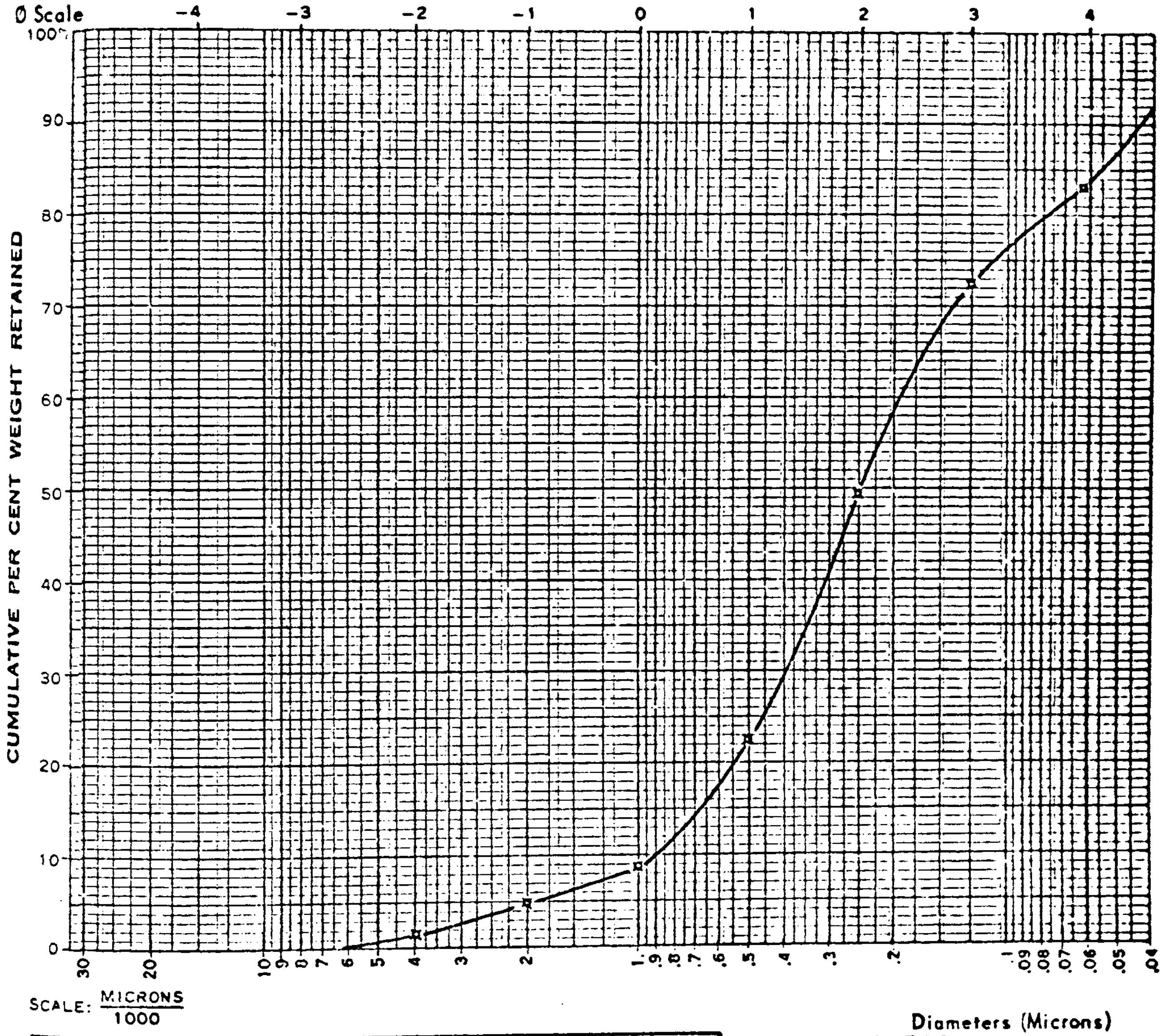
Modal Class (Ø Scale) = (1,2)



Muddy Sand

Sample No. S 12-8

Screen Analysis



SCALE: $\frac{\text{MICRONS}}{1000}$

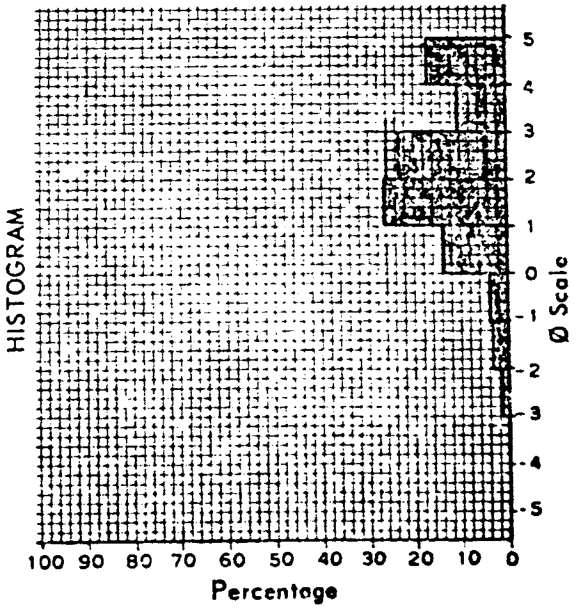
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2	1.15	1.5	1.15	1.5
2	-1	2.53	3.4	3.68	4.9
1.00	0.00	2.91	3.9	6.59	8.8
(1/2) 0.5	1.00	10.30	13.8	16.89	22.6
(1/4) 0.250	2.00	19.89	26.7	36.78	49.3
(1/8) 0.125	3.00	17.49	23.5	54.27	72.3
(1/16) 0.062	4.00	7.72	10.3	61.99	83.1
Pan		12.57	16.9	74.56	100.0
TOTAL		74.56	100.0		
Loss					

Diameters (Microns)

1% = 4,500

50% = 245

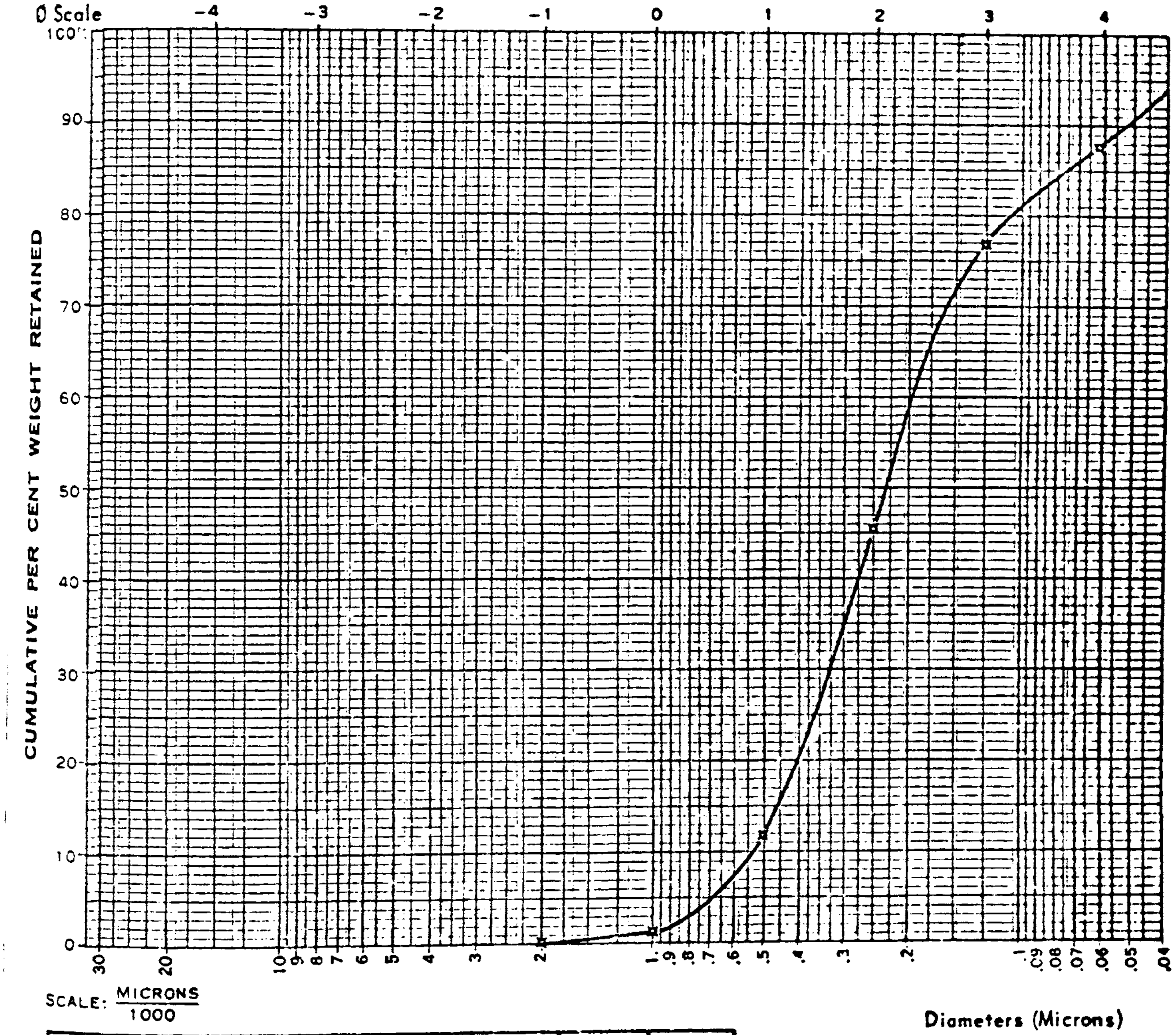
Modal Class (Ø Scale) = (1,2)



Sample No. S 13-1

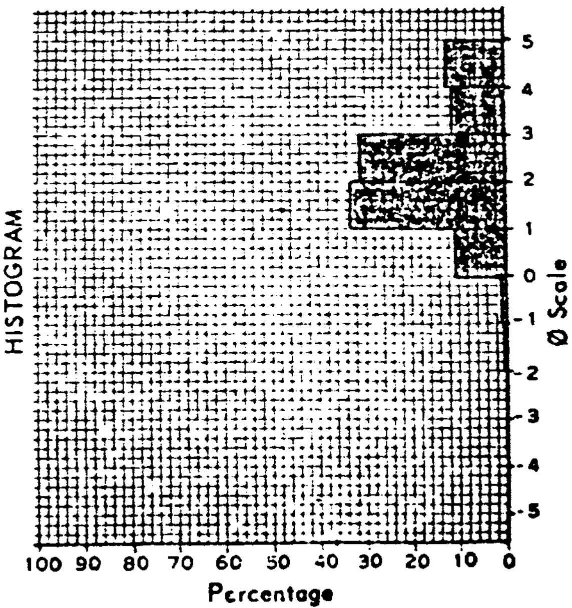
Screen Analysis

Sand



1% = 1,200
50% = 230
Modal Class (Ø Scale) = (1,2)

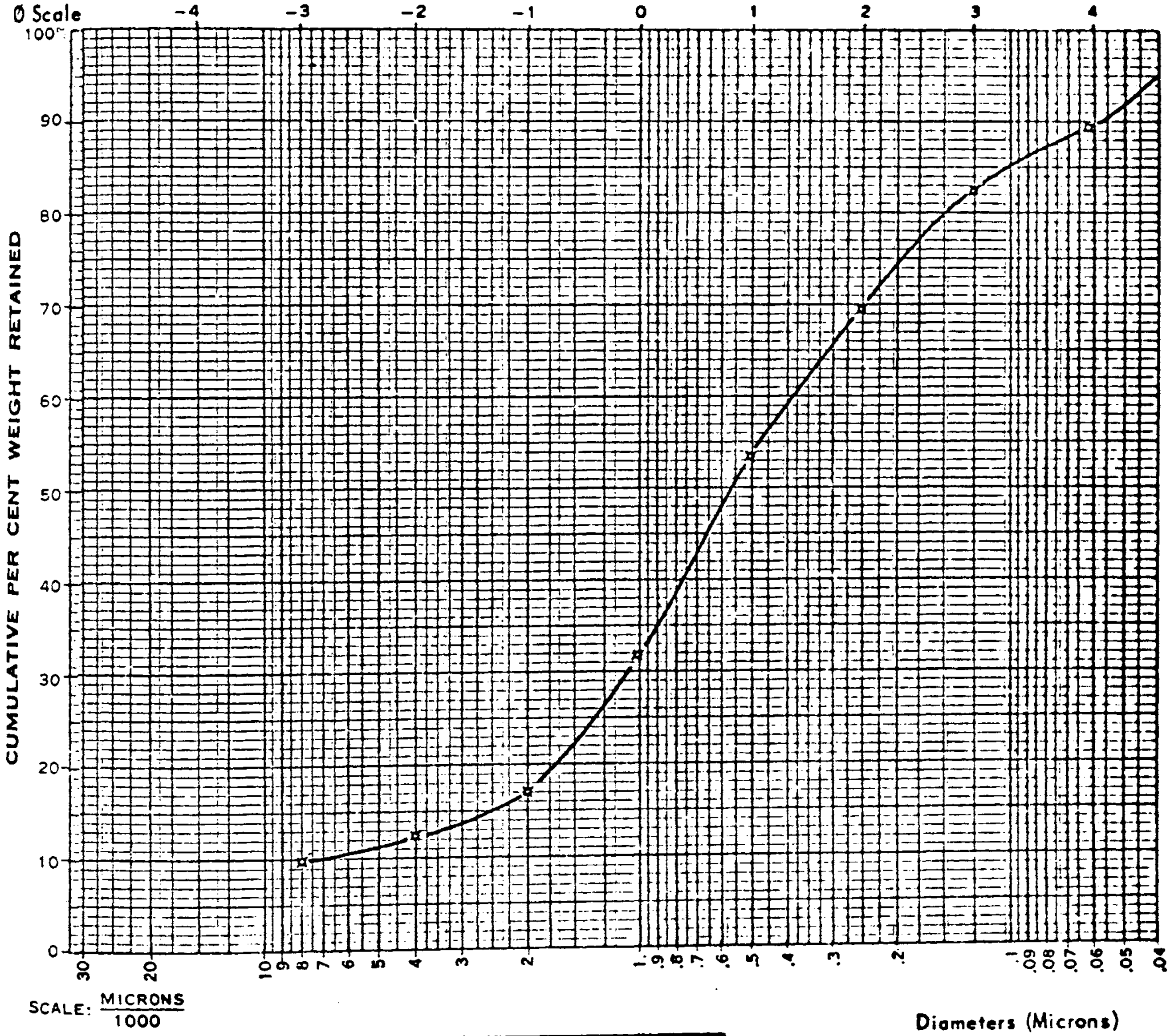
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2				
2	-1	0.21	0.3	0.21	0.3
1.00	0.00	0.91	1.2	1.12	1.4
(1/2) 0.5	1.00	8.13	10.5	9.25	11.9
(1/4) 0.250	2.00	26.26	33.8	35.51	45.7
(1/8) 0.125	3.00	24.33	31.3	59.84	77.0
(1/16) 0.062	4.00	8.46	10.9	68.30	87.9
Pan		9.42	12.1	77.72	100.0
TOTAL		77.72	100.1		
Loss					



Sample No. S 13-2

Screen Analysis

Gravelly Sand

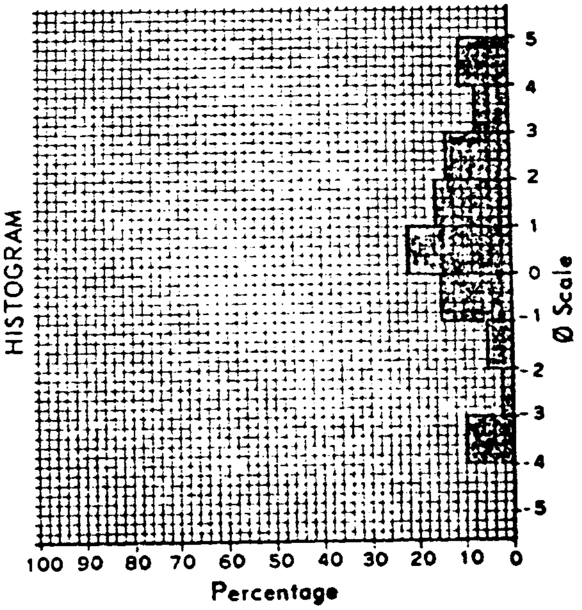


Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3	7.78	9.9	7.78	9.9
4	-2	1.73	2.2	9.51	12.2
2	-1	3.80	4.9	13.31	17.0
1.00	0.00	11.44	14.6	24.75	31.6
(1/2) 0.5	1.00	17.02	21.8	41.77	53.4
(1/4) 0.250	2.00	12.34	15.8	54.11	69.2
(1/8) 0.125	3.00	10.37	13.3	64.48	82.4
(1/16) 0.062	4.00	5.55	7.1	70.03	89.5
Pan		8.18	10.5	78.21	100.0
	TOTAL	78.21	100.1		
	Loss				

1% =

50% = 555

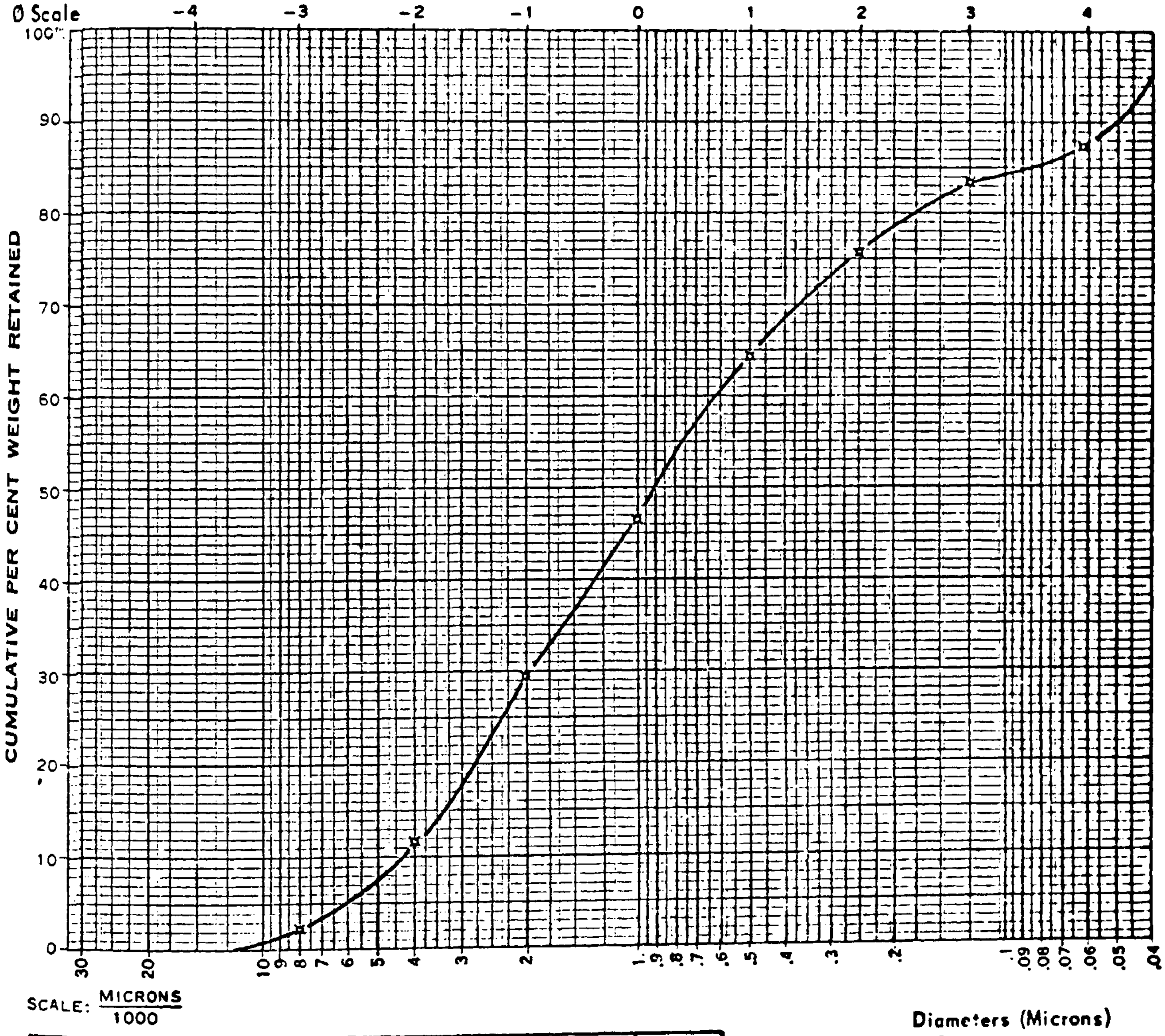
Modal Class (Ø Scale) = (0, 1) (-4, -3)



Sample No. S 13-3

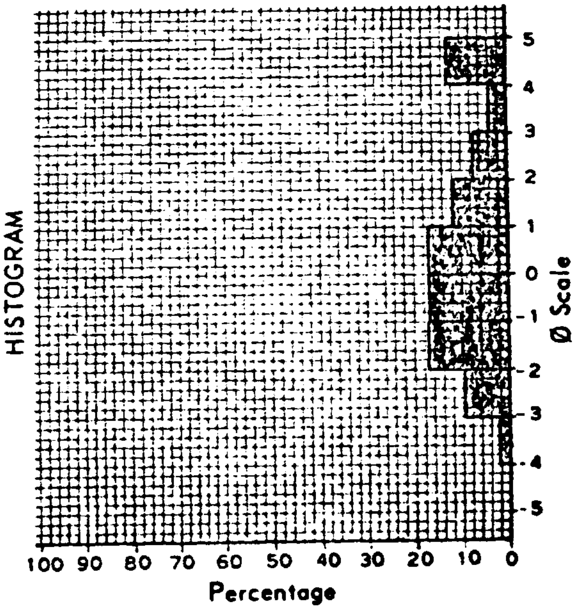
Screen Analysis

Gravelly Sand

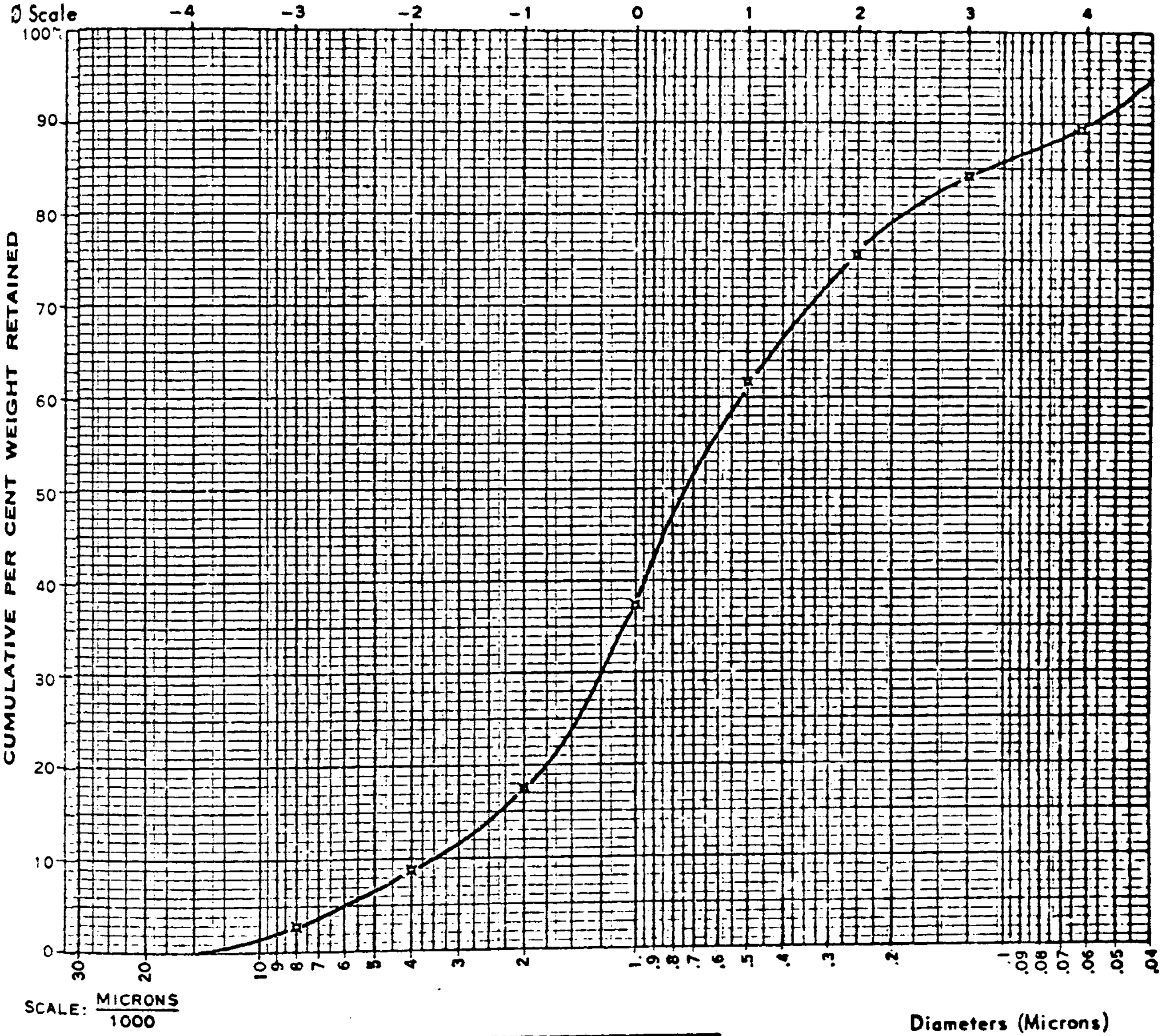


Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3	1.40	2.2	1.40	2.2
4	-2	6.00	9.4	7.40	11.6
2	-1	11.28	17.7	18.68	29.3
1.00	0.00	11.01	17.3	29.69	46.5
(1/2) 0.5	1.00	11.18	17.5	40.87	64.1
(1/4) 0.250	2.00	7.56	11.8	48.43	75.9
(1/8) 0.125	3.00	4.78	7.5	53.21	83.4
(1/16) 0.062	4.00	2.47	3.9	55.68	87.3
Pan		8.12	12.7	63.80	100.0
	TOTAL	63.80	100.0		
	Loss				

1% = 9,500
50% = 900
Modal Class (Ø Scale) (-2,-1) (4,5) Pan



Sample No. S 13-4 **Screen Analysis** Gravelly Sand



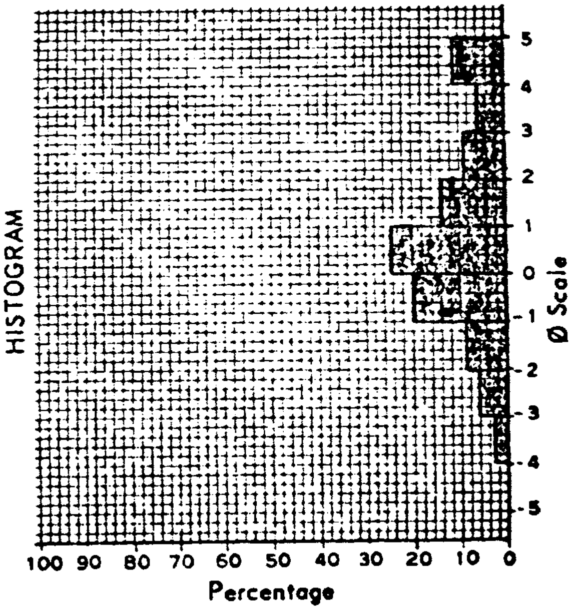
Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3	2.03	2.6	2.03	2.6
4	-2	4.80	6.2	6.83	8.9
2	-1	6.55	8.5	13.38	17.4
1.00	0.00	15.32	19.9	28.70	37.2
(1/2) 0.5	1.00	18.81	24.4	47.51	61.7
(1/4) 0.250	2.00	10.57	13.7	58.08	75.4
(1/8) 0.125	3.00	6.79	8.8	64.87	84.2
(1/16) 0.062	4.00	3.81	4.9	68.68	89.1
Pan		8.37	10.9	77.05	100.0
	TOTAL	77.05	99.9		
	Loss				

Diameters (Microns)

1% = 11,000

50% = 700

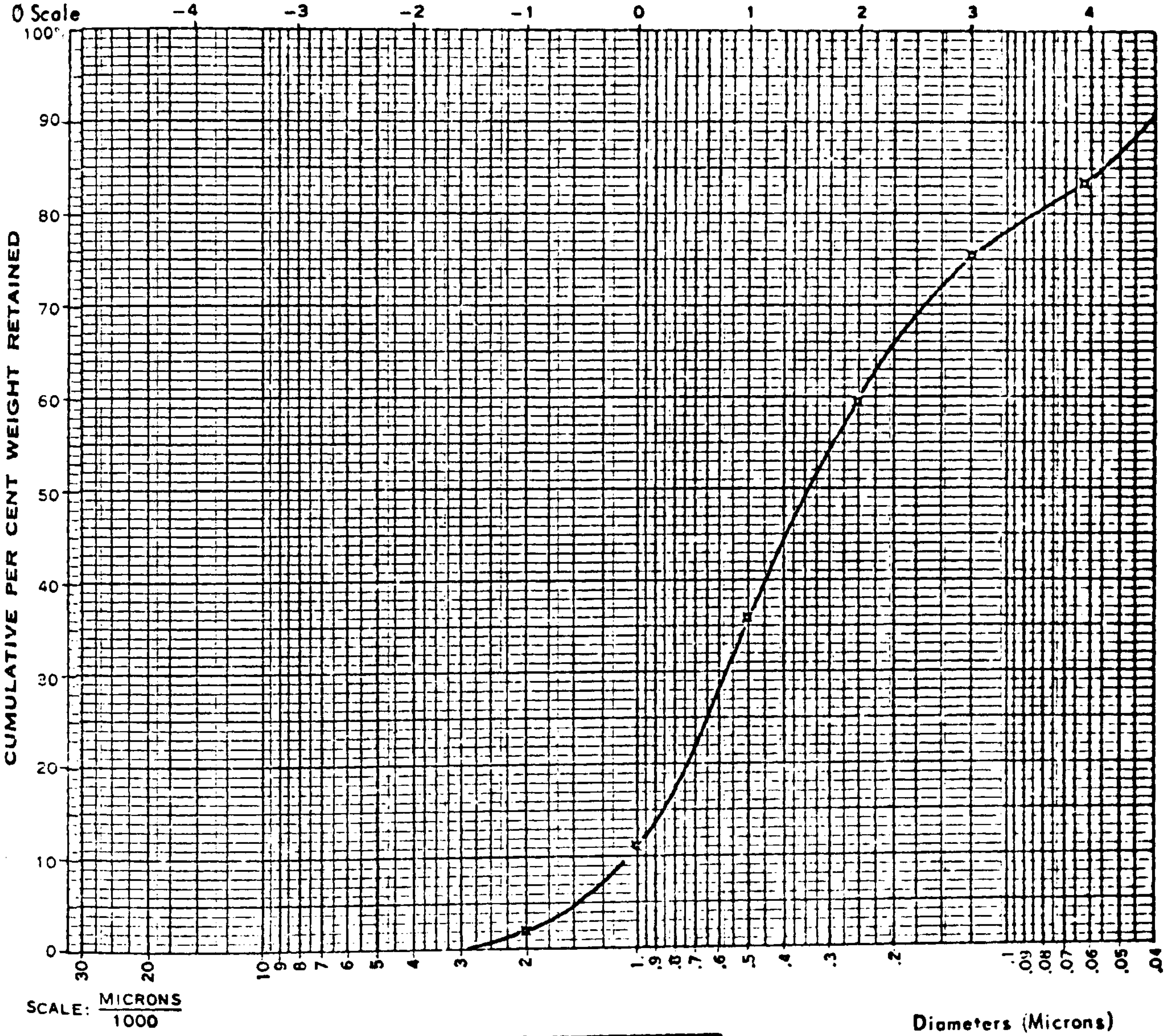
Modal Class (Ø Scale) = (0,1)



Sample No. S 13-6

Screen Analysis

Muddy Sand

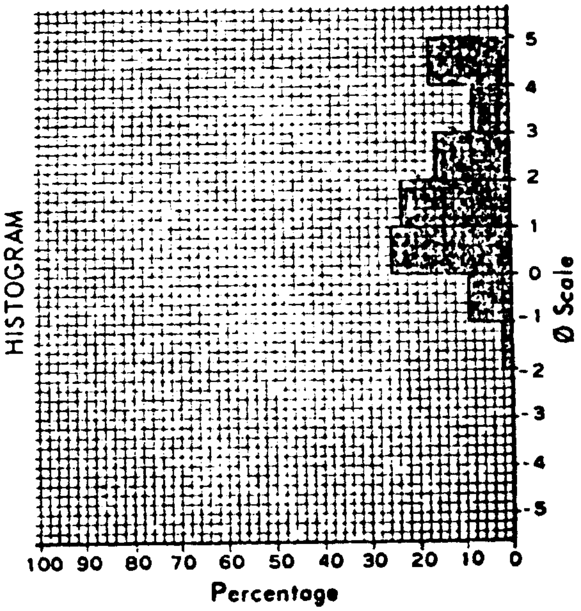


Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2				
2	-1	1.50	2.0	1.50	2.0
1.00	0.00	6.92	9.1	8.42	11.0
(1/2) 0.5	1.00	19.23	25.2	27.65	36.3
(1/4) 0.250	2.00	17.67	23.2	45.32	59.5
(1/8) 0.125	3.00	12.03	15.8	57.35	75.3
(1/16) 0.062	4.00	6.02	7.9	63.37	83.2
Pan		12.83	16.8	76.20	100.0
	TOTAL	76.20	100.0		
	Loss				

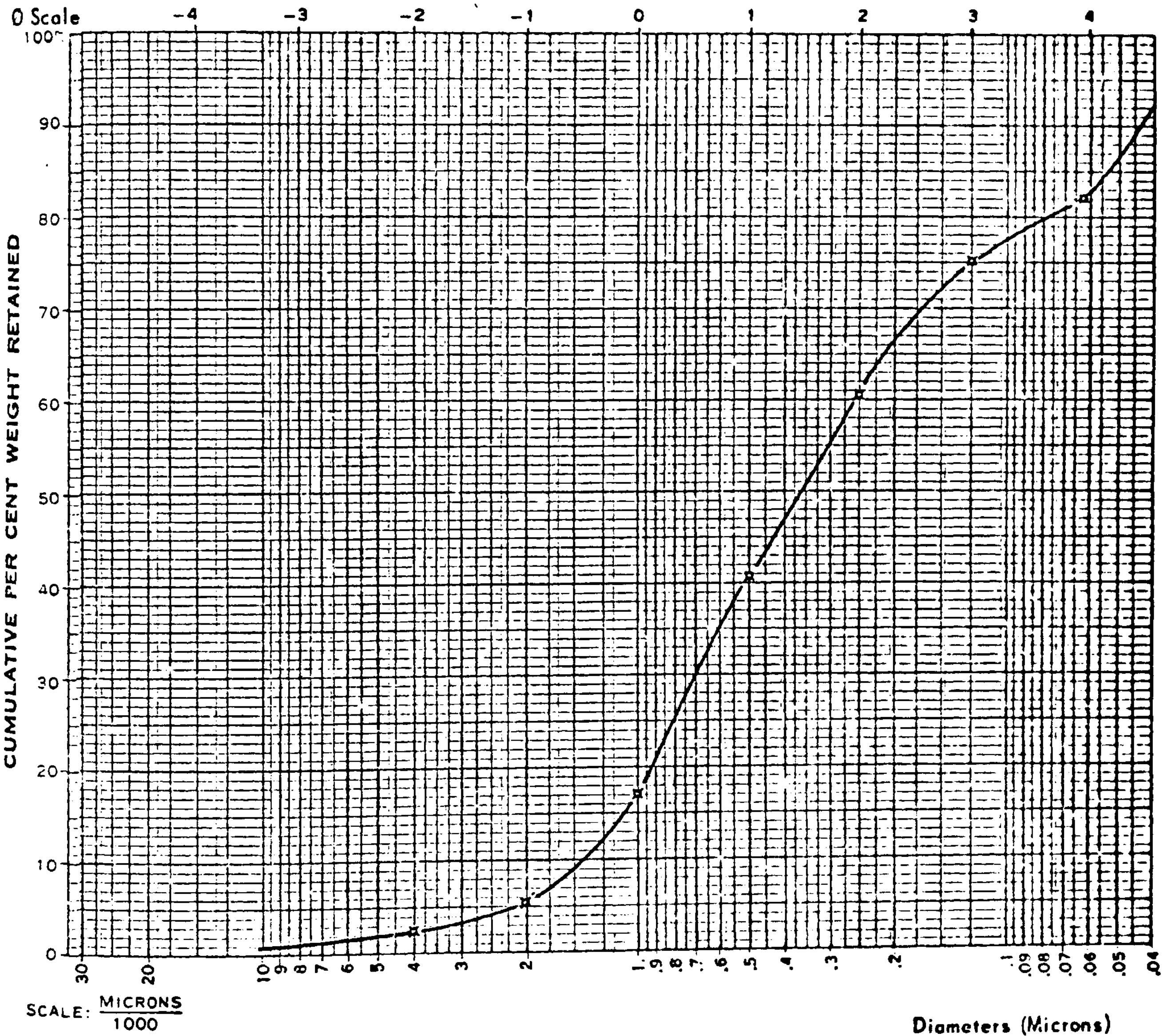
1% = 2,300

50% = 340

Modal Class (Ø Scale) = (0,1)

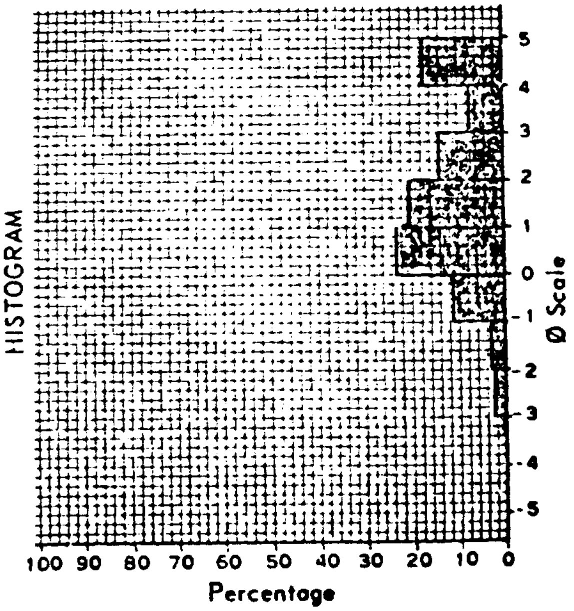


Sample No. S 13-7 **Screen Analysis** Gravelly Muddy Sand



Wentworth grade scale mm.	Scale Ø	Weight of Product on Screen (Grams)	% on Screen	Cum. Weight	Cum. %
16	-4				
8	-3				
4	-2	1.88	2.5	1.88	2.5
2	-1	2.19	2.9	4.07	5.3
1.00	0.00	8.92	11.7	12.99	17.0
(1/2) 0.5	1.00	18.05	23.7	31.04	40.7
(1/4) 0.250	2.00	15.39	20.2	46.43	60.9
(1/8) 0.125	3.00	10.71	14.0	57.14	75.0
(1/16) 0.062	4.00	5.54	7.3	62.68	82.2
Pan		13.54	17.8	76.22	100.0
	TOTAL	76.22	100.1		
	Loss				

1% = 8,500
50% = 355
Modal Class (Ø Scale) = (0, 1)



VITA

Carlos Enrique Reijenstein d'Acierno was born in San Martin, Province of Buenos Aires, Argentina, on August 5, 1943. He received his elementary and secondary education in the City of San Martin. In 1961 he entered the School of Ciencias Exactas Fisicas y Naturales of the University of Buenos Aires. In June 1967, he completed the requirements for the "Licenciado in Geology" Degree.

After graduation he left his country and enrolled, on a Fulbright Scholarship, in the Graduate School of the University of Missouri at Rolla to work toward the Master in Science Degree in Geology.

The author is a member of the Asociacion Geologica Argentina, and of the American Association of Petroleum Geologists.