THE GEOLOGY OF A PROPOSED TUNNEL IN THE SOUTHERN APPALACHIANS

by

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CONTENTS

INTRODUCTION

During the summer of 1924 the writer was employed by a power company in making a geological examination for a proposed hydroelectric tunnel in the Southern Appalachians. A period of about six weeks was spent in the field. The work was in Graham County, N. C., which lies in the Great Smoky Mountains, in the extreme southwestern part of the state.

The investigation, which is taken as the basis of this thesis, was for the purpose of determining the nature and structure of the rocks likely to be encountered in driving the tunnel and also to locate a suitable quarry site for concrete aggregate necessary in building a dam and lining the tunnel.

The position of the dam and tunnel are shown on the accompanying portion of the U.S.G.S. topographic map, Plate 1. The proposed tunnel, which is about five miles long, is a part of the project for developing the power of the Cheoah River by building a dam two hundred feet high, diverting the impounded waters through the mountains and dropping them six hundred feet into the Little Tennessee River.

This study has involved first, the field work of mapping in considerable detail the geology of a strip of county along the tunnel line and of examining the general vicinity for all information of value in interpreting the geology of the area mapped; second, the preparation of a geological map and a longitudinal section along the tunnel line; and third, a detailed report on the geological and engineering features of the problem.

FIELD WORK

At the time of the examination the only available topographic map covering all of the region to be studied was the U.S.G.S sheet of the Nantahala Quadrangle, surveyed in 1892. This was useful for some purposes, but the scale is too small and the topography too approximate to be of much use in the detailed geolog mapping required. Excellent use was made, however, of some maps which the company supplied. These were photostat copies of splendid large scale maps with ten foot contours, showing the Cheoah River valley from its mouth to the damsite at Santeetlah and for 200 to 250 feet in elevation above the river. The company had also maps showing limited topography at all the tunnel portals i.e., at the damsite, the two Cheoah River crossings, Yellow Creek, and the Little Tennessee River, and certain small scale land maps. All these were useful in compiling the large map herewith included (plate IV).

For control on the rest of the topographic and geologic mapping, numerous traverses were run. The company furnished a transit party which staked out the tunnel line by stadia. This transit party was used also in running a number of other traverses for mapping outcrops particularly in the rougher parts of the territory on both sides of the tunnel line. In addition to these stadia traverses, numerous compass and pacing traverses were run, some of them with the aid of a small plane table and Brunton alidade. Most of the area covered in detail is shown on the map.

GEOLOGIC MAP AND SECTION

In the analysis of the collected date, the engineering aspects of the tunnel problem have been of primary consideration. A topographic map of a fairly wide strip along the tunnel line was highly desirable, and as none existed, the accompanying one has been compiled from the various sources already indicated. See plate 1V.

The colors show the distinctions in the country rock which it seemed desirable to make. There are no horizon markers which can be traced throughout the Great Smoky Formation; therefore, one color does not represent the same stratigraphic horizon throughout the area; but on the other hand, it attemps to represent a certain lithologic type or grouping which is fairly uniform within certain limits.

The geological section along the tunnel line is drawn to the same scale as the map vertically and horizontically i.e., one inch to 400 feet; hence the lines drawn parallel to the bedding show, with some approximation to be sure, the actual apparent dips. They do not indicate anything in regard to the thickness of the beds. It is evident that the apparent dips along the direction of the tunnel are not the true dips of the beds, for the line does not cross them at right angles to their strike.

This map and section should be useful in preparing estimates based on the nature and structure of the rocks to be tunneled, as well as for many other uses of general layout map. The topography in the vicinity of the tunnel portals is quite reliable. The sketchy portions are over the rough high areas between.

On the map just east of Johnson is shown the most desirable quarry site to be found near the dam and on the side of the river where the construction railroad will be located. Another site with good rock but less advantageous location is shown about 2000 feet downstream from Johnson at the river bend.

GEOLOGY OF THE AREA

1. NATURE OF THE ROCKS

The rocks in the zone traversed by the tunnel line are all within a single arkose formation, of great but unknown thickness, known as the Great Smoky Conglomerate. It is a part of the Ocoee group, and is described by Arthur Keith in his report of 1904 on the geology of the Nantahala Quadrangle.

Only minor portions of the formation appear to be coarse enough to be properly called conglomerate.

Quartz-feldspar conglomerate and sandstone--mainly the latter--and some of it schistose, together with slate, quartzite, and mica and chlorite schists, make up the formation. It is essentially a unit, several hundred feet in thickness, with variations in composition due partly to differences in the material originally deposited to form the rock and partly to the dynamic metamorphism which has occurred since.

The distinctions made by the colors on the map are between several approximate combinations of massive arkose, schistose arkose, mica-chlorite schist, and slate. Quartzite and vein quartz also occur but in minor amounts.

(A) Massive Arkose

Much of the formation--herein called massive arkose--is a very hard, grayish, well cemented, sedimentary rock composed of angular grains of quartz and feldspar in about equal proportions and with a little dark mica.

It occurs in beds from one to forty feet thick. In places these beds are separated by thin beds of slate or schist, from a few inches to three feet thick.

The beds are usually remarkably uniform in texture, a laminations are exceptionally difficult to detect. There i however, more or less difference in texture frequently nota tween adjacent beds and cross-bedding is not uncommon.

There are occasionally to be seen fragments of an old up to a foot long in the arkose and also faintly outlined r boulders of either previously cemented arkose or the origin igneous rock.

(B) Schistose arkose and mica-chlorite schist.

Where the massive arkose has given way to excessive p and shear during the deformation, schistosity has been deve in varying degrees. Mica has developed during the deformat so that the schistose arkose contains considerably more of than the massive arkose. Where the schistosity has been mo intensely developed, the rock is changed almost wholly to a chlorite schist,--a greenish appearing rock, with abundant garnets in it in many places.

The schistose arkose is for the most part a hard rock unweathered-practically as hard as the massive arkose excep it has the capacity to break more readily. Only when it ha come dominantly mica and chlorite is it much softer.

(C) Slate

Interbedded with the arkose there are some dark bluis slates and slaty schists which evidently were originally d ted as clayey material. In some sections of the formation is quite abundant. It is composed essentially of chlorite mica, and hence is not very hard.

The rocks in the vicinity of Yellow Creek contain a g deal of slate and slaty schist interbedded with more or les schistose arkose.

The cleavage in the schists and schistose arkose is everywhere steeply dipping, usually to the southeast.

(D) Quartzite, Vein Quartz, and White Mica Schist

There is a small amount of thinly bedded quartzite interbedded with the arkose and slates. These quartzite layers--originally the beds of pure quartz sand in the formation--usually are less than a foot or so thick, often only a few inches. They probably are scattered throughout the whole formation but are most conspicuous in the slaty sections due to their greater resistance to weathering.

Vein quartz, practically indistinguishable from the quartzite also is rather abundantly scattered--though in minor amounts--mostly through the slates and schists in narrow stringers and lenses. Veins up to four feet wide are found-as, for example, the one striking N.45°E on top of Yellow Creek Mountain 300 feet east of station 194. These veins are usually parallel to the schistosity and nearly parallel to the bedding where seen in outcrops. But the slate and schist weather so readily that the quartz is seen mostly in the surface debris.

There is a small amount of white mica schist also, notably on the north slope of Yellow Creek Mountain.

(E) General Observations

It is evident that the softest sections of the rocks are those containing the most slate and schist. Usually these are interbedded with harder arkose so that the mass as a whole may be considered hard.

The massive arkose is very resistant to weathering. Some of the schistose arkose is deeply decayed. In some places where it is interbedded with more massive arkose it is weathered to a soft micaceous clay to a depth of over thirty feet while the massive arkose remains hard and fresh.

The schist and slate yield readily to weathering--especially disintegration and erosion. Their presence is often marked by lack of outcrops and by low places in the topography.

2. DEFORMATION

(A) Folding

The rocks have been folded so that the beds are rather steeply dipping--usually from thirty to ninety degrees. The strike throughout the area is almost uniform--about north fifty-five degrees east.

The folding is not of a simple type. There appears to be intense crumpling of the beds concentrated within rather narrow zones--only a few hundred feet wide across the strike in some places--with, between these zones, distances up to half a mile or more where the attitude of the beds remains about uniform.

Just north of the lower crossing of the tunnel line and the Cheoah River is a notable example of this concentrated folding in massive arkose. (See Plate 11). There the river has taken advantage of the shattered zone and follows the axes of the folds where they intersect it, a few hundred feet west.

The axes of the folds extend northeast and southwest and are not usually horizontal but pitch as much as thirty-five degrees. Hence it is impossible to project a particular fold horizontally very far northeast or southwest in the direction of its axis, for probably it dies out and other nearly parallel folds appear.

Slight differences in original composition and in the degree of deformation make it impossible to assume that one type of rock persists very far even in the same apparent horizon; for example, beds of hard massive arkose in one place may be highly schistose arkose or pure schist a thousand feet away.

(B) Jointing

Jointing is conspicuous in the massive arkose nearly everywhere it outcrops. This is to be expected under such deformation as has occurred. Usually there are joints--variously spaced--about parallel to the bedding, and a more prominent set striking northeast within fifteen degrees of the strike of the beds and intersecting the bedding at angles of from forty to seventy degrees.

Parallel joints developed in massive arkose were often difficult to distinguish from the similarly spaced bedding planes. In fact, this abundant parallel jointing is one of the most misleading features to any observer. Note the sketches of outcrops on Plate 111.

Where the rocks have yielded more readily to the deformation, the arkose has developed schistosity and hence shows little widely spaced jointing. The slates have become schists also. The crumpled zones in the slaty rocks are very closely folded and should be tight and nearly impervious.

(C) Faulting

There is no direct evidence of faulting, but it is not at all unlikely to accompany this type of folding. The most likely possibility of a fault seems to be in Yellow Creek Mountain just south of the summit. This would be an overthrust fault dipping southeast with the beds on the southeast riding up over those to the northwest. It could account for the change in attitude of beds between station 180 and 190 and some shattering and quartz veins thereabouts.

(D) Structural Interpretation

The unraveling of the structures in this region is not at all simple. Where schistosity is much developed, the bedding is often obliterated. In the most massive arkose the beds are so thick and uniform throughout in composition that the average sized moss-covered outcrop does not readily reveal which lines or joints represent bedding planes or in which direction is top or bottom of the beds.

The determination of top and bottom of beds was essential in working out the folding, hence outcrops constantly were scrutinized for evidence on this point. Ripple marks, cross-bedding, gradation in size of grain, and relative attitude of cleavage and bedding all were valuable criteria. The two latter were most frequently observable and hence most useful. The sketches on plate 111 are from notes on outcrops observed.

Thin slaty beds sheared between hard beds as the latter slid over each other in folding have developed beautiful fracture cleavage. By its attitude this shows which bed has moved up and hence which is the top bed stratigraphically.

In the highly schistose arkose and in the mica chlorite schist, bedding is sometimes plainly marked by certain color lines intersecting the cleavage.

The intersecting cleavage and bedding reveal not only the limb of the fold on which the outcrop lies, but also the approximate direction and pitch of the axis of the fold. These observations show that most of the folds have considerable pitch. This is well confirmed by observations on some beautiful folds in the same formation cut across by the Little Tennessee River several miles downstream from the tunnel outlet.

In this region as elsewhere in the Appalachians, the main deformation seems to have followed a great thrust from the southeast. The folding varies from fairly open to the closely isoclinal type.

THE TUNNEL

It is evident that the tunnel will traverse hard rock for the most of its course. The arkose beds are in many places ten to forty feet thick but the jointing breaks them sufficiently to relieve the difficulties of blasting perfectly massive rock. In the schistose zones, the rock breaks readily along the cleavages which everywhere strike northeast and southwest and dip steeply--usually to the southeast.

It does not seem likely that lining the tunnels to prevent leakage would be necessary except perhaps in the most intensely folded and shattered zones in the hard rock which has not entirely yielded to flowage. Certainly the closely folded schist zones are tight.

It may be desirable to line the tunnel for purely hydraulic reasons.

If there is a fault in Yellow Creek Mountain or anywhere else it may present a problem in itself.

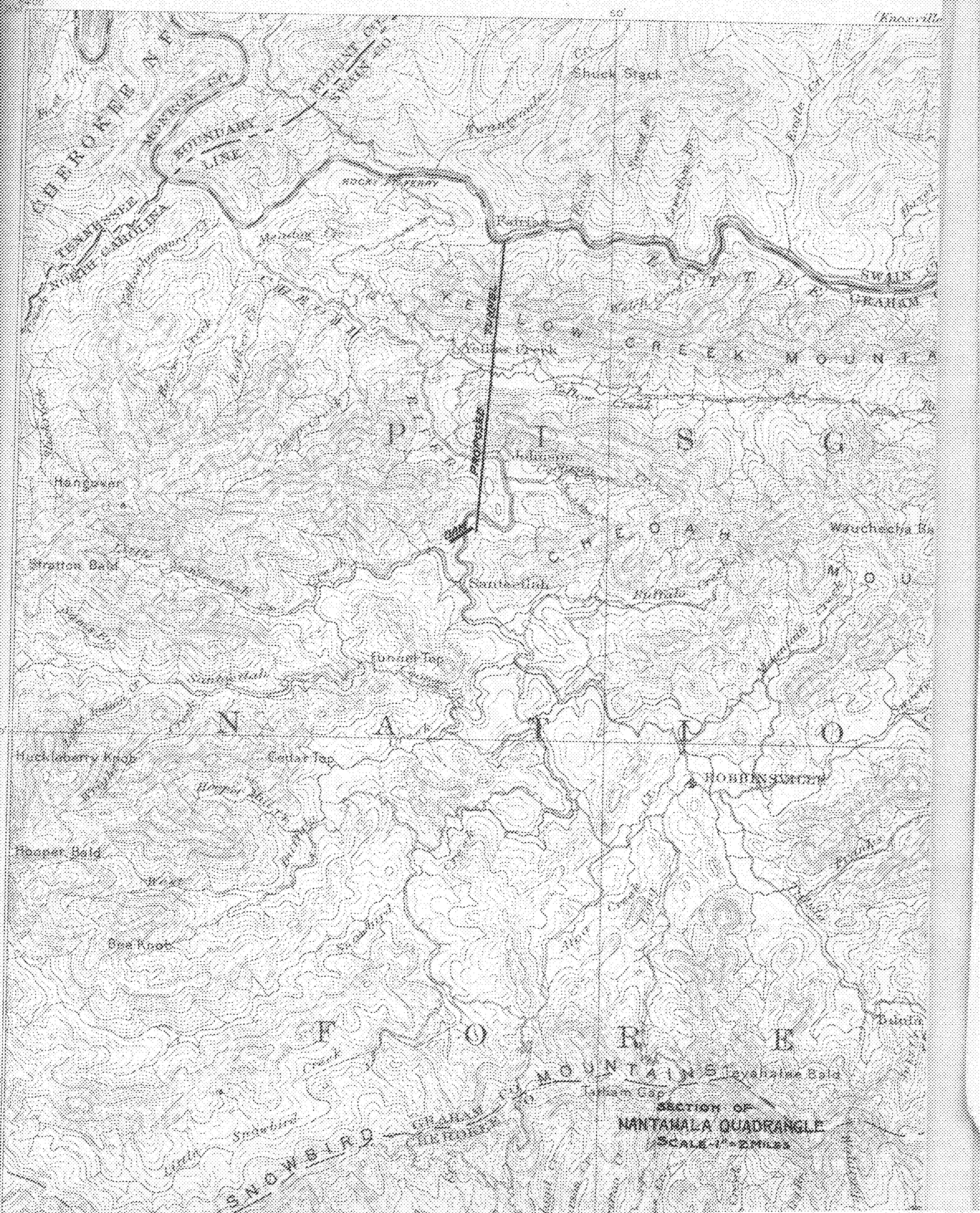
QUARRY SITE

In selecting a site for a quarry adequate to supply the concrete aggregate for the dam, several things were kept in mind.

The rock must be abundant, of good quality, practically free from clay seams, slate, or schist. The attitude of the bedding should render it easy to quarry from the face of entry and it should not be so much shattered and jointed but that large "plums" can be obtained for the dam. As the construction railroad has to be built in to the damsite along the Cheoah River from its mouth, the quarry should be at some convenient place enroute and as near as possible to the dam, and there should be available space adjacent for yards or storage tracks.

These conditions appear to be best fulfilled by the quarry site just east of Johnson which is shown on the map, plate lV. The rock is thick bedded and massive arkose with very little interbedded slate or schist. It stands up in a bold outcrop. The beds strike north fifty-five degrees east and dip about seventy-five degrees northwest and vary in thickness from three feet to thirty feet. The main joints, irregularly spaced but not too close, strike about north forty degrees east and dip seventy-five degrees southeast.

It is notable that this quarry site is bounded on the north by a zone of schist several hundred feet wide which would be utterly useless for concrete aggregate.

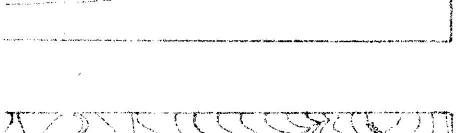

Shuck Stack
Ferry
Yellow Creek
Hangover
Stratton Bald
Santeetlah
Wauchecha Bald
Sunset Top
Huckleberry Knob
Cedar Top
ROBBINSVILLE
Hooper Bald
Sea Knob
Teyahalee Bald
Tatham Gap
SECTION OF
NANTAHALA QUADRANGLE
SCALE-1"=2MILES
SWAIN
GRAHAM
TENNESSEE
NORTH CAROLINA
BOUNDARY LINE
CHEOAH
SNOWBIRD
GRAHAM
CHEROKEE

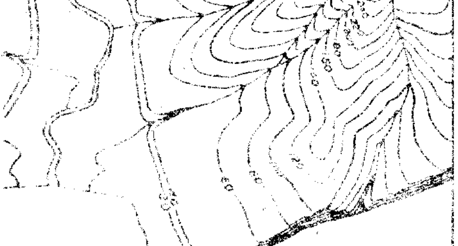
S OF THE UNITED STATES

al signs used to represent these
ined below. Variations appear on
tional features are represented on

represented in blue, the smaller
blue lines and the larger streams,
water lining or blue tint. Inter-
e beds are dry for a large part of
of blue dots and dashes.

r lines in brown, which on some
shading showing the effect of light
across the area represented, for the
rance of relief and thus aiding in
tour lines. A contour line repre-
he ground (a contour) every part
ude above sea level. Such a line
ude, but in practice only the con-
rvals of altitude are shown. The
contour, the datum or zero of alti-
The 20-foot contour would be the
rise 20 feet. Contour lines show
tains, and valleys, as well as their
r lines that are far apart on the
lines that are close together indi-
that run together indicate a cliff.
ntour lines express altitude, form,
gure below.





their lower ends by a sea cliff. The hill at the left terminates abruptly at the valley in a steep scarp, from which it slopes gradually away and forms an inclined table-land that is traversed by a few shallow gullies. On the map each of these features is represented, directly beneath its position in the sketch, by contour lines.

The contour interval, or the vertical distance in feet between one contour and the next, is stated at the bottom of each map. This interval differs according to the topography of the area mapped: in a flat country it may be as small as 1 foot; in a mountainous region it may be as great as 250 feet. Certain contour lines, every fourth or fifth one, are made heavier than the others and are accompanied by figures showing altitude. The heights of many points—such as road corners, summits, surfaces of lakes, and bench marks—are also given on the map in figures, which show altitudes to the nearest foot only. More exact altitudes—those of bench marks—as well as the geodetic coordinates of triangulation stations, are published in bulletins issued by the Geological Survey.

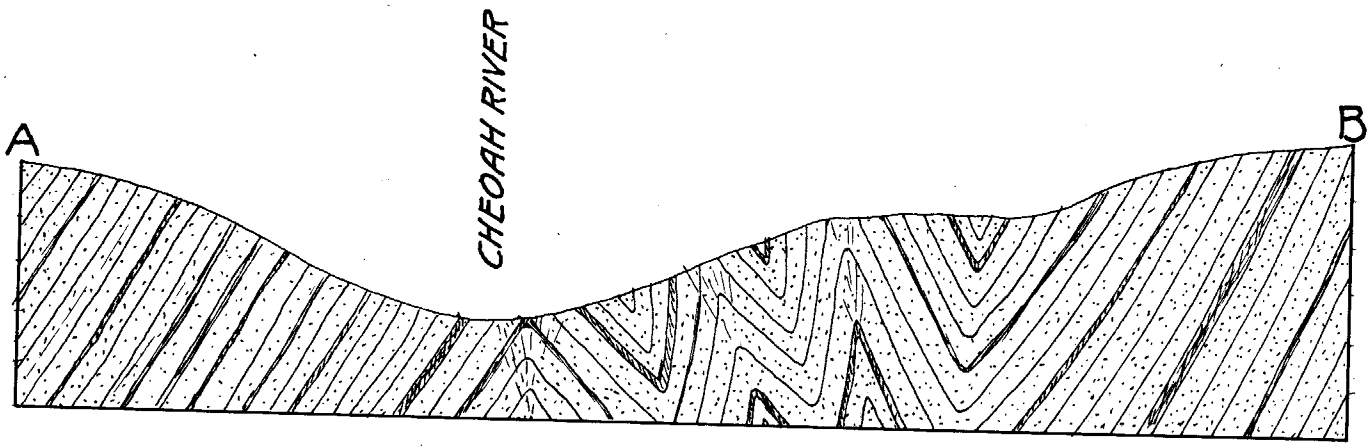
Lettering and the works of man are shown in black. Boundaries, such as those of a State, county, city, land grant, township, or reservation, are shown by continuous or broken lines of different kinds and weights. Metaled roads are shown by double lines, one of which is accentuated. Other public roads are shown by fine double lines, private and poor roads by dashed double lines, trails by dashed single lines.

Each quadrangle is designated by the name of a city, town, or prominent natural feature within it, and on the margins of the map are printed the names of adjoining quadrangles of which maps have been published. Over 3,000 quadrangles in the United States have been surveyed, and maps of them similar to the one on the other side of this sheet have been published.

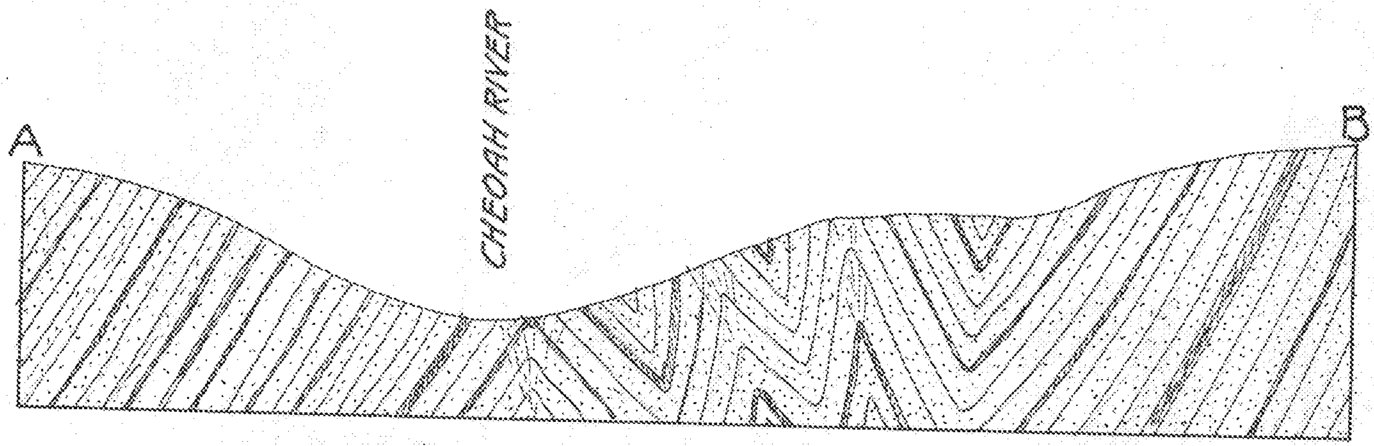
The topographic map is the base on which the geology and mineral resources of a quadrangle are represented, and the maps showing these features are bound together with a descriptive text to form a folio of the Geologic Atlas of the United States. More than 200 folios have been published.

Index maps of each State and of Alaska and Hawaii showing the areas covered by topographic maps and geologic folios published by the United States Geological Survey may be obtained free. Copies of the standard topographic maps may be obtained for 10 cents each; some special maps are sold at different prices. A discount of 40 per cent is allowed on an order for maps amounting to $5 or more at the retail price. The geologic folios are sold for 25 cents or more each, the price depending

PLATE II

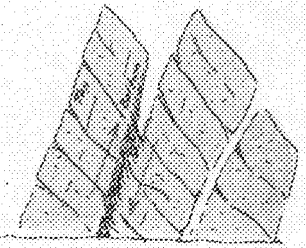


SECTION A-B, N35°W THROUGH T.L. STA. 70
SHOWING CRUMPLED ZONE IN HARD MASSIVE ARKOSE.
SCALE-1" = 400'.

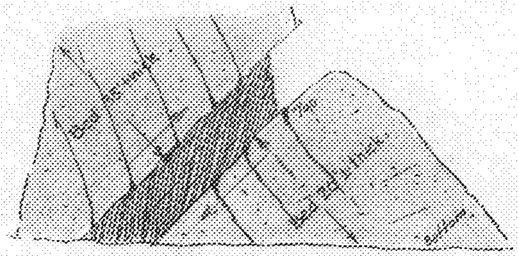


SECTION A-B, N35°W THROUGH T.L. STA. 70
SHOWING CRUMPLED ZONE IN HARD MASSIVE ARKOSE.
SCALE-1" = 400'.

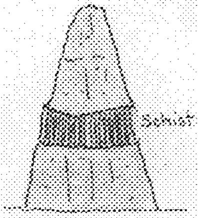
PLATE III



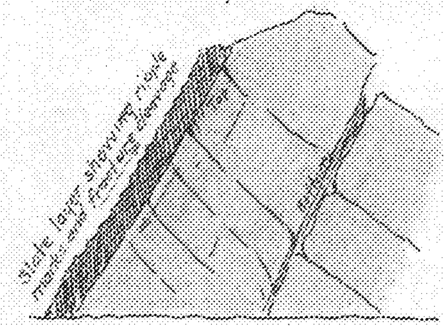
NEAR DAMSITE - SHOWING STEEP DIP, JOINTING, & CLEAVAGE (Anticline to right)



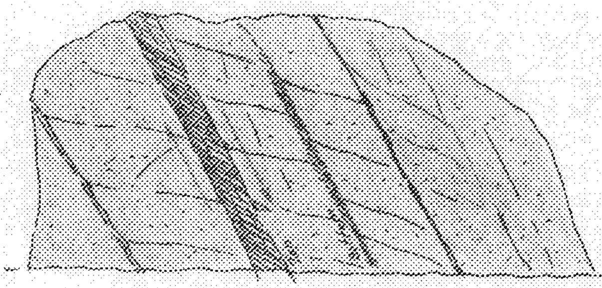
NEAR STATION 200 ON T.L. - CLEAVAGE IN SHEARED SLATE BETWEEN THICK BEDS MASSIVE ARKOSE



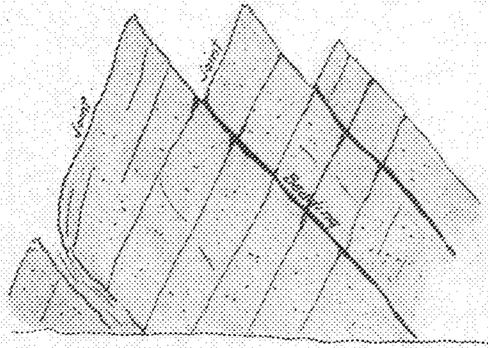
NEAR STA. 75 TROUGH OF SYNCLINE



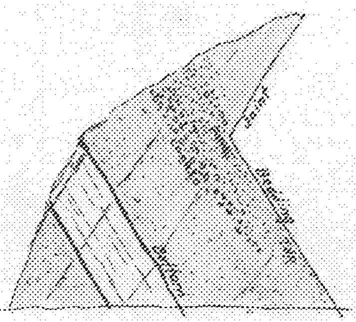
NEAR BEAR CREEK ON CHEOAH RIVER



NEAR BEAR CREEK ON CHEOAH RIVER (Limb of Overturned Fold - Anticline to right)

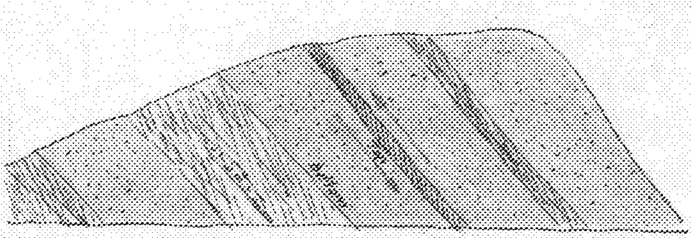


NEAR STA. 187 ON T.L. - SHOWING REGULAR JOINTS APT TO BE CONFUSED WITH BEDDING.

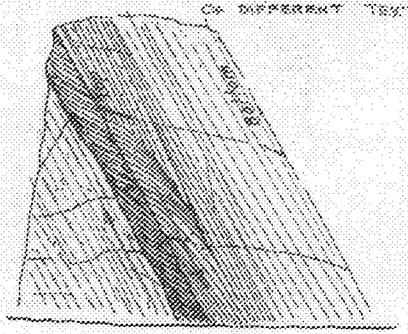


NEAR STA. 80 ON T.L. - SHOWING BEDDING DISTINGUISHED FROM JOINT BY ROCK TEXTURE.

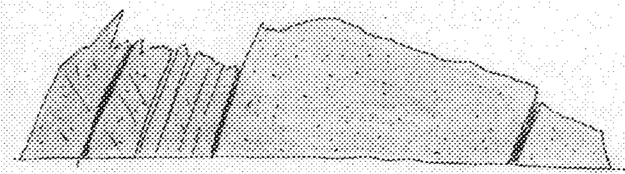
NEAR STA. 80 ON T.L. - SHOWING SLATY CLEAVAGE BETWEEN BEDS OF DIFFERENT TEXTURE.



NEAR STA. 220 ON T.L. - SHOWING INTERBEDDED MASSIVE ARKOSE, SCHISTOSE ARKOSE, AND SHEARED SLATE LAYERS. (Anticline to Left)



NEAR BARKER CREEK ON CHEOAH R. SHOWING SLATY CLEAVAGE & CROSSBEDDING. (Overturned fold, Anticline to right.)



AT QUARRY SITE NEAR JOHNSON - SHOWING CHARACTER OF BEDS OF MASSIVE ARKOSE.

— LEGEND —

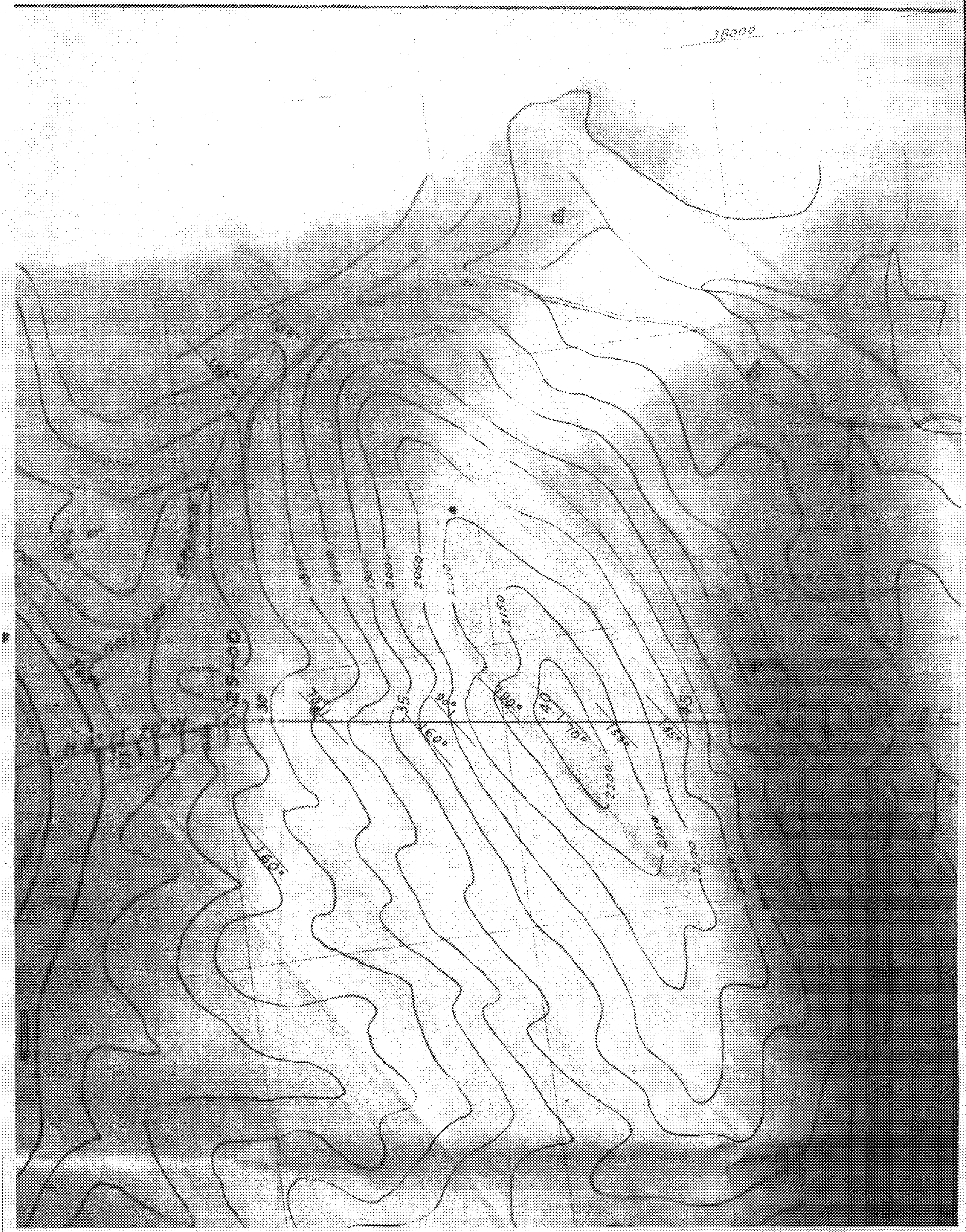
- MASSIVE ARKOSE.
- SCHISTOSE "
- SLATE & SCHIST.

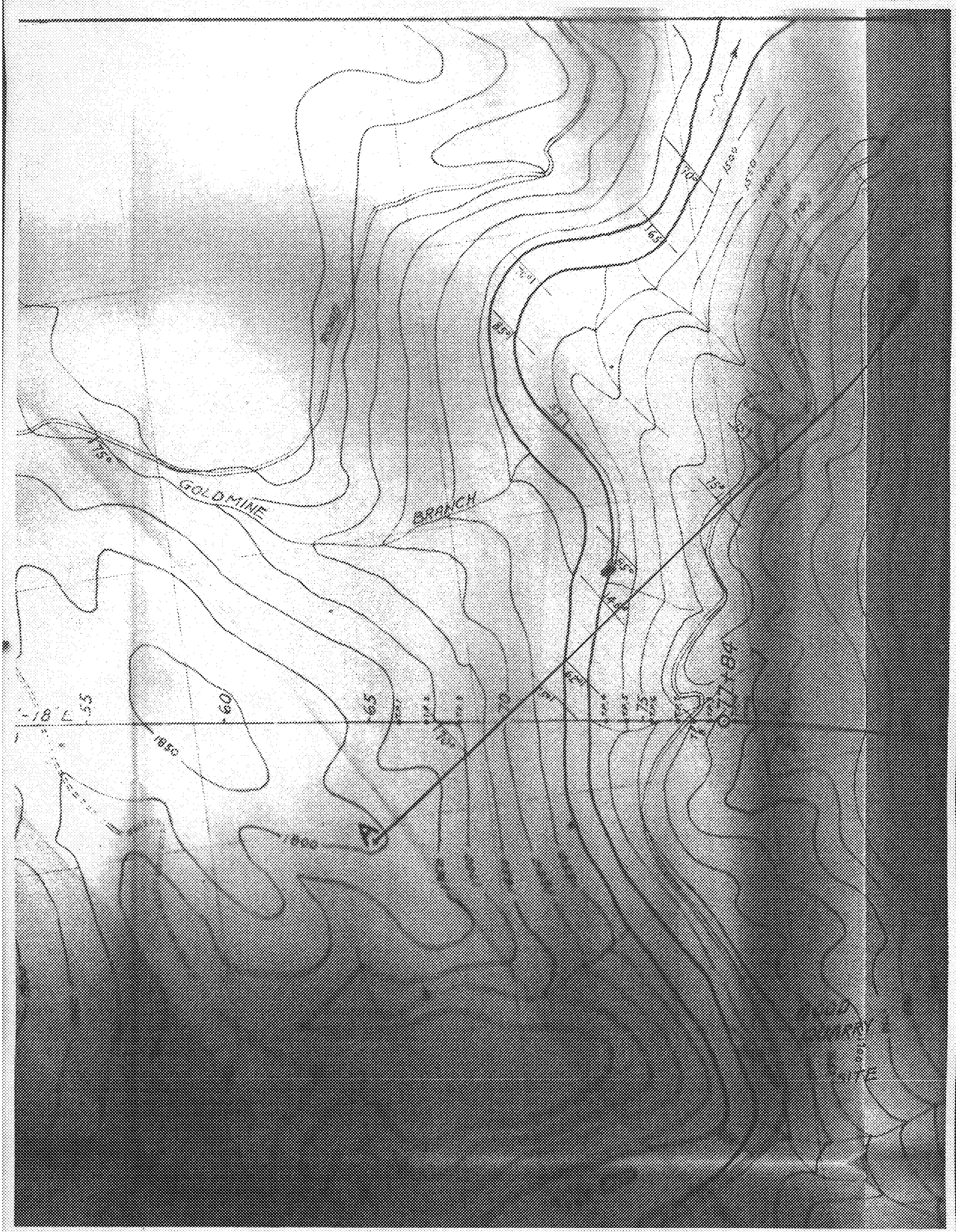
SKETCHES OF OUTCROPS

SHOWING

STRUCTURAL FEATURES.

SCALE - 1" = 10'




GOLDMINE
BRANCH
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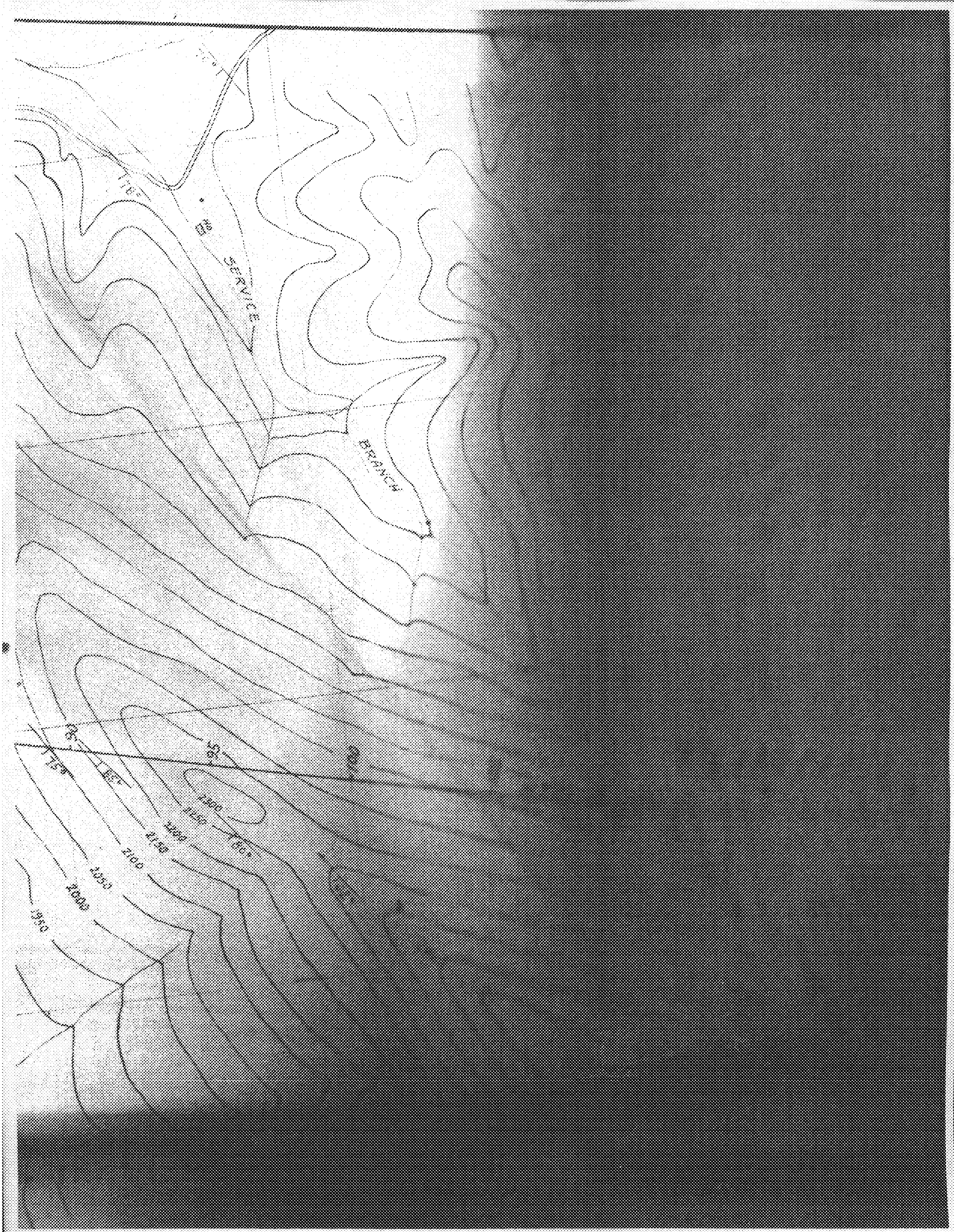
55
60
65
75


SERVICE
BRANCH
2300
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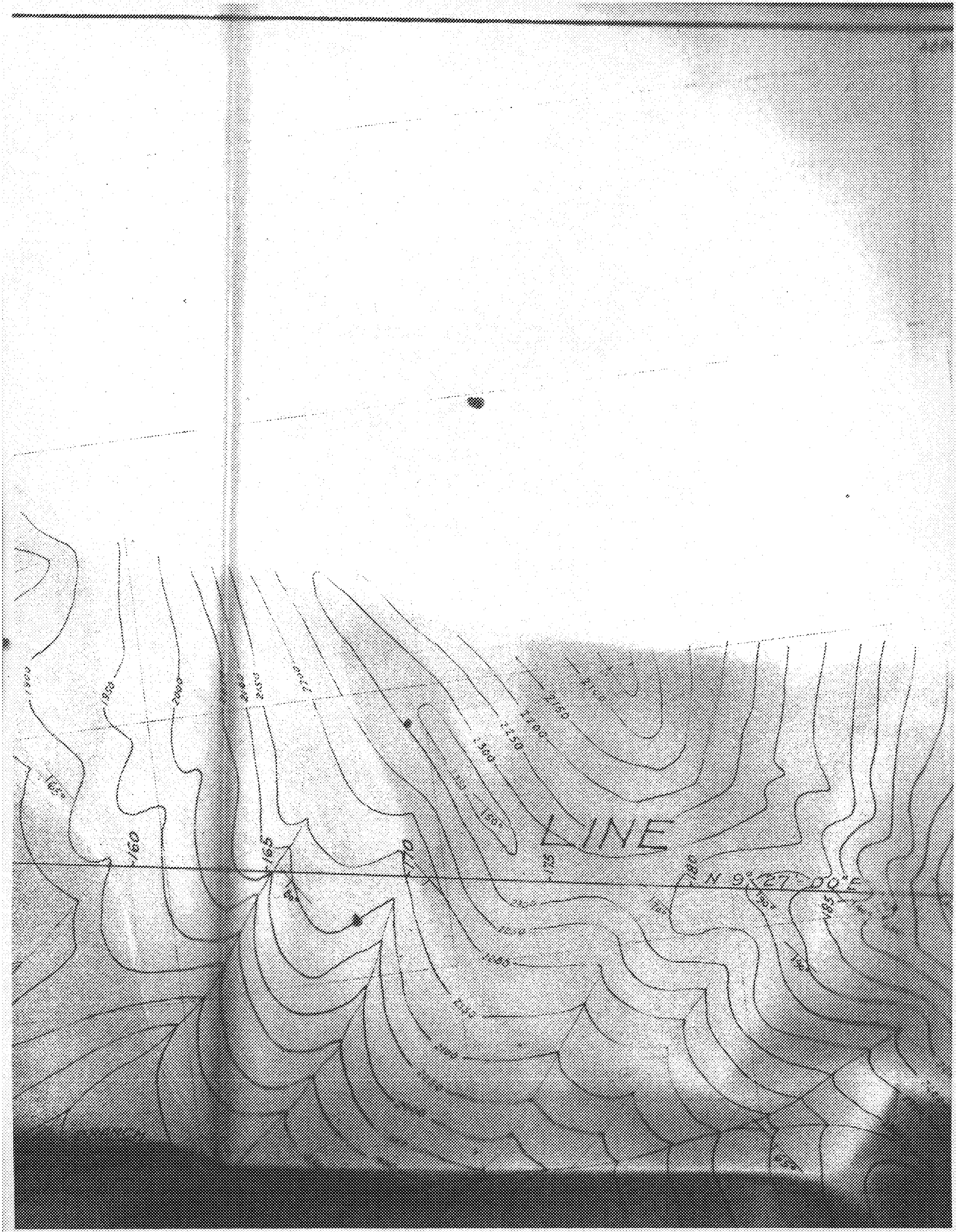
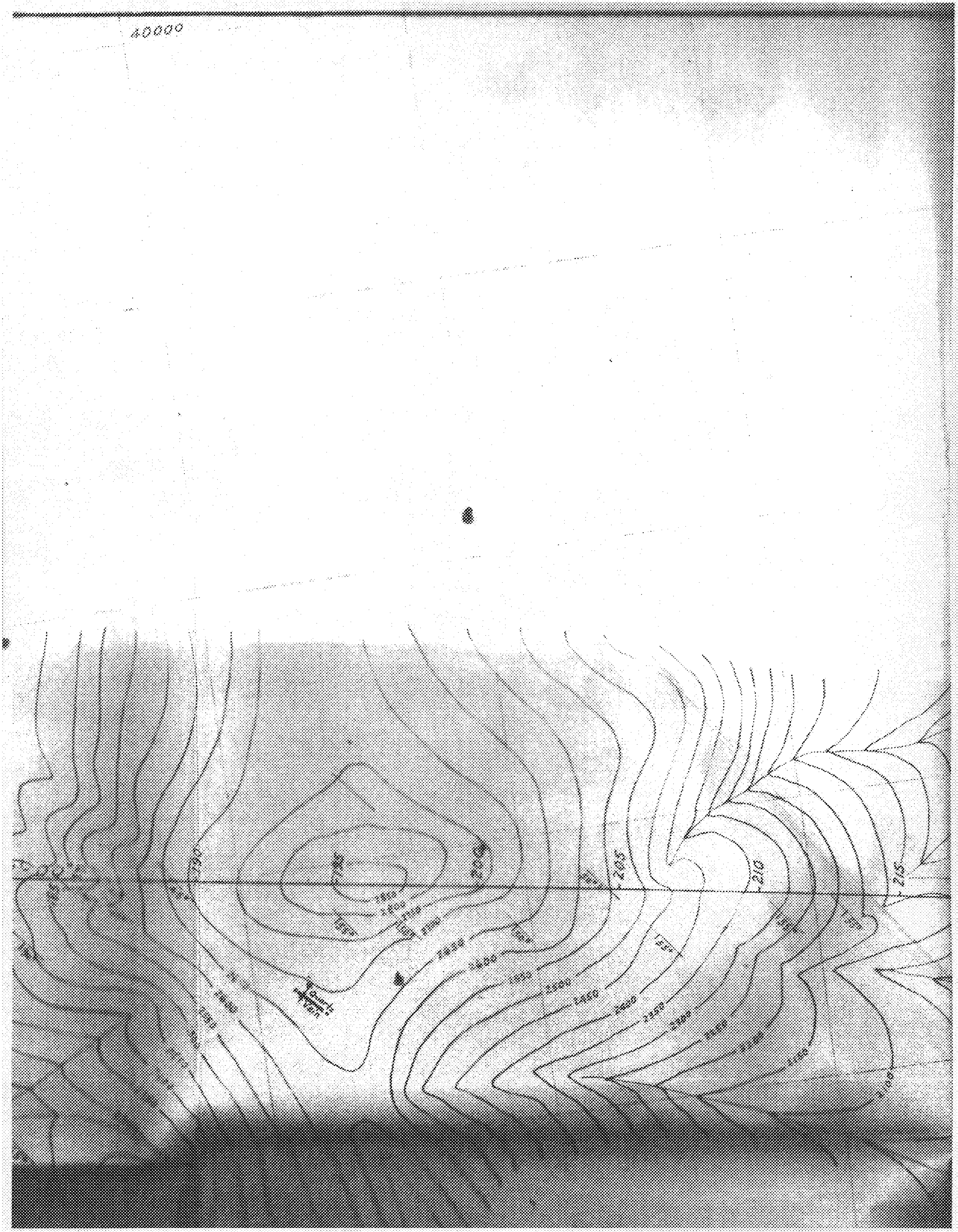
2200
2150
2100
2050
2000
1950


LINE
160
165
170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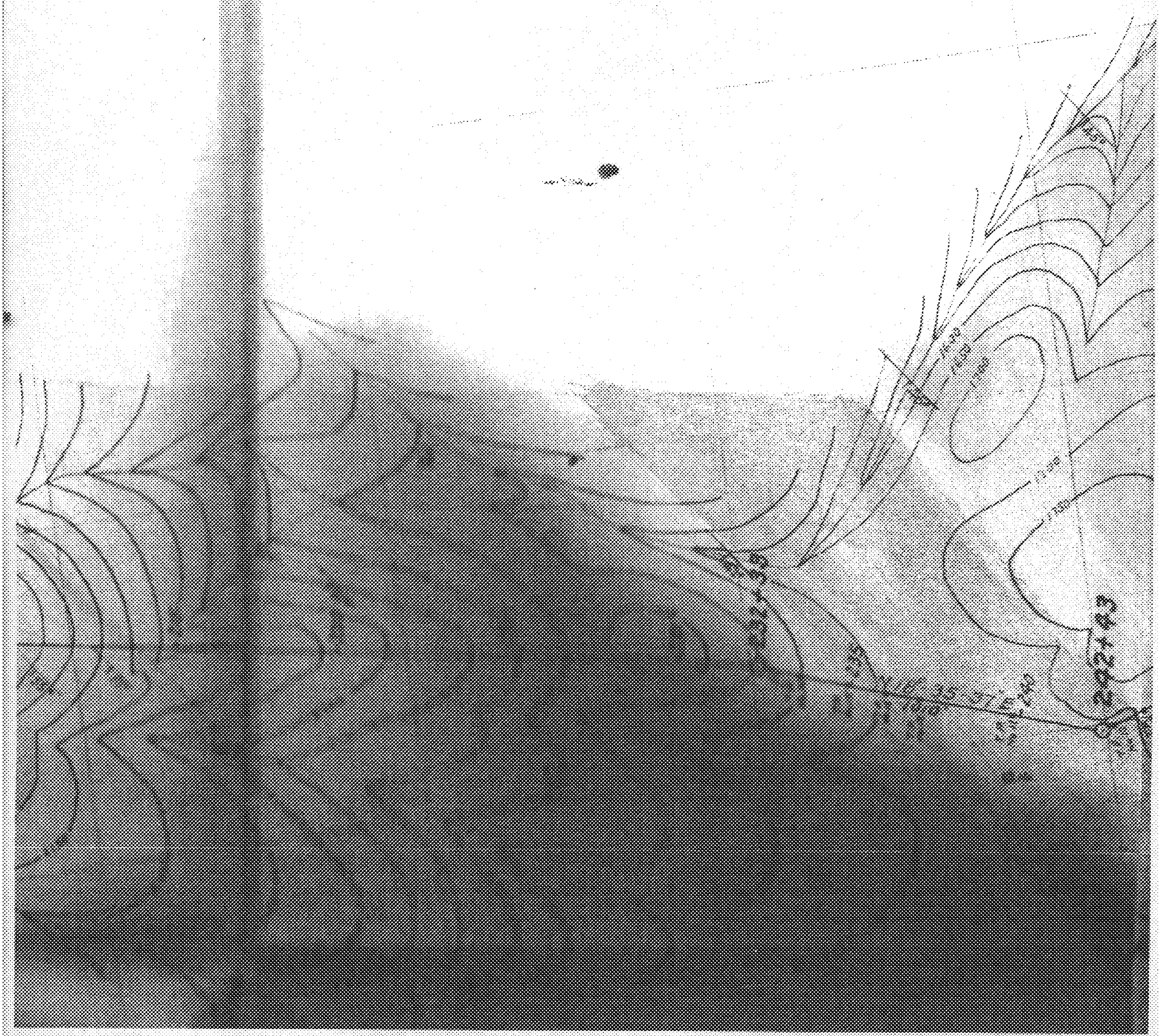
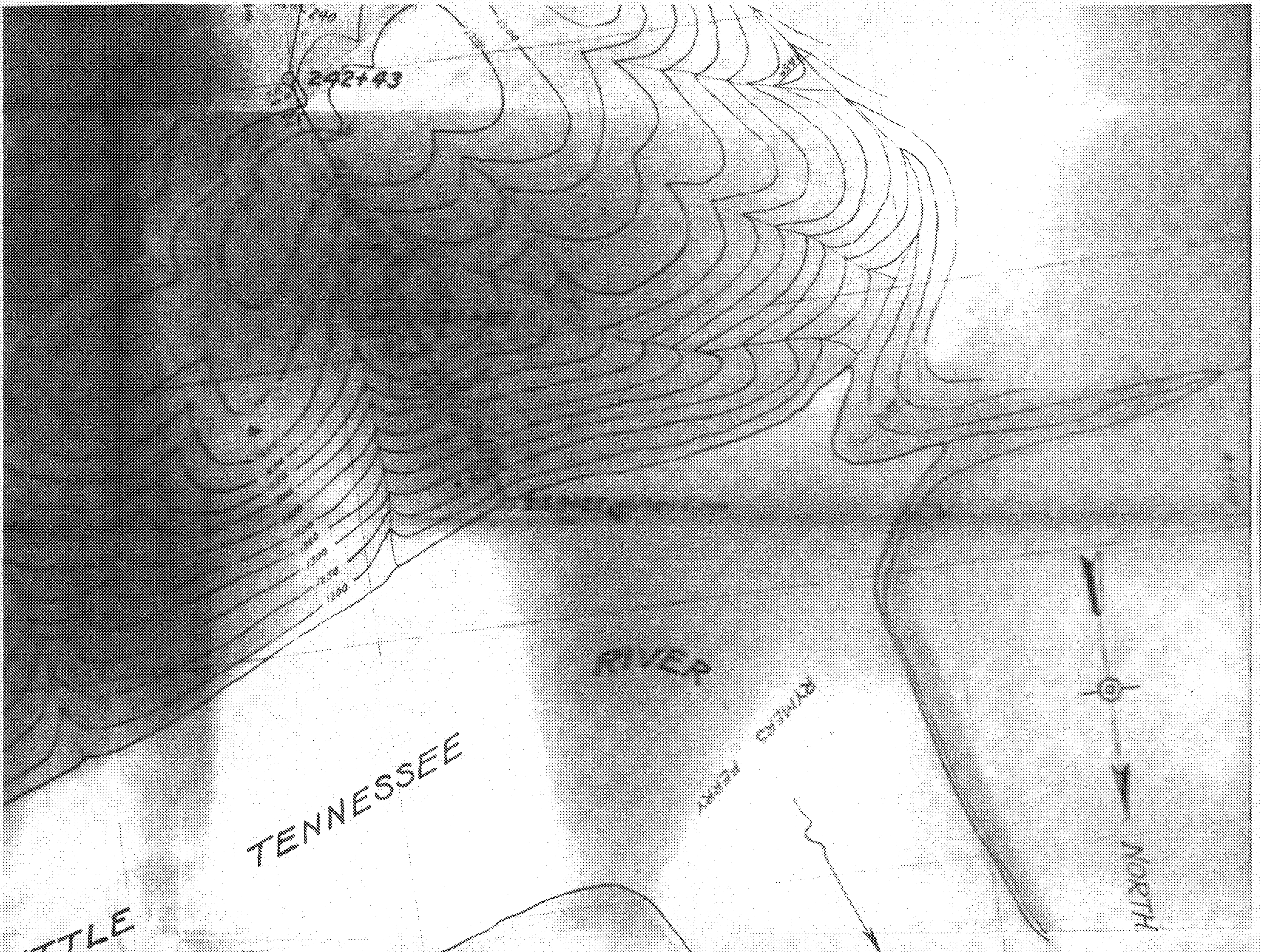
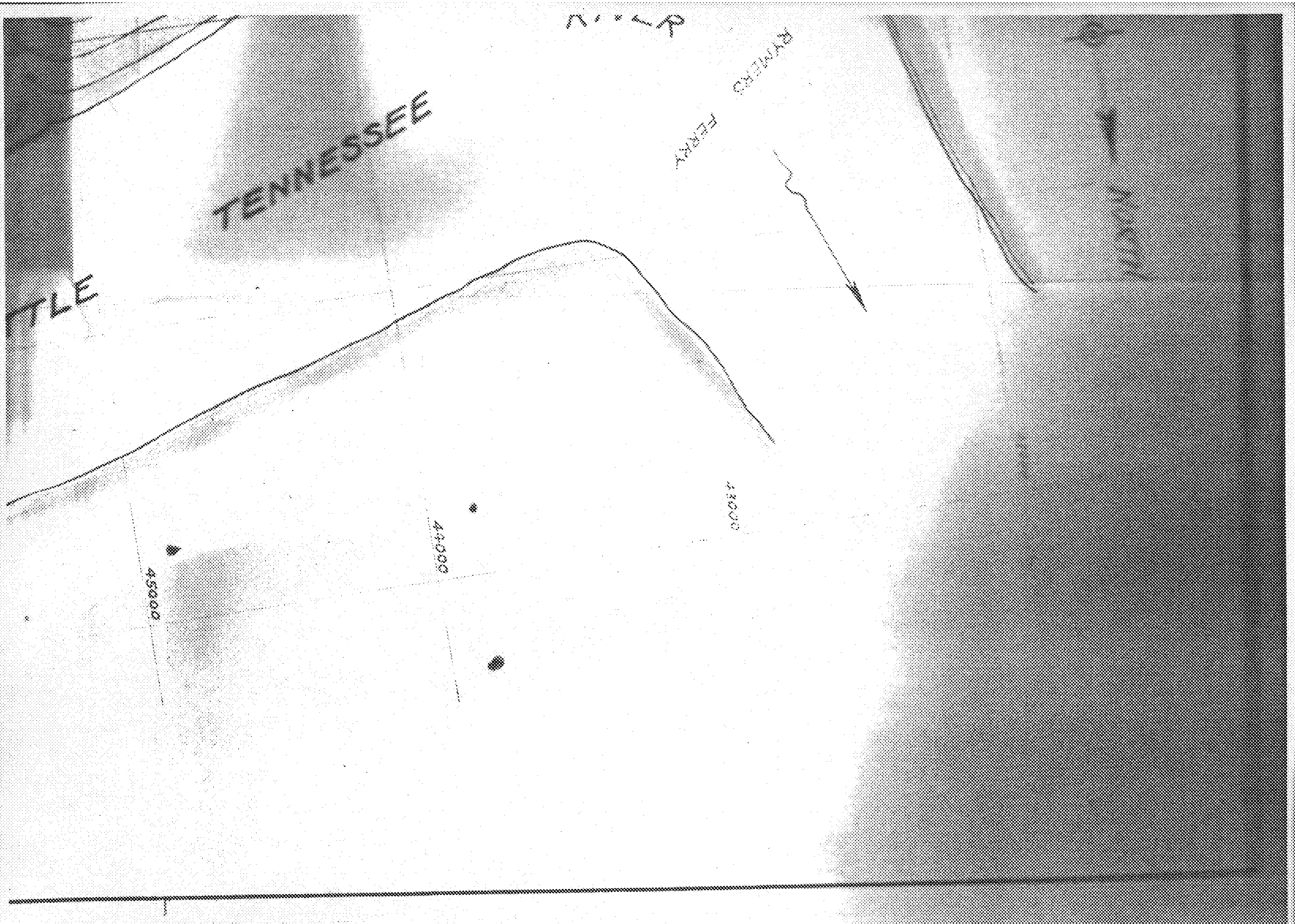
210

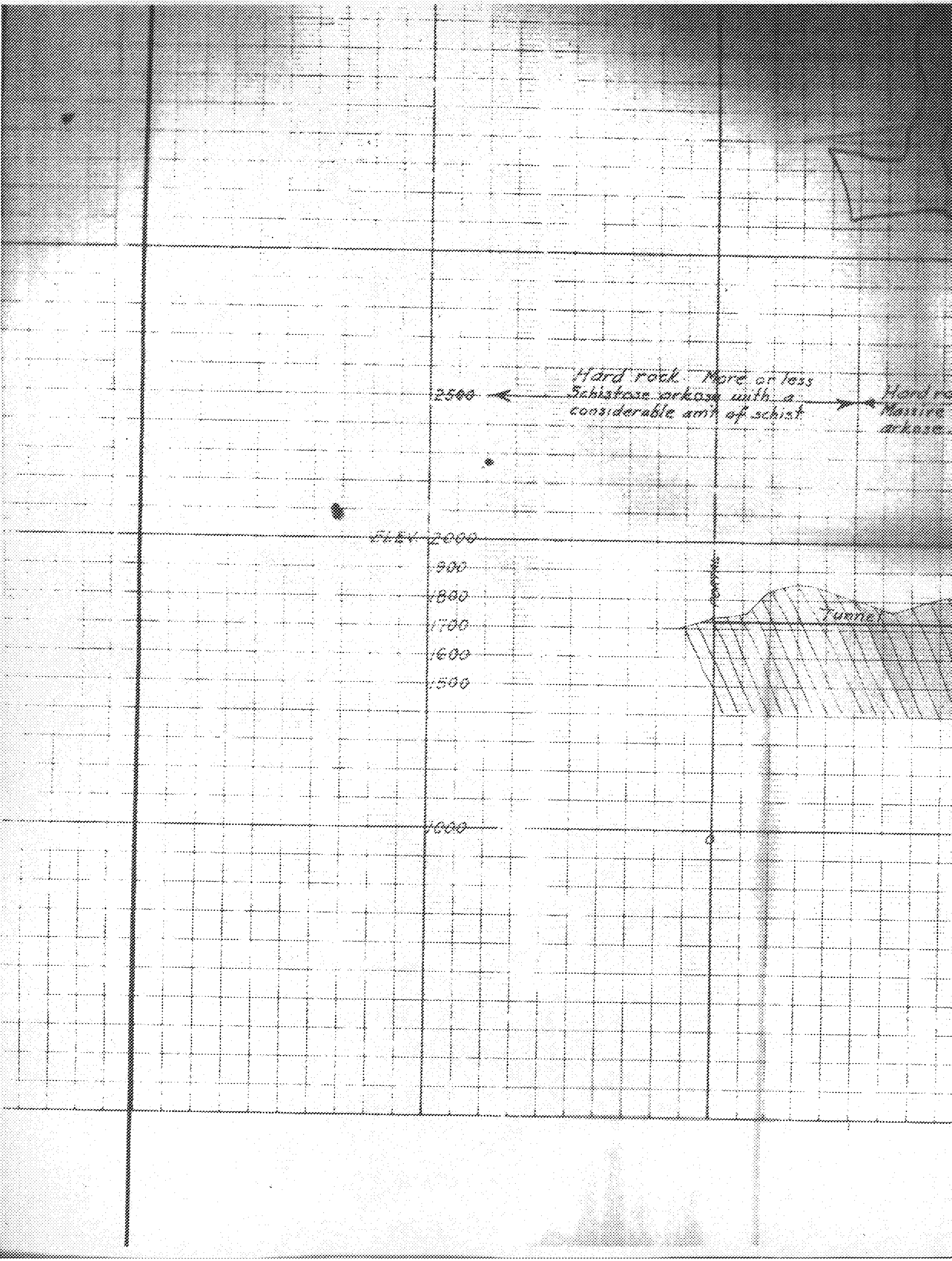

292+83



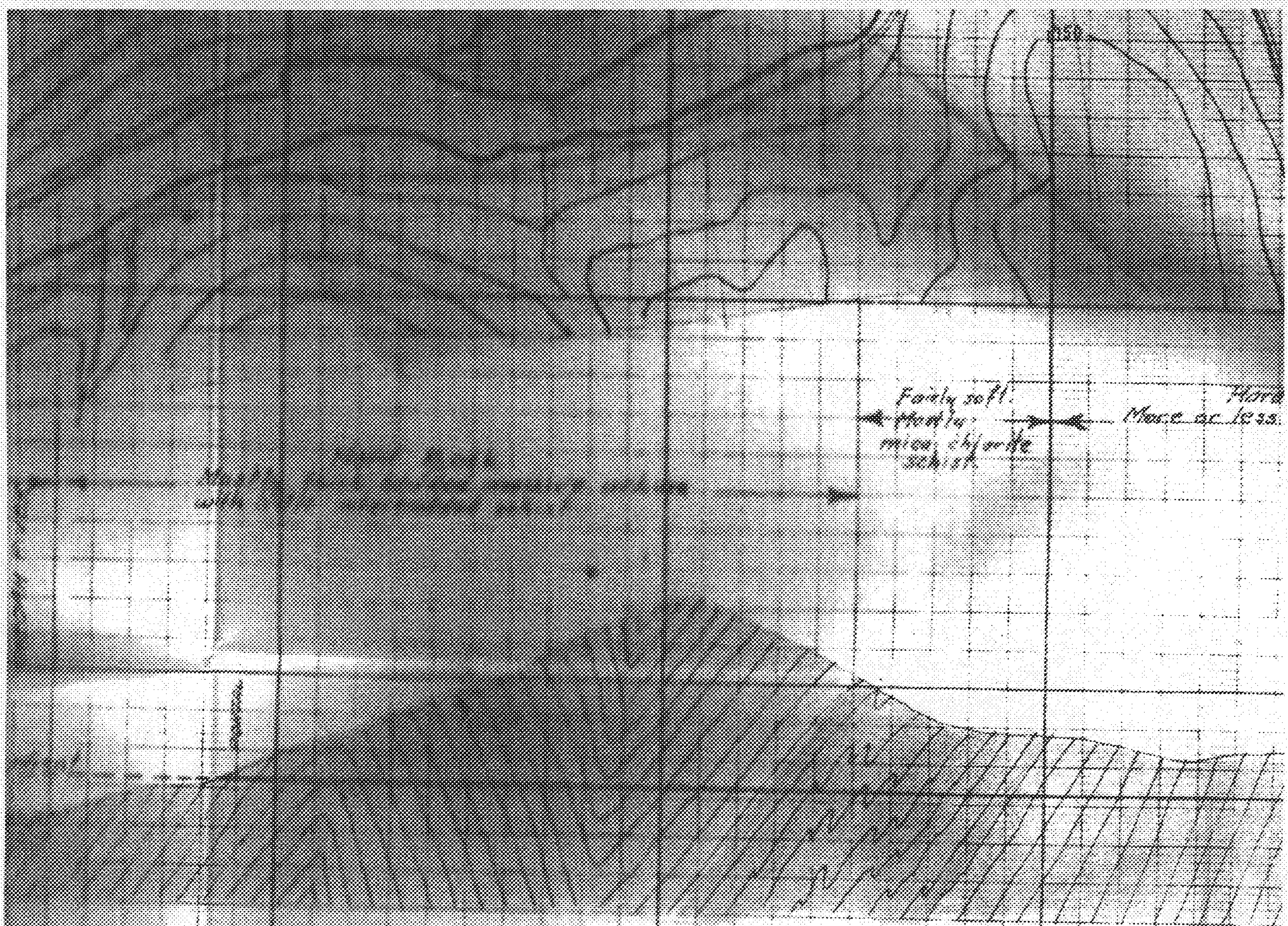
242+43
ITTLE
TENNESSEE
RIVER
RYMERS FERRY
NORTH

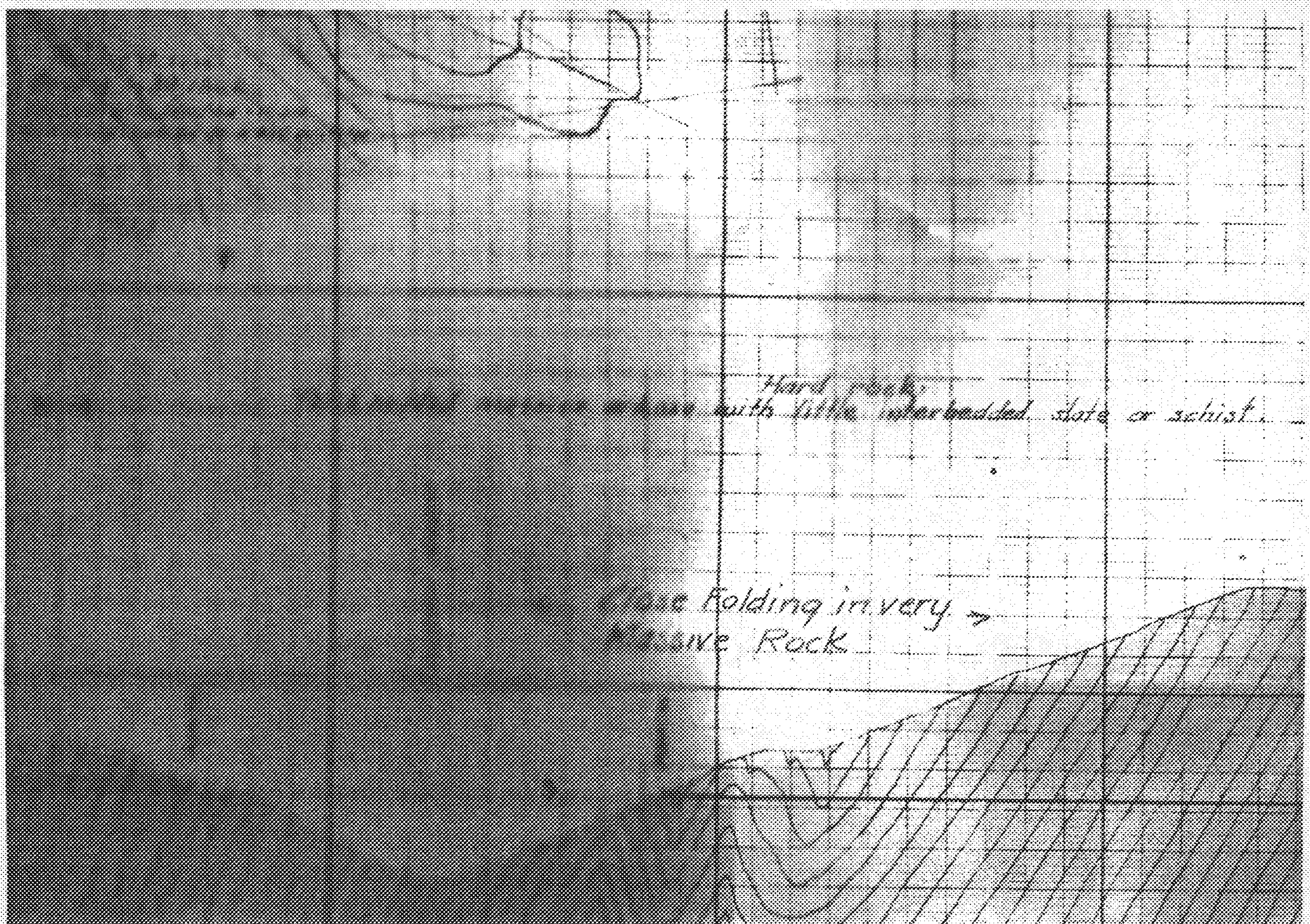


TENNESSEE
RYMERS FERRY
NORTH
43000
44000
45000

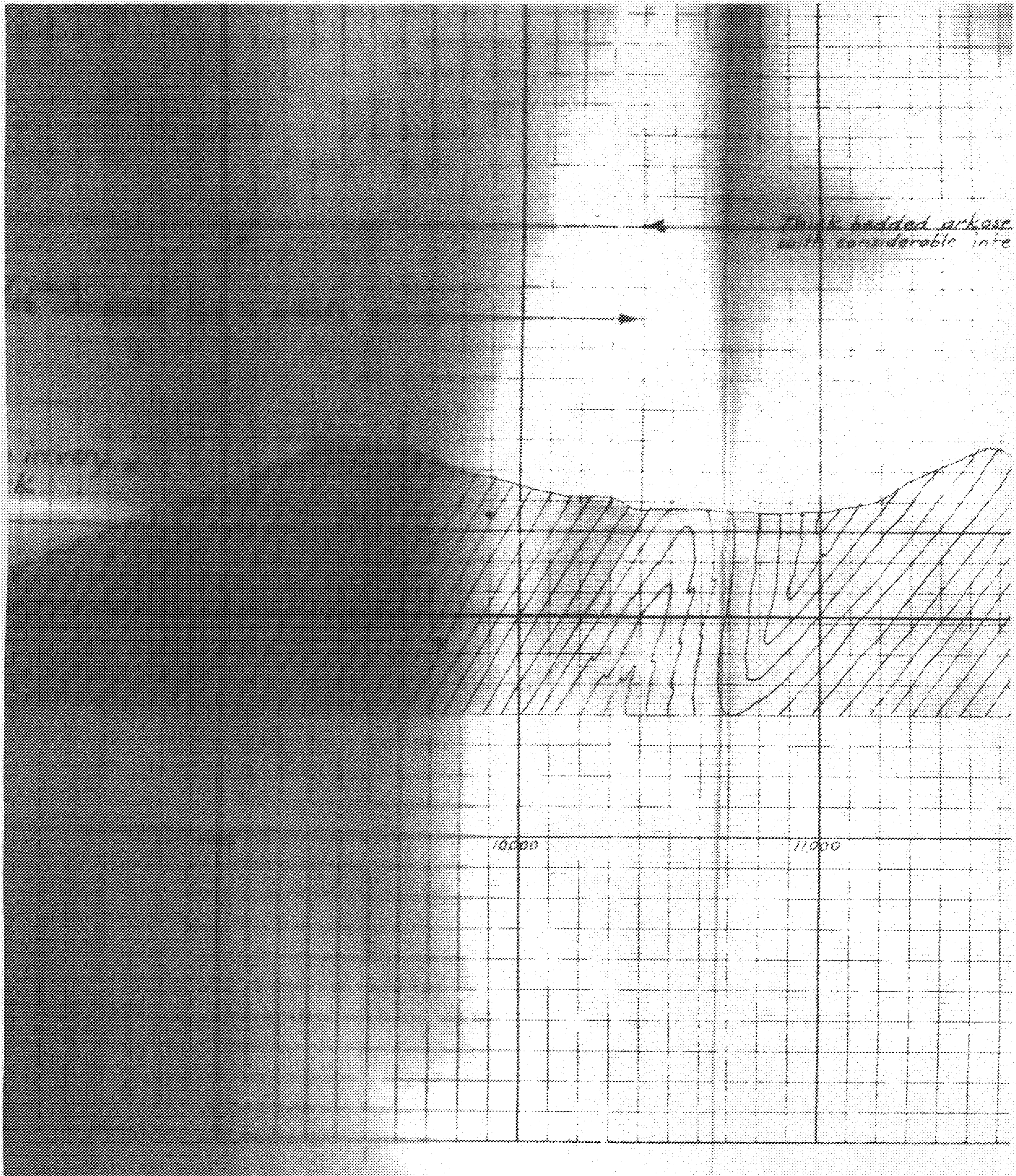


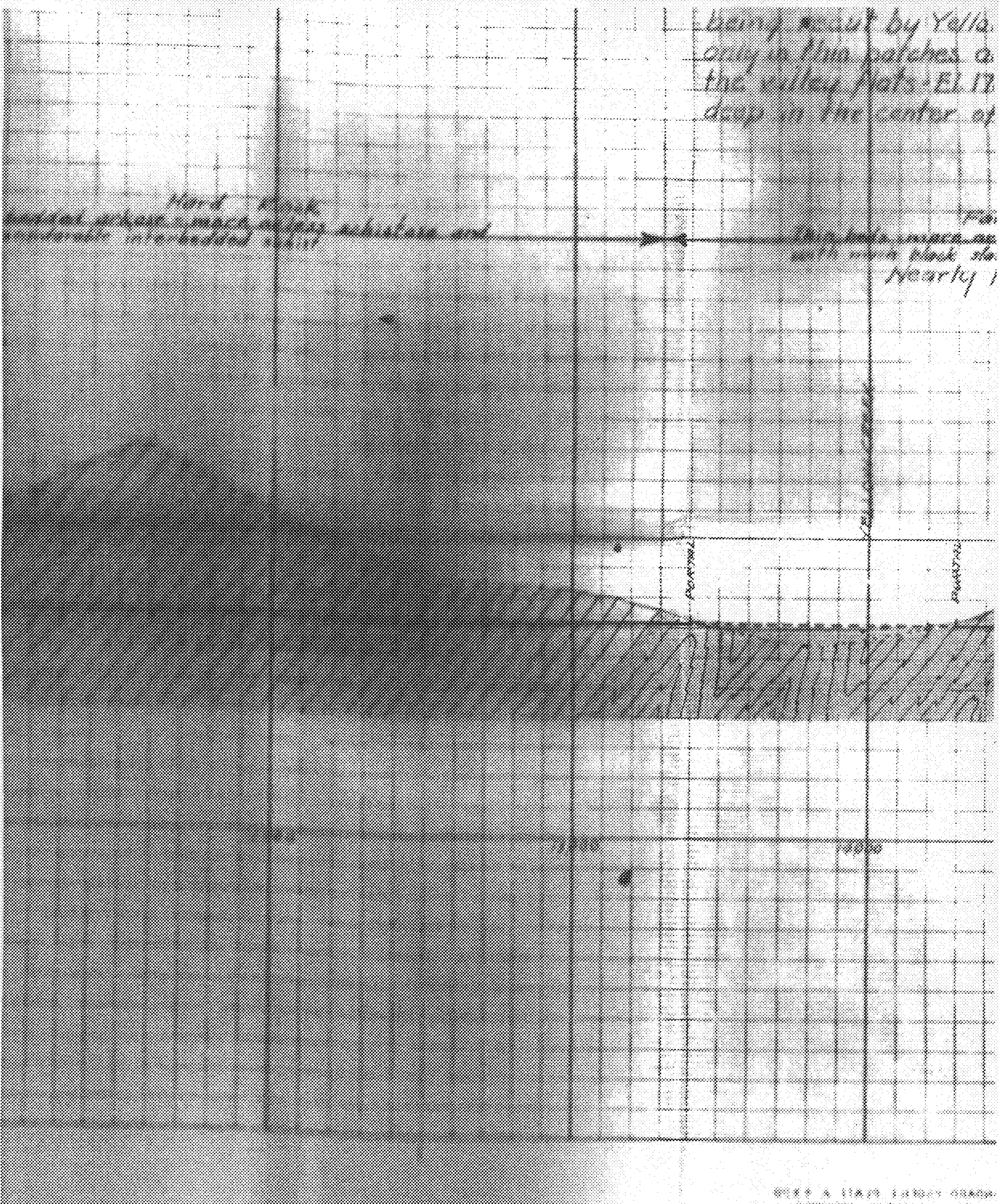
Hard rock. More or less
Schistose arkose with a
considerable amt of schist
Hard ro
Massive
arkose.
2500
Elev. 2000
1900
1800
1700
1600
1500
1000
0
Tunnel


Fairly soft.
Mostly
mica chlorite
schist.
Hard
More or less
4000
5000

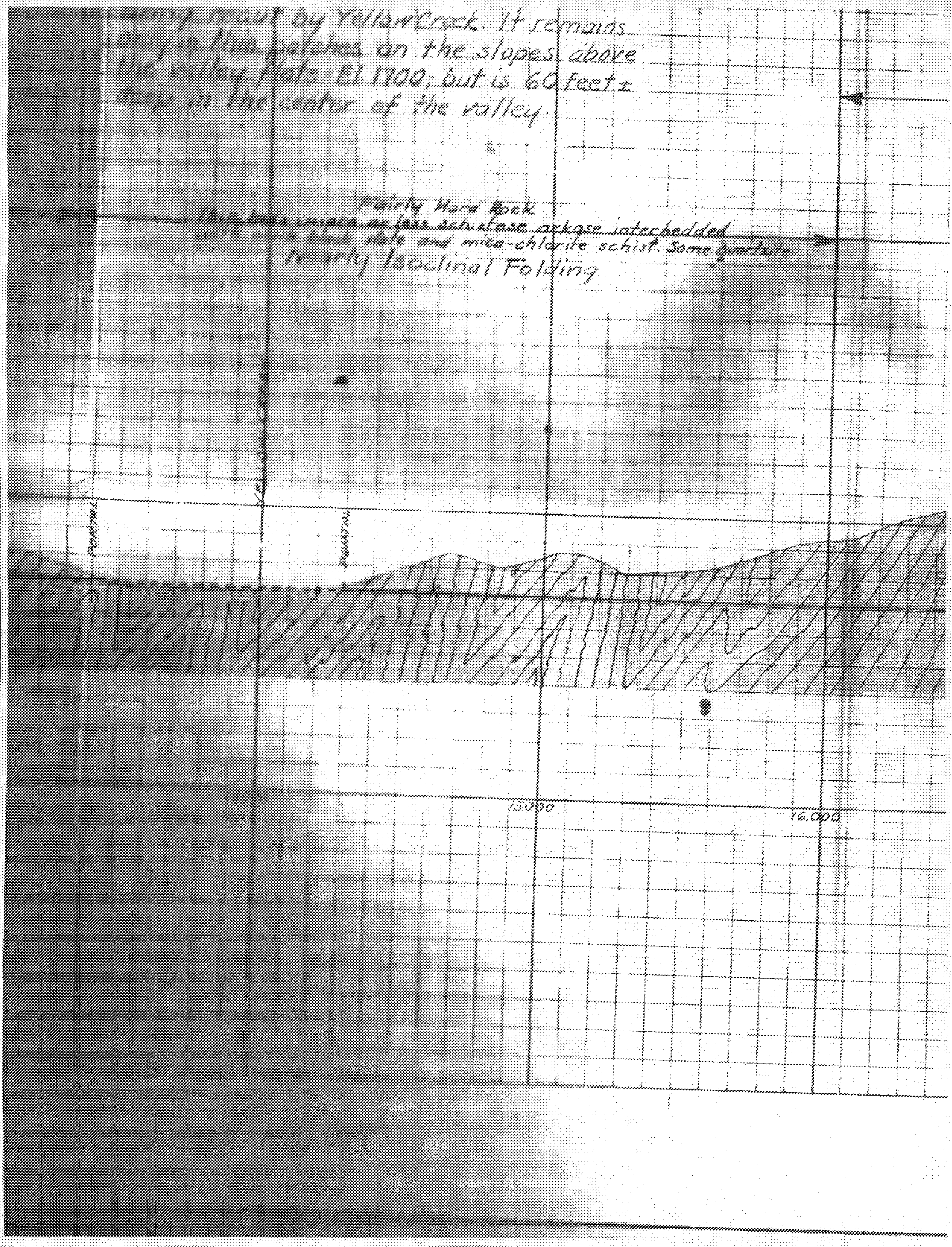


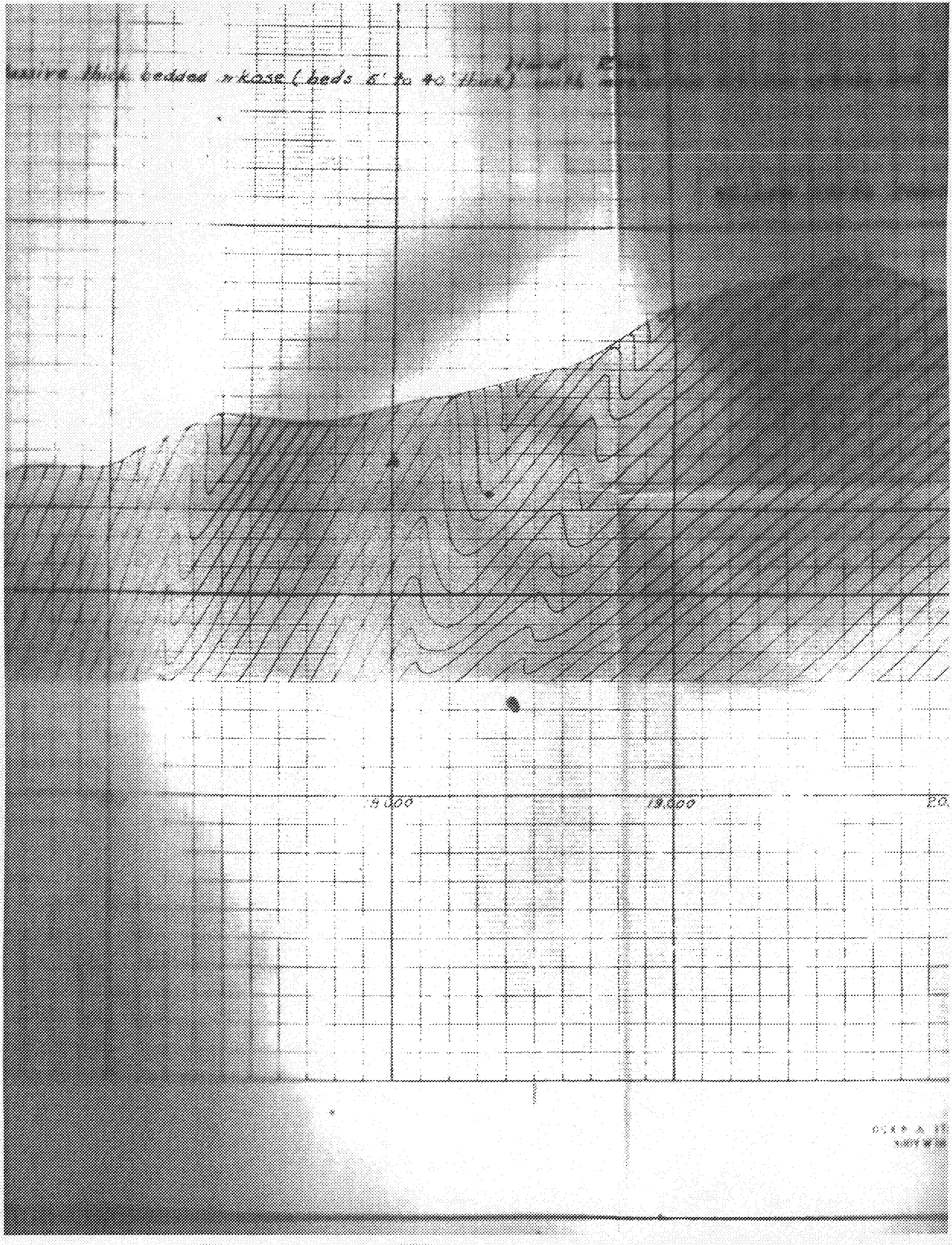
Hard rock:
with little interbedded slate or schist.
Folding in very
Rock
3000

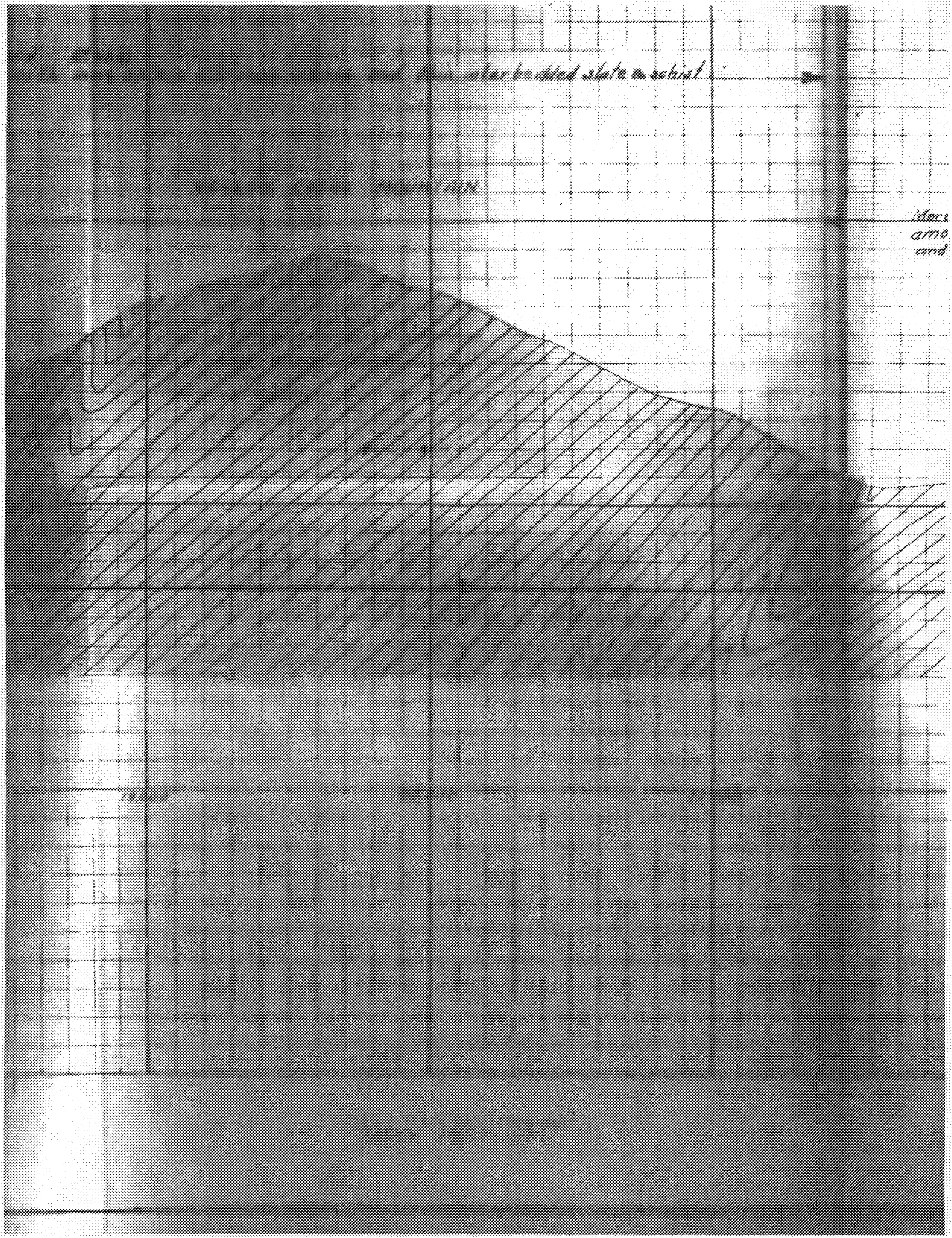

Thick bedded arkose
with considerable inte
10000
11000

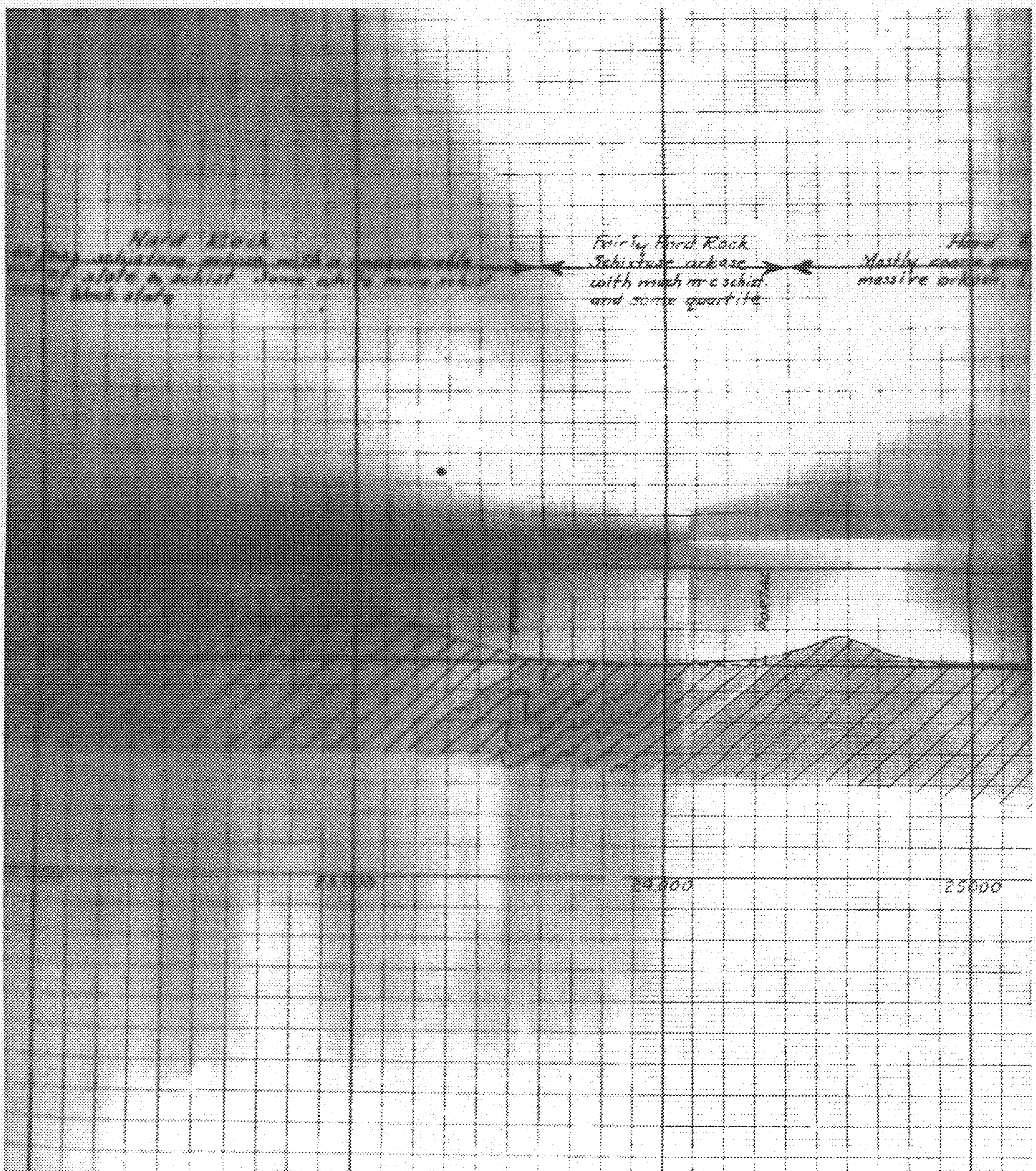


being cut by Yello
only in thin patches a
the valley flats - El 17
deep in the center of
Hard Rock
Nearly

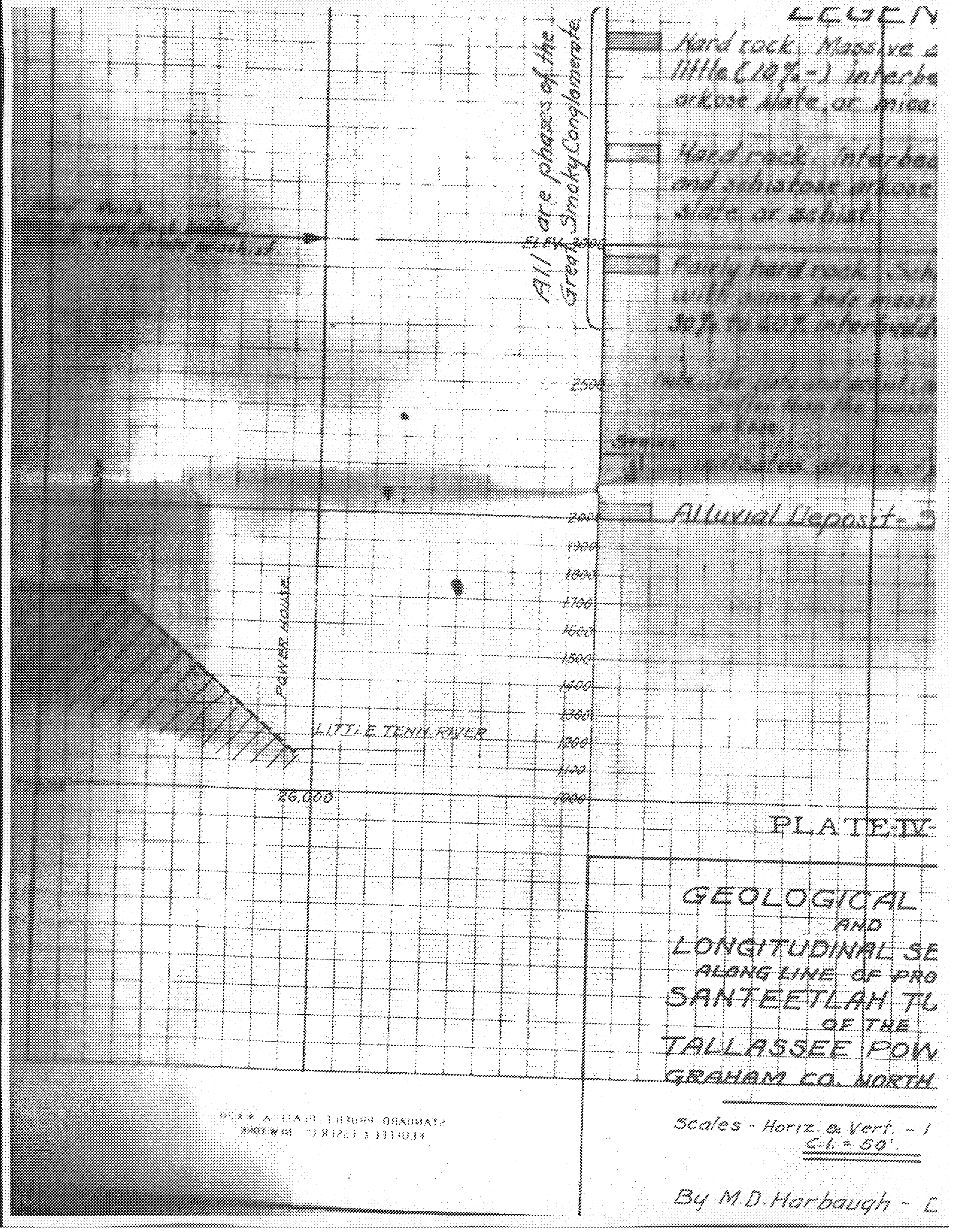

by Yellow Creek. It remains
in thin patches on the slopes above
the valley flats El 1700; but is 60 feet ±
in the center of the valley.
Fairly Hard Rock
schistose arkose interbedded
black slate and mica-chlorite schist. Some quartzite
Nearly Isoclinal Folding
PORTAL
PORTAL
15,000
16,000

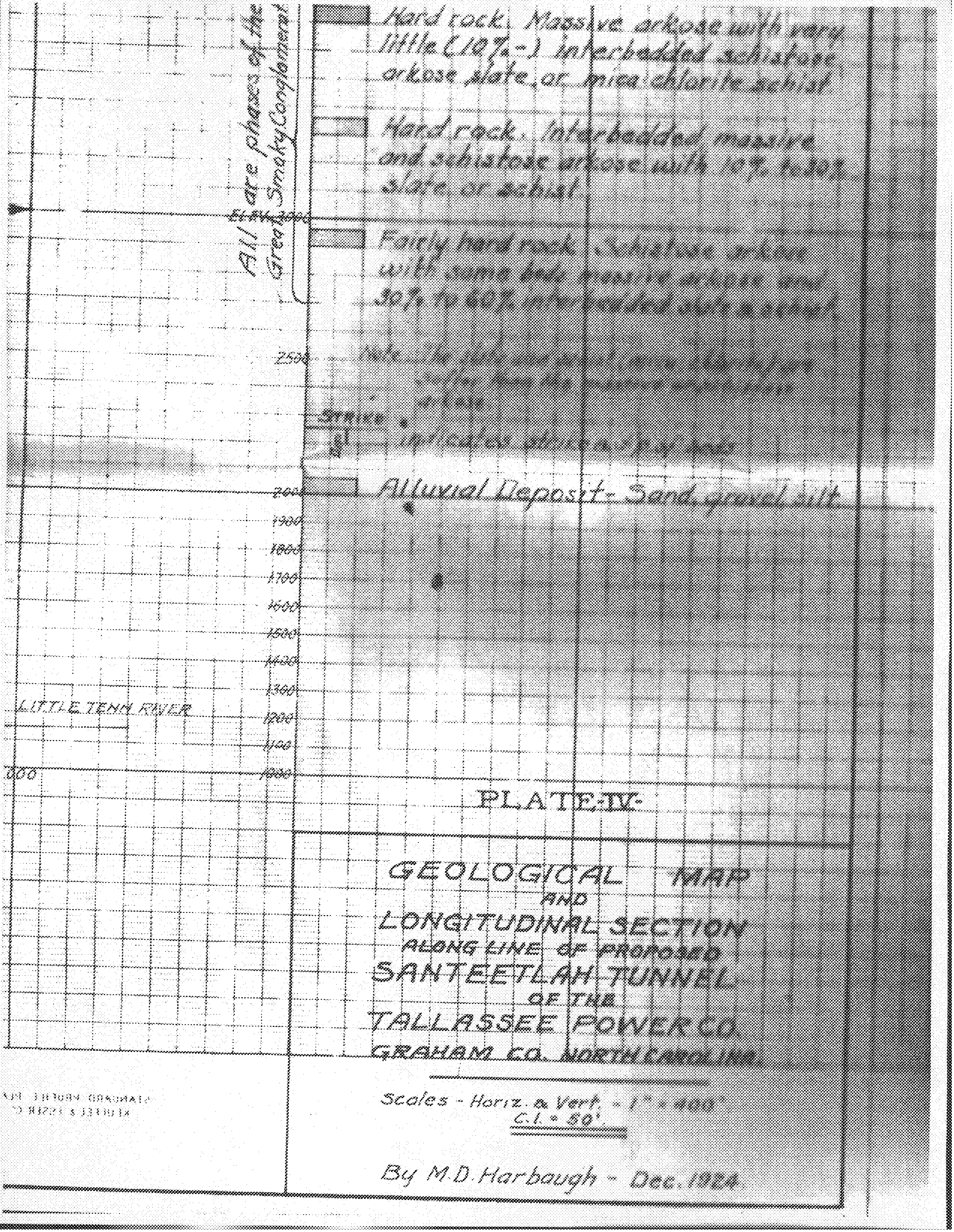

ssive thick bedded arkose (beds 5' to 40' thick) with
18,000
19,000
20


slate
schist



Hard Rock
Fairly Hard Rock
Schistose arkose
and some quartzite
massive arkose
24000
25000


LEGEN
Hard rock. Massive a
little (10%-) interbe
arkose slate, or mica
Hard rock. Interbed
and schistose arkose
slate, or schist
Alluvial Deposit- S
All are phases of the
Great Smoky Conglomerate
ELEV. 3000
2500
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
POWER HOUSE
LITTLE TENN RIVER
26,000
PLATE-IV-
GEOLOGICAL
AND
LONGITUDINAL SE
ALONG LINE OF PRO
SANTEETLAH TU
OF THE
TALLASSEE POW
GRAHAM CO. NORTH
Scales - Horiz. & Vert. - 1
C.I. = 50'.
By M.D. Harbaugh - C


All are phases of the Great Smoky Conglomerate
Hard rock. Massive arkose with very little (10%-) interbedded schistose arkose slate or mica chlorite schist
Hard rock. Interbedded massive and schistose arkose with 10% to 30% slate or schist
Fairly hard rock. Schistose arkose with some beds massive arkose and 30% to 60% interbedded slate or schist
ELEV. 3000
2500
Strike
Alluvial Deposit - Sand, gravel, silt
1900
1800
1700
1600
1500
1400
1300
LITTLE TENN RIVER
1200
1100
1000
PLATE-IV-
GEOLOGICAL MAP
AND
LONGITUDINAL SECTION
ALONG LINE OF PROPOSED
SANTEETLAH TUNNEL
OF THE
TALLASSEE POWER CO.
GRAHAM CO. NORTH CAROLINA
Scales - Horiz. & Vert. - 1" = 400'
C.I. = 50'.
By M.D. Harbaugh - Dec. 1924.