FIELD TRIP NO. 2 Ducktown, Tennessee

PART I. Introduction and Road Guide[1]

by Robert A. Laurence

Geologist, U. S. Geological Survey, Knoxville, Tennessee

Field Trip Guides: Robert A. Laurence, (Owen Kingman and Staff, Tennessee Copper Company)

Gatlinburg (el. 1292) is situated in a fault-controlled valley at the foot of the Great Smoky Mountains. There are abundant exposures of the slightly metamorphosed sedimentary rocks of the Ocoee Series (upper Precambrian) along the highway which follows Little Pigeon River, between Gatlinburg and Pigeon Forge to the north. Shortly after leaving Gatlinburg, the bus will ascend the Great Smokies to Newfound Gap (el. 5045), passing many excellent exposures of the Ocoee rocks.

The Ocoee Series is a thick wedge of clastic rocks, resting on a much older crystalline basement in the eastern part of the Great Smokies, and overlain conformably or with slight disconformity by sedimentary rocks of probable Early Cambrian age in the western foothills of the Great Smokies, but the two areas are separated by faults, and the entire thickness is nowhere present in an unbroken sequence. The complex stratigraphic relations of the Ocoee Series were discussed in a paper by King and others (1958).

Most of the rocks seen between Gatlinburg and Cherokee, N. C., are in the Great Smoky Group, characterized by thick

---

[1] Publication authorized by the Director, U. S. Geological Survey.

graded beds of coarse feldspathic metasandstone and thinner beds of dark, sulfide-rich slate and argillite. For the first 10 miles south of Gatlinburg these rocks dip regularly toward the mountains; near Newfound Gap and farther south they are folded and steep. They are approximately equivalent and show many similarities to the rocks of the Ducktown area.

Metamorphic grade of the Ocoee increases southward across the Great Smokies (Hadley and Goldsmith, 1963). Coming southward on US-441, the biotite isograd is crossed at about Gatlinburg, the garnet isograd at about the Chimneys Campground as the northern slope is ascended, the staurolite isograd about $2\frac{1}{2}$ miles east of Newfound Gap on the southern slope, and the kyanite isograd near the Oconaluftee Ranger Station about 4 miles farther southeast.

After leaving the Cherokee Indian Reservation and joining U. S. Highway 19, the route crosses two dome-shaped areas of granitic rocks near Ela and Bryson City. These have been interpreted as basement complex (Keith, 1907; Hadley and Goldsmith, 1963) and as Ocoee sedimentary rocks which have been thoroughly granitized (Cameron, 1951). There are many pegmatites in the vicinity of Bryson City, and the district has been an important producer of feldspar, but there is little mining in the district now.

Southwest of Bryson City, the route follows the deep Nantahala Gorge for several miles. Here the upper part of Nantahala River apparently was captured by a tributary of Little Tennessee River flowing in a strike valley of the soluble, nonresistant Murphy Marble (Keith, 1907). Most of the route from there to Murphy is in the Murphy Marble Belt, an area of metasedimentary rocks of uncertain age, apparently younger than the Ocoee Series, and possibly of Early Cambrian age. They have been described by Van Horn (1948).

Near Murphy, two varieties of dolomitic marble, white and blue, are quarried commercially. The Cherokee County Court House, in the center of Murphy, is built of this stone. Also near Murphy, a high-grade white talc is mined. This occurs in altered zones of impure dolomitic marble. Both crayons and ground talc are shipped (Van Horn, 1948).

Leaving the Murphy Marble Belt near the extreme southwestern corner of North Carolina, the route follows U. S. Highway 64, again crosses a broad belt of the Ocoee metasedimentary rocks, and shortly after entering Tennessee, reaches the starkly bare highly eroded Ducktown basin.

(Detailed description and itinerary of trip in Ducktown Basin and mines--prepared by the geological staff of Tennessee Copper Company--will be given in Part II of this portion of the guidebook.)

Leaving Ducktown, Highway 64 follows Ocoee River across the less metamorphosed part of the Ocoee Series, excellently exposed along most of the route (Hurst and Schlee, 1962). At Parksville Dam, Lower Cambrian(?) rocks of the Chilhowee Group are thrust over shales and limestones of Early and Middle Ordovician age. This is the boundary between the Blue Ridge and Valley and Ridge physiographic provinces. For the next hundred miles, the route is in the Valley and Ridge Province in the broad belt of folded and faulted lower Paleozoic rocks, generally deeply weathered, poorly exposed, and covered either by a thick cherty residual mantle or by alluvial deposits of Tertiary(?) and Quaternary age (Rodgers, 1953; C. W. Wilson, 1958, p. 68-69, 78-79, 84-86; Neuman and Wilson, 1960). About seven miles east of Maryville, on State Highway 73, the route crosses the Great Smoky fault, and again enters the Blue Ridge province. Here, as at Parksville, Lower Cambrian(?) clastic rocks are thrust upon Middle Ordovician shales. A short distance east, after traversing the several formations of the Chilhowee Group of Early Cambrian(?) and Early Cambrian age exposed in Chilhowee Mountain, the road crosses Miller Cove, a long narrow valley developed on the Shady Dolomite, also of Early Cambrian age, which overlies the Chilhowee Group. Deep roadcuts in this area expose the Shady and its residual cover.

Beyond Miller Cove, another thrust fault is crossed and the rocks of the Ocoee Series are well exposed in deep cuts on the new road along Little River. Particularly noteworthy are the conspicuous graded layers of quartz-pebble conglomerates, of which several different beds, separated by siltstone beds, are exposed.

Next, the route enters a broad, open, cleared and farmed area, which, in topography, soils, and culture, resembles the Valley and Ridge. This is Tuckaleechee Cove, one of the large windows in the Great Smoky thrust sheet (King, 1964). Knox Dolomite and its residual cover are exposed in some of the roadcuts; Middle Ordovician rocks are present but not readily seen along the bus route, except right at the margin of the window. As one leaves the window, and re-enters the overthrust mass of Ocoee rocks, the Great Smoky fault may be seen (when not concealed by lush vegetation) in the roadcuts on the south side of the road (King, 1964, pl. 11).

The Great Smoky Mountains National Park is re-entered just beyond the Tuckaleechee Cove window, and the road follows the winding Little River Gorge, with abundant exposures of the Ocoee Series (King, 1964), to Elkmont, where it climbs through Fighting Creek Gap (el. 2300) and descends again to Little Pigeon River and back to Gatlinburg. Coming down from Fighting Creek Gap, one sees an excellent view of Mount Le Conte and the northern slope of the Great Smokies (King, 1964, p. 12).

This rapid trip through the Great Smokies has permitted only fleeting glimpses of the interesting and highly complex geology of the region. In recent years, much detailed fieldwork has been done here, especially by P. B. King, J. B. Hadley, R. B. Neuman, and others, and the reference list below is highly recommended to those who would like to know more than can be put in this condensed "travelog."

SELECTED REFERENCES

Cameron, E. N., 1951, Feldspar deposits of the Bryson City district, North Carolina: North Carolina Div. Mineral Resources Bull. 62, 100 p.

Hadley, J. B., and Goldsmith, Richard, 1963, Geology of the eastern Great Smoky Mountains, North Carolina and Tennessee: U. S. Geol. Survey Prof. Paper 349-B, 118 p.

Hadley, J. B., King, P. B., Neuman, R. B., and Goldsmith, Richard, 1955, Outline of the geology of the Great Smoky Mountains area, in Russell, R. J., ed., Guides to southeastern geology: New York, Geol. Soc. America, p. 395-427.

Hamilton, W. B., 1961, Geology of the Richardson Cove and Jones Cove quadrangles, Tennessee: U. S. Geol. Survey Prof. Paper 349-A, 55 p.

Hurst, V. J., and Schlee, J. S., 1962, Ocoee metasediments, north central Georgia-southeast Tennessee: Georgia Dept. Mines, Mining and Geology, Guidebook No. 3, 28 p.

Keith, Arthur, 1895, Description of the Knoxville sheet (Tennessee-North Carolina): U. S. Geol. Survey Geol. Atlas, Folio 16, 6 p.

________, 1907, Description of the Nantahala quadrangle (North Carolina-Tennessee): U. S. Geol. Survey Geol. Atlas, Folio 143, 11 p.

King, P. B., 1964, Geology of the central Great Smoky Mountains, Tennessee: U. S. Geol. Survey Prof. Paper 349-C, 148 p.

King, P. B., Hadley, J. B., Neuman, R. B., and Hamilton, W. B., 1958, Stratigraphy of the Ocoee Series, Great Smoky Mountains, Tennessee and North Carolina: Geol. Soc. America Bull., v. 69, p. 947-966.

Neuman, R. B., and Nelson, W. H., 1965, Geology of the western part of the Great Smoky Mountains, Tennessee: U. S. Geol. Survey Prof. Paper 349-D (in press).

Newman, R. B., and Wilson, R. L., 1960, Geology of the Blockhouse quadrangle, Tennessee: U. S. Geol. Survey Geol. Quad. Map GQ-131.

Rodgers, John, 1953, Geologic map of east Tennessee with explanatory text: Tennessee Div. Geology Bull. 58, 168 p.

Van Horn, E. C., 1948, Talc deposits of the Murphy Marble Belt: North Carolina Div. Mineral Resources Bull. 56, 54 p.

Wilson, C. W., 1958, Guidebook to geology along Tennessee highways: Tennessee Div. Geology, Rept. Inv. no. 5, 115 p.

Part II The Ducktown Copper District

by Owen Kingman, Chief Geologist, and
R. N. Diffenbach, Geologist

Tennessee Copper Company, Copperhill, Tennessee

The recorded history of the Ducktown mining district dates back to 1843, when a prospector looking for gold panned metallic minerals from the outcrop of the Burra Burra lode. The first production did not take place until 1847 when a single shipment of 31,000 lbs. of 25% copper ore, mined from secondary chalcocite ore, was shipped to Massachusetts. The same year operations began mining gossan for iron ore. In 1850 copper mining operations again started up, at the Hiwassee mine, and by 1855 all of the ore bodies in the district had been found and opened. The first smelter was erected in 1854, and within several years, four others came into operation. About 1870 the secondary chalcocite ores were nearing exhaustion and several mills were built to concentrate the underlying primary sulfide ores, which could be profitably mined from the more copper-rich ore bodies. By 1879 the richer primary ores had been mined out and operations ceased until 1890, when the completion of a railroad through Ducktown and metallurgical advances made possible the economic exploitation of the lower grade primary ores.

In 1899 Tennessee Copper Company was formed, and in 1907 the new company began recovering SO_2 from the roasting of the sulfide ores for the production of sulfuric acid. In 1936 Tennessee Copper Company purchased the only other remaining company in the district and since that time has been the sole operator in the district.

In 1963, Tennessee Corporation, of which Tennessee Copper Company is a division, became a subsidiary of Cities Service Company. Figure 1 outlines the important dates in Tennessee Copper Company and Copper Basin history. Figure 2 illustrates the present operations and the various products of these operations.

Itinerary

Arrive at Mine office, Tennessee Copper Co., Ducktown, Tennessee. See Figure 3.

Proceed to Boyd man shaft, pick up caps, lamps and belts. One half the group to proceed underground.

The alternate half will proceed to Calloway Mine to eat lunch and collect from mine dump. Underground trip will last about one hour. On returning to surface, the first underground group will proceed to Calloway for lunch and collecting.

Mineralization and Country Rocks

The country rocks are thought to be part of the Great Smoky group of late Precambrian age. They consist of graywackes, graywacke conglomerates, and mica schists, and intermediate types that are locally called graywacke-schists. A very few of the schists are graphitic. Regional metamorphism was intense enough to produce staurolite and kyanite in some of the schist beds. Mineralogically the majority of the rocks consist of

Dates in TCC and Copper Basin History

1838 Removal of Cherokee Indians to reservations West of the Mississippi.

1839 First land purchases in the Ducktown area by white settlers. Polk County organized.

1843 Copper discovered at Ducktown.

1850 First mine, "Hiwassee," opened at Ducktown.

1853 Wagon road completed through Ocoee River gorge to Cleveland, Tennessee, a rail station 30 miles nearer than Dalton, Georgia.

1861 Civil War, first stimulating, then threatening the new industry employing about 1,000 men and boys. First copper rolling mill at Cleveland just being completed. Scarcity of trees becoming noticeable in the Ducktown vicinity. Cord-wood only fuel available.

1863 Federal occupation of Cleveland; copper rolling mill burned; Ducktown mining halted; population leaving Basin; guerrillas active.

1865 End of war. Mining operations resumed.

1872 First Basin use of new machine, the diamond drill, and of new explosive, dynamite.

1878 Mining and smelting stopped after production of 24 million pounds of copper following the Civil War; approximately 50 square miles of Copper Basin stripped of trees for operational fuel.

1890 Railroad between Marietta, Georgia, and Knoxville, Tennessee, through Basin completed. New mining, smelting activities begun.

1899 Tennessee Copper Company formed; Burra Burra shaft sunk. Grading for the Company railroad and smelter construction at Copperhill begun.

1901 First pig copper produced at TCC.

1904 Pyritic process for copper smelting accomplished at Isabella furnaces, ending the "open roasting" of ores.

1907 TCC produces sulfuric acid by using sulfur gases from copper furnaces.

1922 All-milling program is started with operation of London flotation plant to produce copper concentrate. TCC production of copper sulfate begun.

1925 Iron sinter made from TCC iron concentrate.

1927 Zinc concentrate produced at London Mill.

1936 Purchase of Ducktown Chemical and Iron Company by TCC.

1940 Reverberatory furnace operation begun.

1942 Large contact sulfuric acid plant built at Copperhill Plant.

1949 First production of liquid sulfur dioxide in new plant.

1952 Organic chemicals plant built at Copperhill to produce Sul-Fon-Ates and sulfonic acids.

1956 Sodium hydrosulfite plant began operation.

1958 Flotation plants consolidated.

1959 Burra Burra Mine closed after continuous operation for more than 50 years and extraction of 15,636,000 tons of ore. Production of Ferri-Floc transferred from East Point, Georgia, and Lockland, Ohio, plants to Copperhill.

1960 Connection of drift from Boyd Mine and Cherokee shaft, providing access to TCC's newest orebody—Cherokee Mine. Miami Copper Company (Miami, Arizona) becomes a division of the Tennessee Corporation.

1961 Fluid-solids roaster, for treatment of copper concentrate, added at Smelter.

1963 Tennessee Corporation joins Cities Service Company, as a subsidiary.

1964 Chamber acid plant closes; its replacement, No. 4 contact, starts producing sulfuric acid.

THE COPPER BASIN

The denuded, brownish-colored earth in the Copper Basin, in the southeastern corner of Tennessee, is the result of 19th century open-roast processes. Large quantities of wood were needed to roast ore, so operating companies of that era cut down the timber. Sulfur dioxide gas, caused by the open fires, settled on the Basin and the remaining vegetation died-- leaving the soil vulnerable to the elements. For the past 25 years, however, Tennessee Copper has been carrying on a reforestation program.

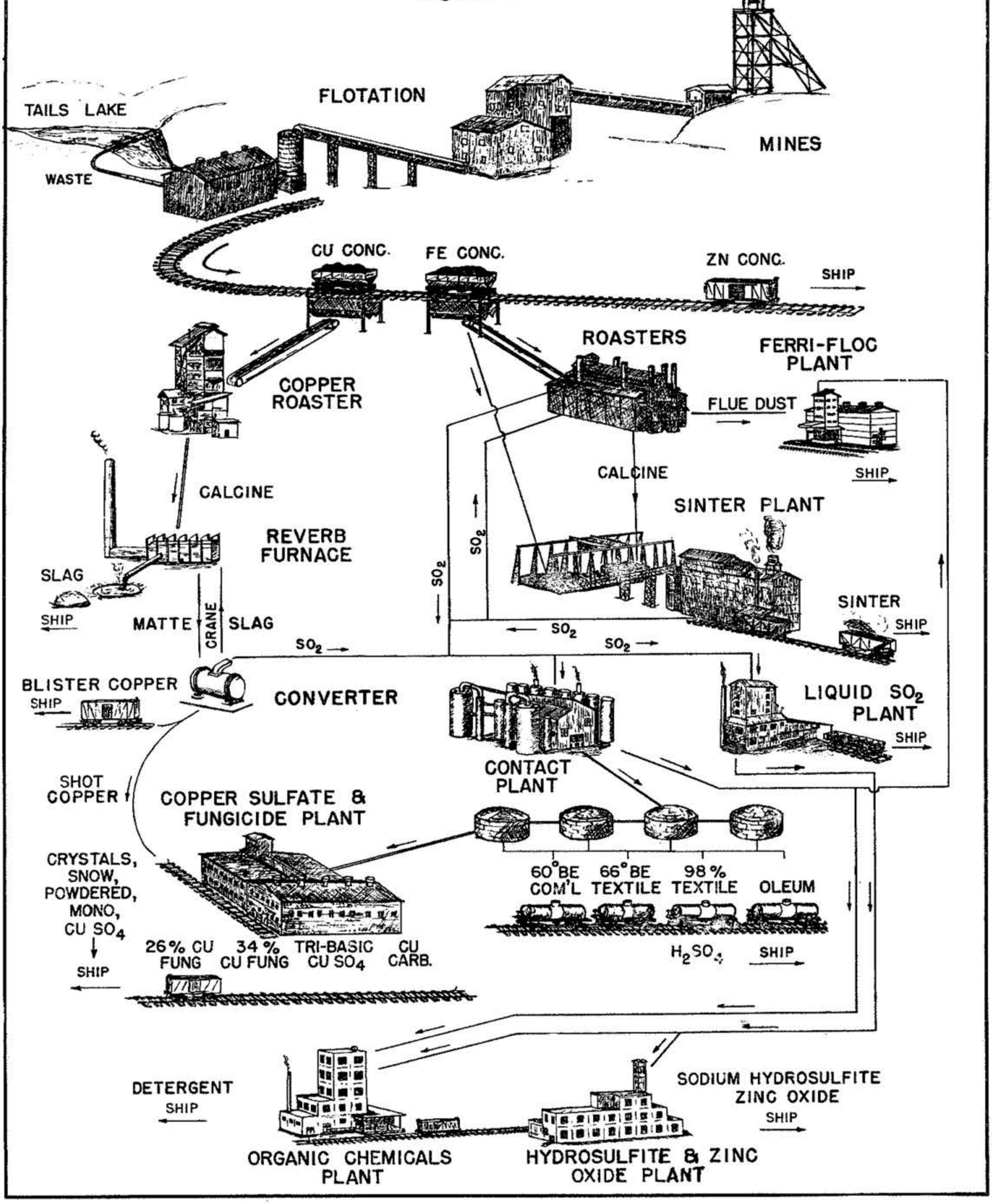
Through landscaping, and planting of kudzu crowns and "wonder-weed" roots, the once barren central zone is getting a green coat. Besides natural forest encroachment, thousands of pine seedlings are set out in the outer belt, or grass-land zone, every spring. It will take decades for plantings to cover the Copper Basin. But, slowly, the scars caused by ore roasting methods of yesteryear are healing.

Figure 1

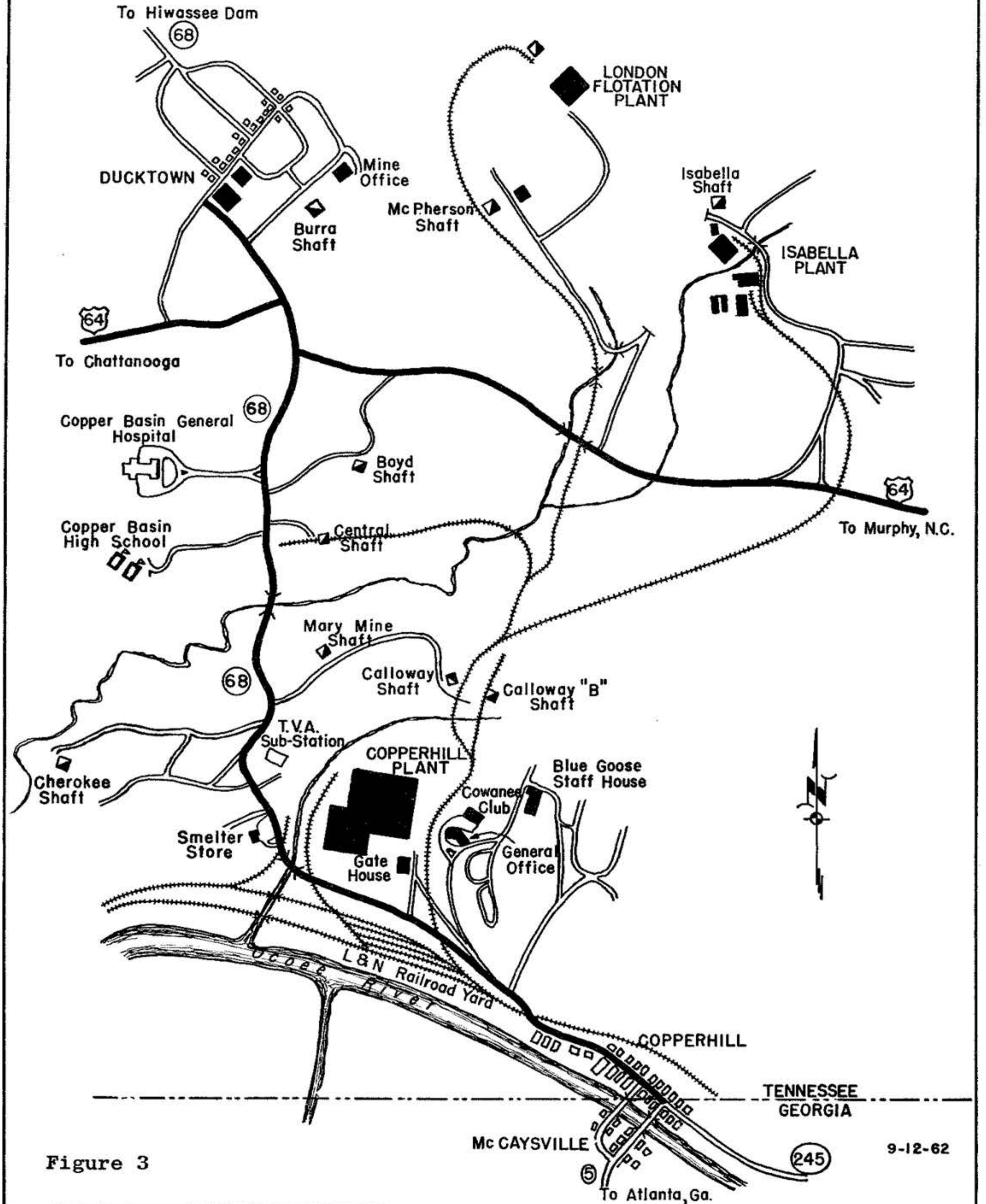
TENNESSEE COPPER COMPANY

GENERALIZED FLOW SHEET

Figure 2



LOCATION OF TENNESSEE COPPER COMPANY OPERATIONS IN THE COPPER BASIN



9-12-62

Figure 3

varying amounts of quartz, plagioclase (oligoclase-andesine), orthoclase, biotite, muscovite, garnet, zoisite, sphene, zircon, and chlorite. Some of the graywackes are calcareous and almost all contain 0.5 to 1.0% pyrrhotite and pyrite.

Occurrence of Ore Bodies

The ore bodies are complex, generally tabular lenses of massive sulfides that are generally conformable with the enclosing meta-graywacke and schist country rocks. Drag-folded configurations of the ore bodies, as both subordinate and dominant features, are common. The dominant structure of the district is the Burra anticline, which is overturned to the northwest so that both limbs dip about 60° to the southeast. The relationship of the orebodies to each other and to the Burra anticline can be seen on the accompanying sketch map (See Figure 4).

The maximum widths obtained by the orebodies exceed 300' locally, but 100 feet is a rough average. To date, the deepest development is at the 2800 ft. level, in Calloway mine. The mining method used is sub-level stoping.

The ores from the various mines average about 75% pyrrhotite, 20% pyrite, 1 to 2% each of magnetite, chalcopyrite, and sphalerite, with minor amounts of galena. Other minerals that have been reported, occurring only rarely, include bornite, specularite, molybdenite, arsenopyrite, cubanite, valleriite, stannite, and troilite.

The gangue minerals are chiefly quartz, carbonates, and

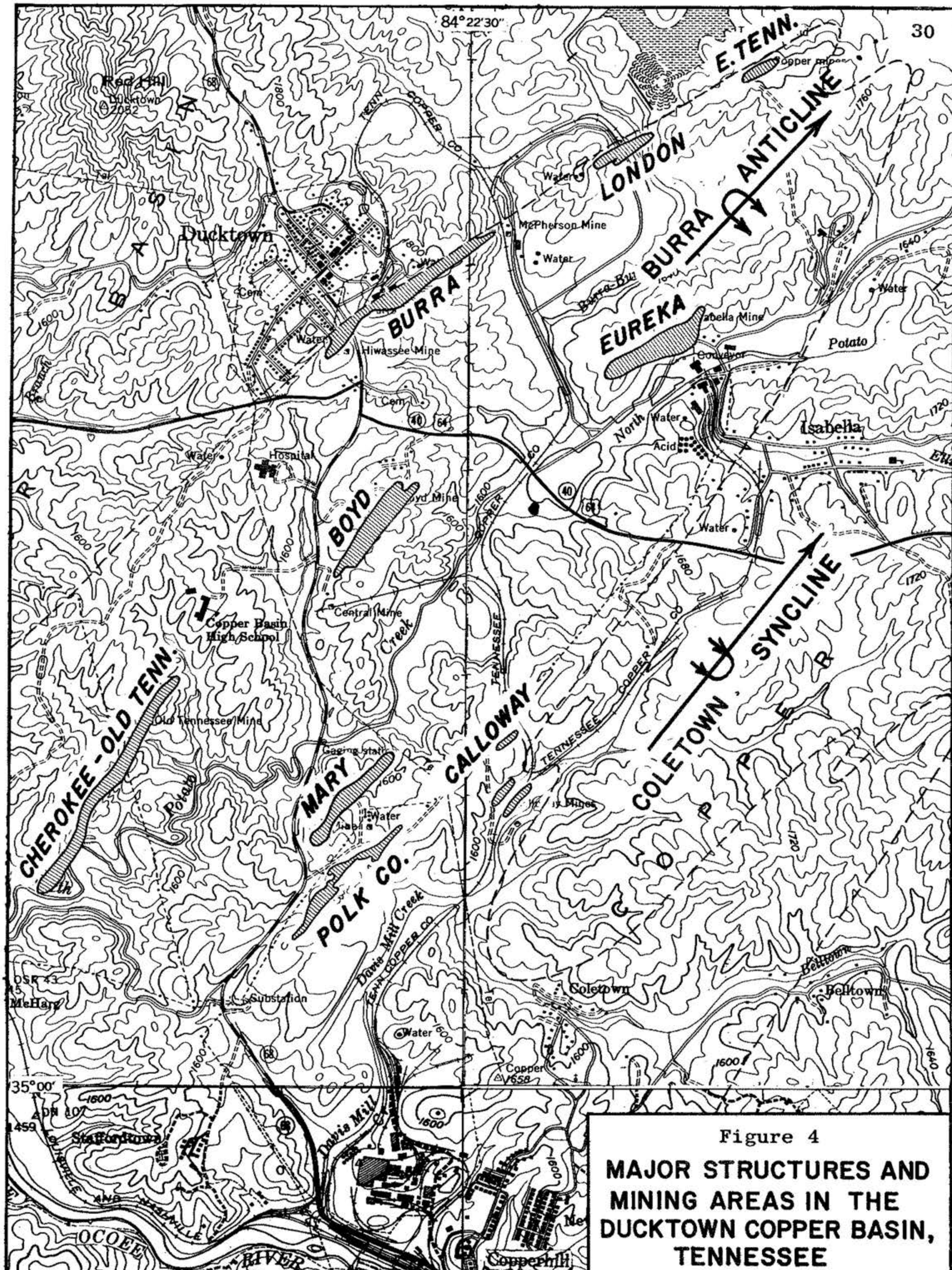


Figure 4
MAJOR STRUCTURES AND MINING AREAS IN THE DUCKTOWN COPPER BASIN, TENNESSEE

actinolite-tremolite. Other gangue minerals include diopside-hedenbergite, hornblende, Ca-garnet, zoisite, biotite, chlorite, sericite, talc, and plagioclase. Also present in minor amounts are sphene, apatite, rutile, anthophyllite, and barite. Masses of gangue minerals that do not contain enough sulfides to be ore are locally referred to as ore zone.

Underground Itinerary (See Figures 5-8)

Stop I

These are typical country rocks: graywacke and graywacke-schist. Chlorite has formed along the fractures. A narrow band of pseudodiorite is in the back and along the right rib. The exposed fault zone with dark breccia and slickensides is typical of faulting in wall-rock. The character or magnitude of this fault is unknown.

Stop II

Ore and vein material may be observed at this stop. Siliceous mineral zone and quartzite occur at the wall-ore contact. The sharp contact between the mineralized zone and wall is typical.

Three types of ore occur here: (1) solid pyrrhotite, (2) mixed pyrrhotite-pyrite, and (3) solid pyrite. The pyrrhotite ore may be seen near station 262. It is fine grained and contains few inclusions. The pyrrhotite-pyrite ore is characterized here by a matrix of pyrrhotite with metacrysts(?) of rounded pyrite grains. The pyrite ore is medium grained and

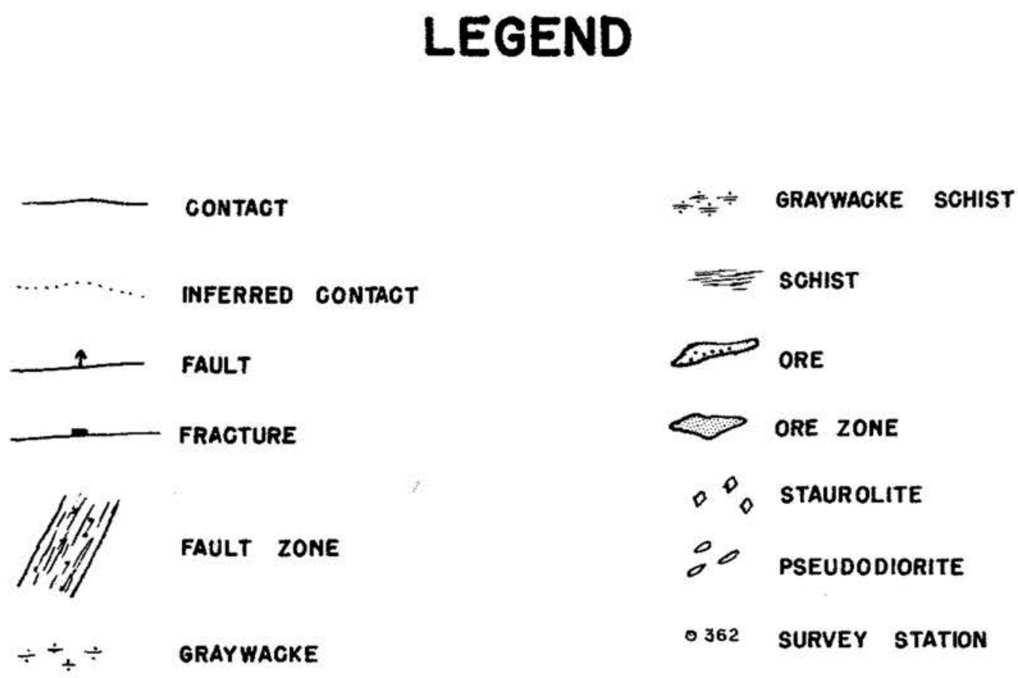

LEGEND
CONTACT
INFERRED CONTACT
FAULT
FRACTURE
FAULT ZONE
GRAYWACKE
GRAYWACKE SCHIST
SCHIST
ORE
ORE ZONE
STAUROLITE
PSEUDODIORITE
362
SURVEY STATION

Figure 5

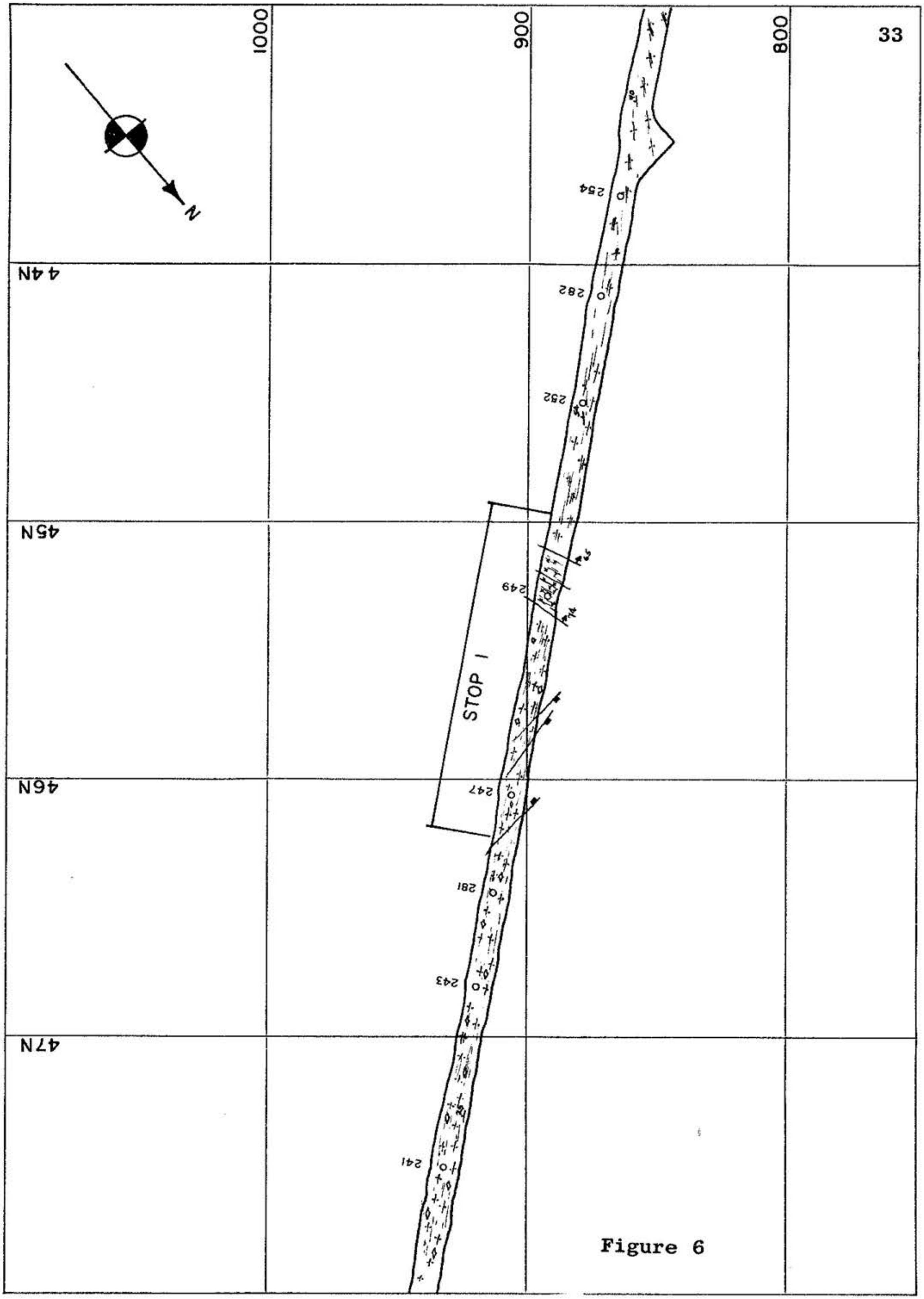

1000
900
800
N
44N
45N
46N
47N
STOP I
254
282
252
249
247
281
243
241

Figure 6

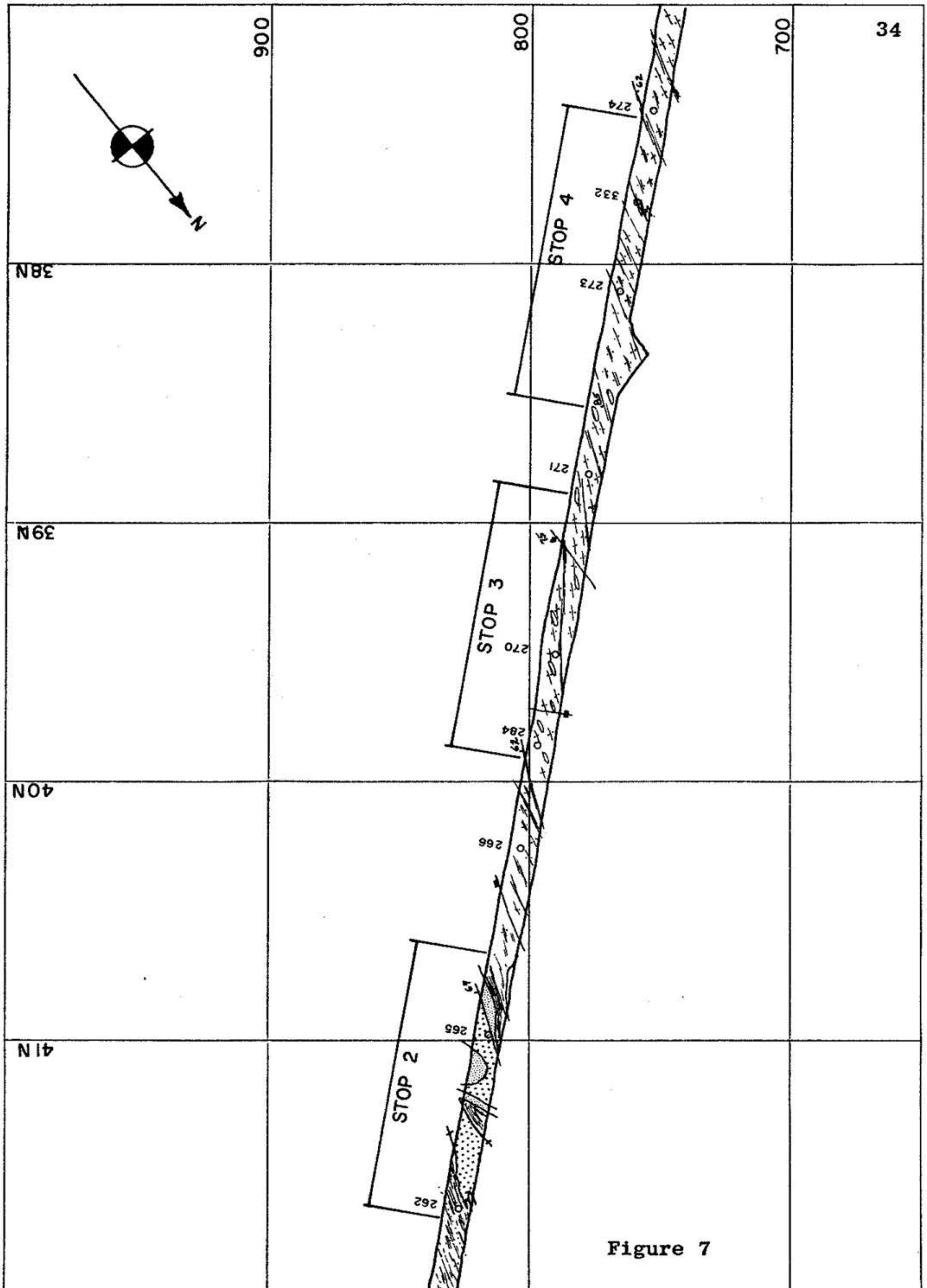

900
800
700
N
38N
39N
40N
41N
STOP 4
STOP 3
STOP 2
274
332
273
271
270
284
266
265
262

Figure 7

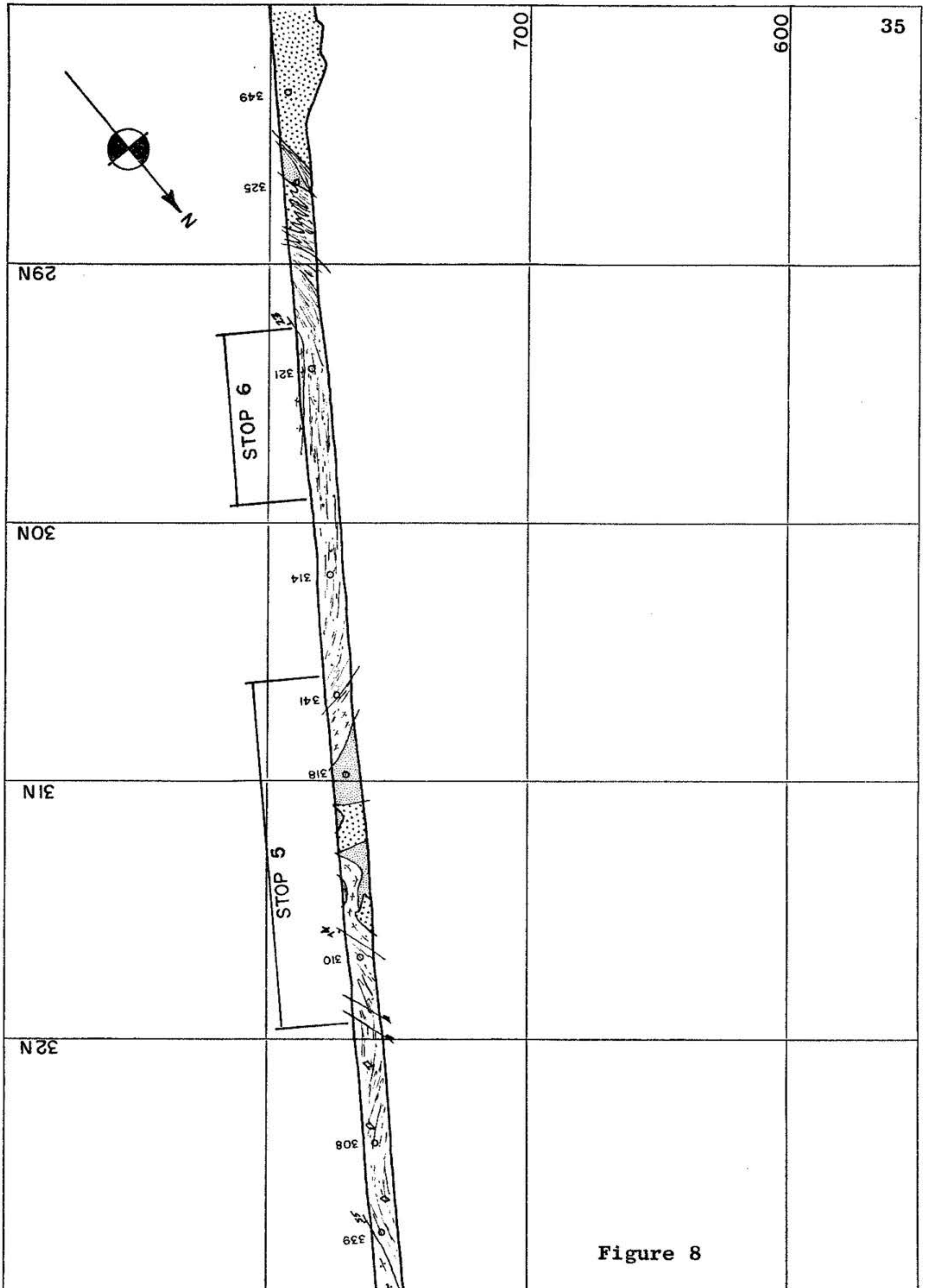

700
600
N
349
325
29N
321
STOP 6
30N
314
341
318
31N
STOP 5
310
32N
308
339

Figure 8

bonded with dark quartzite. A good exposure of chlorite schist is at the footwall contact.

Stop III

Many different shapes and sizes of pseudodiorite are exposed at this stop. Several "pseudodiorites" are cut by minor faults of small displacement. The nodules are elongated parallel to the schistosity and to strike and dip of the beds in which they occur.

According to Emmons, the mineralogy of pseudodiorites is as follows, listed in order of abundance: quartz, plagioclase, ranging from albite to labradorite, orthoclase, hornblende, biotite, calcite, zoisite, muscovite, garnet, sulfides, sphene. They may contain up to 25% calcite.

Averages of chemical analyses of pseudodiorites and graywackes (after Emmons) are listed below:

	Graywacke	Pseudodiorite
SiO_2	73.17	71.53
Al_2O_3	12.67	13.06
Fe_2O_3	0.85	0.71
FeO	3.15	3.35
MgO	1.81	0.81
CaO	1.42	5.85
Na_2O	2.56	2.42
K_2O	1.65	0.15
H_2O	0.78	0.79
TiO_2	0.66	0.55

	Graywacke	Pseudodiorite
P_2O_5	0.15	0.17
MnO	0.13	0.33

Stop IV

Thin bedded sericite-biotite schist with chlorite metacrysts is exposed here. Drag folding is developed.

Stop V

The grain size of the schists increases as the ore contact is approached. Large chlorite and biotite metacrysts are in the sericite schists of the hanging wall. Chlorite schist with small garnets is in sharp contact with the ore. Some calcite and lime silicates occur in the vein near station 313.

Stop VI

Several sericite schist bands with chlorite-rimmed sericite pseudomorphs after staurolite can be observed at this stop. The sericite pseudomorphs are common in several places near the orebody, however the chlorite rims are uncommon.

Stop VII

Battery charging station - typical chlorite schist wall rock. (No smoking in charging station.)

Stop VIII

Freshly exposed ore and footwall.

FIELD TRIP NO. 3 The Mascot-Jefferson City Zinc District

Edited by Robert W. Johnson, Jr.

Geologic Branch, Tennessee Valley Authority, Knoxville

Field Trip Guides: Helmuth Wedow, Jr., Robert W. Johnson, Jr. (James E. Ricketts and Edward McCormick, American Zinc Company)

The field trip to the American Zinc Company's Young Mine, in the Mascot-Jefferson City zinc district will follow U.S. 441 from Gatlinburg to Sevierville, U.S. 411 from Sevierville to Chestnut Hill, and Tenn. Rt. 92 from Chestnut Hill, through Dandridge to Jefferson City. Jefferson City is situated near the eastern end of the zinc district. The Young Mine, located near the center of the district, will be approached via U.S. 11. See Figure 1.

The general geology of the area is well shown by Rodgers (1953). The Gatlinburg-Sevierville leg of the trip follows the West Fork of the Little Pigeon River. About half way to Sevierville the route passes out of the Precambrian Ocoee Series of the Blue Ridge province, and into the area underlain by middle Ordovician shale and siltstone of the Valley and Ridge province. From Sevierville to Chestnut Hill the route essentially follows the regional strike and lies generally along the unconformable contact between middle Ordovician clastic rocks and the lower Ordovician carbonate sequence (upper part of the Knox Dolomite group). From Chestnut Hill the route turns northward across the strike of a broad syncline developed in middle Ordovician shale and siltstone. Douglas Reservoir, a part of the water control system of the Tennessee Valley Authority, located

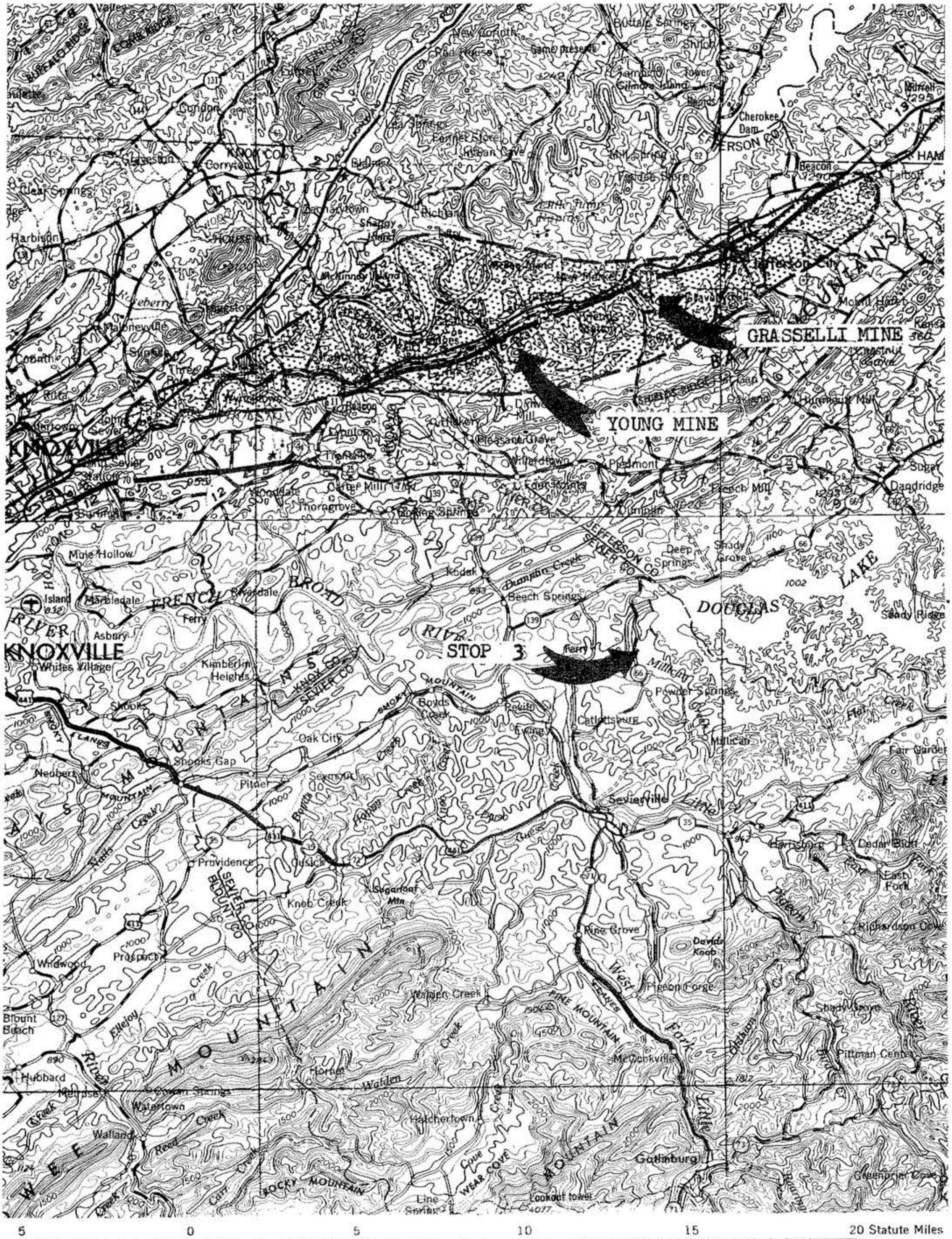


Fig. 2 The Mascot - Jefferson City zinc district of East Tennessee.

on the French Broad River, can be seen from several vantage points along this part of the trip. The French Broad River is crossed just before entering Dandridge.

From Dandridge to Jefferson City the route continues across the regional strike, and various road cuts show typical exposures of bedrock and residual weathering products of formations ranging in age from early Cambrian through early middle Ordovician. This leg of the trip crosses two of the major thrust faults of the region. The first of these, the Dumplin Valley fault, is encountered in the gap in Bays Mountain, about four miles northwest of Dandridge; early Cambrian Rome shale is thrust onto middle Ordovician Lenoir limestone. A second major thrust is encountered about a mile south of Jefferson City--the Rocky Valley fault. At this locality, the fault places late Cambrian Copper Ridge dolomite on early Ordovician Mascot dolomite. The actual fault trace cannot be seen, but its position has been approximately determined by distinctive features of the residuum of the two formations. The Mascot-Jefferson City zinc district lies in the footwall block of the Rocky Valley fault, and two of the principal mines in the district penetrate the fault in their shafts. One of these, the Jefferson City mine of the New Jersey Zinc Company can be seen just northeast of the road, about two miles south of Jefferson City.

The last part of the route to the Young Mine traverses most of the eastern part of the zinc district. Bedrock is very poorly exposed, and the extensive residuum provides excellent soil for farming in the area. On the south side of the highway just west of Jefferson City are the Zinc Mines Works of the United States Steel Company (also known as the Davis-Bible, or Universal mine), the third oldest operating mine in the district. About four miles west of Jefferson City, the headframes of the Grasselli Mine of the American Zinc Company, second oldest operating mine in the district, can be seen to the south of the highway.

* * * * * * * * * * * * *

The geology of the Mascot-Jefferson City zinc district has been well summarized by Bridge (1956), and by Oder and Ricketts (1961). A general statement about the Young Mine is provided by Oder and Ricketts (1961, p. 26-28). The zinc ores of this district occur in the upper part of the Cambro-Ordovician Knox Dolomite group. The main ore-bearing zone is the lower 200 feet of the Kingsport formation and centers chiefly about the contact between the first major limestone beneath the top of the Knox dolomite and the overlying fine-grained dolomite. Some mineralization, however, occurs locally several hundred feet above and a few tens of feet below this zone. Thus, the total stratigraphic range of the mineralization can be as much as 700 feet, straddling the Kingsport formation from the Longview dolomite below to the Mascot dolomite above. The mineralization is comparatively simple, consisting primarily of yellow sphalerite with minor amounts of pyrite, distributed in a gangue that is chiefly breccia blocks of dolomitic and calcareous country rock, with white secondary dolomite. Minor amounts of chert and secondary calcite occur locally, as do traces of chalcopyrite, fluorite, and barite. Only two traces of galena, widely separated, have been reported from the district (Oder and Ricketts, 1961, p. 7-8).

Opinions about the controls of the zinc deposits have been highly divergent. Two basic schools of though exist, with perhaps as many variations in either theme as there have been geological investigators. The differences of opinion center chiefly about the origin of the breccias hosting the ore. One school of thought holds that the breccias are of tectonic origin, originating with warping during the late Paleozoic Appalachian orogeny. In this case, the sphalerite emplacement must have been contemporaneous with, or subsequent to the tectonic activity. Relatively recent selected articles favoring this hypothesis are those by Newman (1933), Currier (1935), Crawford (1945), Brokaw (1948), Behre (1950), and Oder and Hook (1950).

The other school of thought supports the thesis that the sphalerite-bearing breccias were formed by collapse of open cavities. Whether the cavities, and collapse of the cavities, was generated by hydrothermal solution-stoping, as suggested by Odell (Oder and Hook, 1950, p. 78), or was related to the development of a deep karst (or paleo-karst) terrane at the top of the Knox dolomite group in early middle Ordovician time, as intimated by Ulrich (1931), Oder (1958, p. 53), Laurence (1960, p. 114), and Wedow (1961), is at this time open to discussion. The "karst-collapse" hypothesis has been developed more fully in recent papers by Callahan (1964), and Hoagland, Hill, and

Fulweiler (1965). It is perhaps instructive to point out that evidence in the mines indicates that the bulk of the sphalerite must have been emplaced while the enclosing strata were still in a more or less horizontal position (Kendall, 1960, p. 994); in this case, the zinc deposition pre-dates the late Paleozoic orogeny. Oder and Ricketts (1961, p. 15-18) also favor the early, collapse origin of the mineralized breccias, as do Wedow and Marie (1963 and 1965).

The source of the zinc is more problematical. Most students of the district favor some form of hydrothermal origin in the classic sense (ascending warm waters from an unknown igneous source). On the other hand, the environment in which the sphalerite was precipitated was essentially stagnant, as illustrated by the persistent occurrence of sulfides in the lower portions of former open spaces between breccia blocks or fragments, and by the occurrence of much sulphide as "caps" on breccia blocks (Behre, 1950, Fig. 2; Oder and Hook, 1950, Pl. 1). It was also in this environment that the varved, or thinly-laminated breccia matrix was deposited (Kendall, 1960, p. 993-994), further substantiating the near-stagnant condition of the water from which the spalerite was precipitated.

* * * * * * * * * * * * *

The underground trip will take place in the Young Mine of the American Zinc Company. Note that this trip is being made on a working day, so please stay with your guides. At least three areas will be visited underground at which many of the typical features of mineralization in this district are well illustrated.

* * * * * * * * * * * * *

After lunch, the return trip to Gatlinburg will be by way of Jefferson City and Dandridge. From Dandridge, the route will follow Tenn. Rt. 66 to Sevierville, and U.S. 441 from Sevierville to Gatlinburg. A stop will be made at the abandoned Grasselli open-cut mine. This pit was developed where the ore horizon intersects the surface on the west flank of the broad Cherokee anticline. The beds dip gently to the west-northwest. Smithsonite ($ZnCO_3$), and calamine $[Zn_4(OH)_2Si_2O_7 \cdot H_2O]$, the "bone ore" of the miners, can be seen locally in typical development, and sphalerite is present in the exposed breccias at many places in the pit.

It is interesting to note that the sphalerite here occurs in ore grade--about three to four percent of the rock. A different impression is gained when observing this economic mineralization on the surface, in a large open pit, as contrasted with that apparent underground in the mine. This open pit intersects the underground workings of the Grasselli Mine at the lowest exposed point, and this opening is used for ventilation of the mine.

* * * * * * * * * * * * *

West of Dandridge, the return route generally follows the north shore of Douglas Reservoir. Bedrock exposures in road cuts are mostly lower Ordovician formations of the Knox Dolomite

Group. The unconformity at the top of the Knox Group is particularly well exposed along the north shore of the Reservoir during periods of low water. Several paleo-karst features can be seen in great detail (Bridge, 1955). Unfortunately, one of the most interesting of the ancient sinkholes in this paleo-karst terrane was discovered, and immediately concealed, during construction of the left abutment of Douglas Dam. This sinkhole apparently extended several hundred feet down into the Mascot dolomite, and was filled with basal middle Ordovician sediments, including about 60 feet of white, orthoclase-bearing volcanic ash (Laurence, 1945).

* * * * * * * * * * * * *

A short stop will be made at the visitors overlook above the north abutment of Douglas Dam.

* * * * * * * * * * * * *

A stop will be made at a locality on Tenn. Rt. 66, about a mile south of the bridge below Douglas Dam. Many unusual, doubly-terminated quartz crystals have been collected from the road cuts, and after plowing, in the field to the east of the road. The crystals apparently develop in the residuum on the Lenoir limestone. A peculiar feature is the common occurrence of crystals with pyramidal faces much better developed than the prism faces, resulting in nearly tabular crystals, foreshortened along the <u>c</u> - axis.

REFERENCES CITED

Behre, C. H., Jr., 1950, Problems of the genesis of mineral deposits of the southeastern states, in Snyder, F. G., ed., Symposium on mineral resources of the southeastern United States: The University of Tennessee Press, Knoxville, p. 26-41.

Bridge, Josiah, 1955, Disconformity between Lower and Middle Ordovician series at Douglas Lake, Tennessee: Geol. Soc. America Bull., v. 66, p. 725-730.

_______, 1956, Stratigraphy of the Mascot-Jefferson City zinc district, Tennessee: U. S. Geol. Survey Prof. Paper 277, 76 p.

Brokaw, A. L., 1948, Geology and mineralogy of the East Tennessee zinc district, in Dunham, K. G., ed., Symposium on the geology, paragenesis, and reserves of the ores of lead and zinc: 18th Internat. Geol. Cong., London, p. 62-67.

Crawford, Johnson, 1945, Structural and stratigraphic control of zinc deposits in East Tennessee: Econ. Geology, v. 40, p. 408-415.

Currier, L. W., 1935, Structural relations of southern Appalachian zinc deposits: Econ. Geology, v. 30, p. 260-286.

Hoagland, A. D., Hill, W. T., and Fulweiler, R. E., 1965, Genesis of the Ordovician zinc deposits in East Tennessee: Econ. Geology, v. 60 (in press).

Kendall, D. L., 1960, Ore deposits and sedimentary features, Jefferson City mine, Tennessee: Econ. Geology, v. 55, p. 985-1003.

Laurence, R. A., 1945, An early Ordovician sinkhole of volcanic ash and fossiliferous sediments in east Tennessee: Jour. Geology, v. 52, p. 235-249.

_______, 1960, Geologic problems in the Sweetwater barite district, Tennessee: Am. Jour. Science, Bradley Volume, v. 258-A, p. 170-179.

Newman, M. H., 1933, The Mascot-Jefferson City zinc district, Tennessee, in Singewald, J. T., Jr., ed., Mining districts of the eastern states: 16th Internat. Geol. Cong., Guidebook 2, Excursion A-2, p. 152-161.

Oder, C. R. L., 1958, How American Zinc's Tennessee DMEA program proved 35,000,000 tons ore: Mining World, v. 20, p. 50-53.

Oder, C. R. L., and Hook, J. W., 1950, Zinc deposits of the southeastern states, in Snyder, F. G., ed., Symposium on mineral resources of the southeastern United States: The University of Tennessee Press, Knoxville, p. 72-87.

Oder, C. R. L., and Ricketts, J. E., 1961, Geology of the Mascot-Jefferson City zinc district, Tennessee: Tenn. Div. Geol. Rept. Inv. 12, 29 p.

Rodgers, John, 1953, Geologic map of East Tennessee with explanatory text: Tenn. Div. Geology Bull. 58, pt. 2, 168 p.

Ulrich, E. O., 1931, Origin of the stratigraphic horizon of the zinc ores of the Mascot district of east Tennessee (abstr.): Wash. Acad. Sci. Jour., v. 21, p. 30-31.

Wedow, Helmuth, Jr., 1961, Structures underlying prominent Early and Middle Palezoic erosion surfaces in the southern Appalachian Valley (abstr.): Tennessee Acad. Sci. Jour., v. 36, p. 140-141.

Wedow, Helmuth, Jr., and Marie, J. R., 1963, Statistical analysis of solution-collapse structures (abstr.): Geol. Soc. America Spec. Paper 76, p. 262.

______________________________, 1965, Correlation of zinc abundance with stratigraphic thickness variations in the Kingsport Formation, West New Market area, Mascot-Jefferson City mining district, Tennessee: U. S. Geol. Survey Prof. Paper 525-B, p. B17-B22.