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Report of Investigations 5503

APPLICATION OF ELECTRICAL-RESISTIVITY SURVEYS TO EXPLORATION FOR ZINC-LEAD DEPOSITS, RACINE-SPURGEON AREA, NEWTON COUNTY, MO.

By J. W. Chester

United States Department of the Interior — 1959

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by

J. W. Chester[2]

INTRODUCTION

The rapid depletion of zinc-lead ore reserves and the rising costs of exploration have been major factors in the decline of mining activities and explorations for additional reserves in the Tri-State mining district. There is a need to develop new or adopt known, improved exploration techniques that will appreciably lower the costs of exploration. Demonstration of the practicability of using improved techniques to indicate, rapidly and cheaply, mineralized areas or geologic structures where more intensive explorations are justified could stimulate the search for and discovery of additional ore reserves.

Various operators in the Tri-State district have used geophysical surveys to some extent since 1928 to guide exploratory drilling. Some geophysical investigations have also been made in the district by the State Geological Surveys of Kansas (11)[3] and Missouri (8, 13) and by Federal agencies (16), with the objective of directing exploratory drilling to areas where geologic conditions favored ore deposition. Many factual data obtained have not been published. The investigations generally have not been broad enough to permit conclusive evaluation of the usefulness of the geophysical techniques in all parts of the district.

Some parts of the Tri-State district in which ore has been produced in past years have not been adequately or systematically explored and may contain undiscovered ore deposits. Geological evidence has shown that ore deposition is directly related to or was controlled by certain types of geologic structures. If structures favorable for ore deposition are located by a relatively rapid, economic method, the cost of exploring new tracts will be greatly reduced by confining test drilling to areas where ore is most likely to occur and by eliminating areas that do not contain significant concentrations of ore minerals.

1/ Work on manuscript completed January 1959.

2/ Mine examination and exploration engineer, Bureau of Mines, Region IV, Joplin, Mo.

3/ Underlined numbers in parentheses refer to citations in the bibliography at the end of this report.

In advancing this objective, the Bureau of Mines, from December 1953 to July 1957, conducted investigations designed to test the practicability of electrical-resistivity methods for indicating zones of structural deformation favorable to deposition of zinc and lead minerals - logical sites for exploration and development. The area selected for investigation is in western Newton County, Mo., in the southeastern part of the Tri-State district. Racine is in the southwestern part of the site, and Spurgeon is near the northeast corner (fig. 1). The major structural feature in the area is the Seneca fault. The trace runs northeastward through Racine and Spurgeon. There are several small, abandoned zinc-lead mines along the fault.

This report summarizes the results of the research work on exploration in test areas in the northwestern and southwestern parts (figs. 2-5) of the Racine-Spurgeon site. The conclusions are drawn from these results.

SUMMARY

During an investigation of the Racine-Spurgeon area from December 1953 to July 1957, the Bureau of Mines completed 53 miles of reconnaissance electrical-resistivity profiling and 76 test holes aggregating 23,986 feet of churn drilling.

The geophysical survey was made under contract by Sherwin F. Kelly Geophysical Services, Inc. Part of the test drilling was done under contract, and part was accomplished on force account by the Bureau of Mines.

Electrical-resistivity measurements disclosed four large and several smaller low-resistivity anomalies and a few high-resistivity anomalies. Patterns of both high and low readings often vary, but locally the trends are similar for high and low anomalies.

Test drilling shows that most resistivity readings are related to the geology of the area and, in a few places, to the topography. Low-resistivity areas are related to thickness of overburden, very porous limestone and shale, slumped areas that contain clay and broken chert, and occasionally to swampy areas on the surface. High-resistivity readings are usually related to firm, relatively unaltered limestone and chert. The resistivity survey, combined with a study of topographic relationships, indicated favorable areas in which to search for zinc-lead ore deposits.

Test drilling indicated that long, benchlike anomalies between areas of low- and high-resistivity readings, such as the one associated with the Winchester deposit (fig. 4), are probably the most favorable sites for exploration in this part of the district. The pattern of isoresistivity contour on the Milnot property (figs. 2, 3, 5) indicates the presence there of a similar benchlike anomaly. Test drilling disclosed material of ore grade on the Milnot property.

Test drilling near the Ruark deposit on the Snow property (figs. 2, 3, 5) indicated a relationship between a saddlelike anomaly and ore deposition.

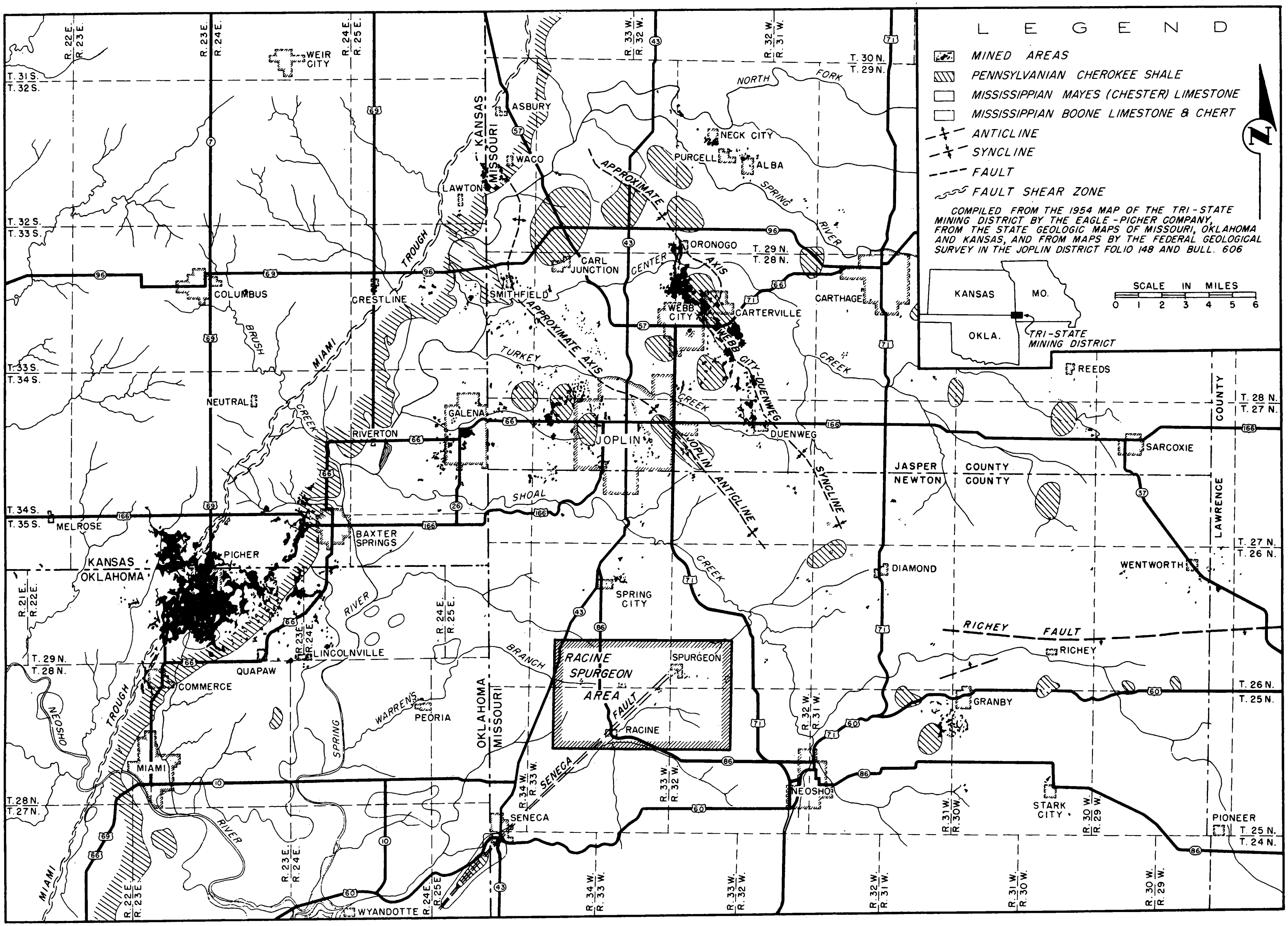

FIGURE 1. - Location Map, Tri-State Zinc-Lead Mining District.

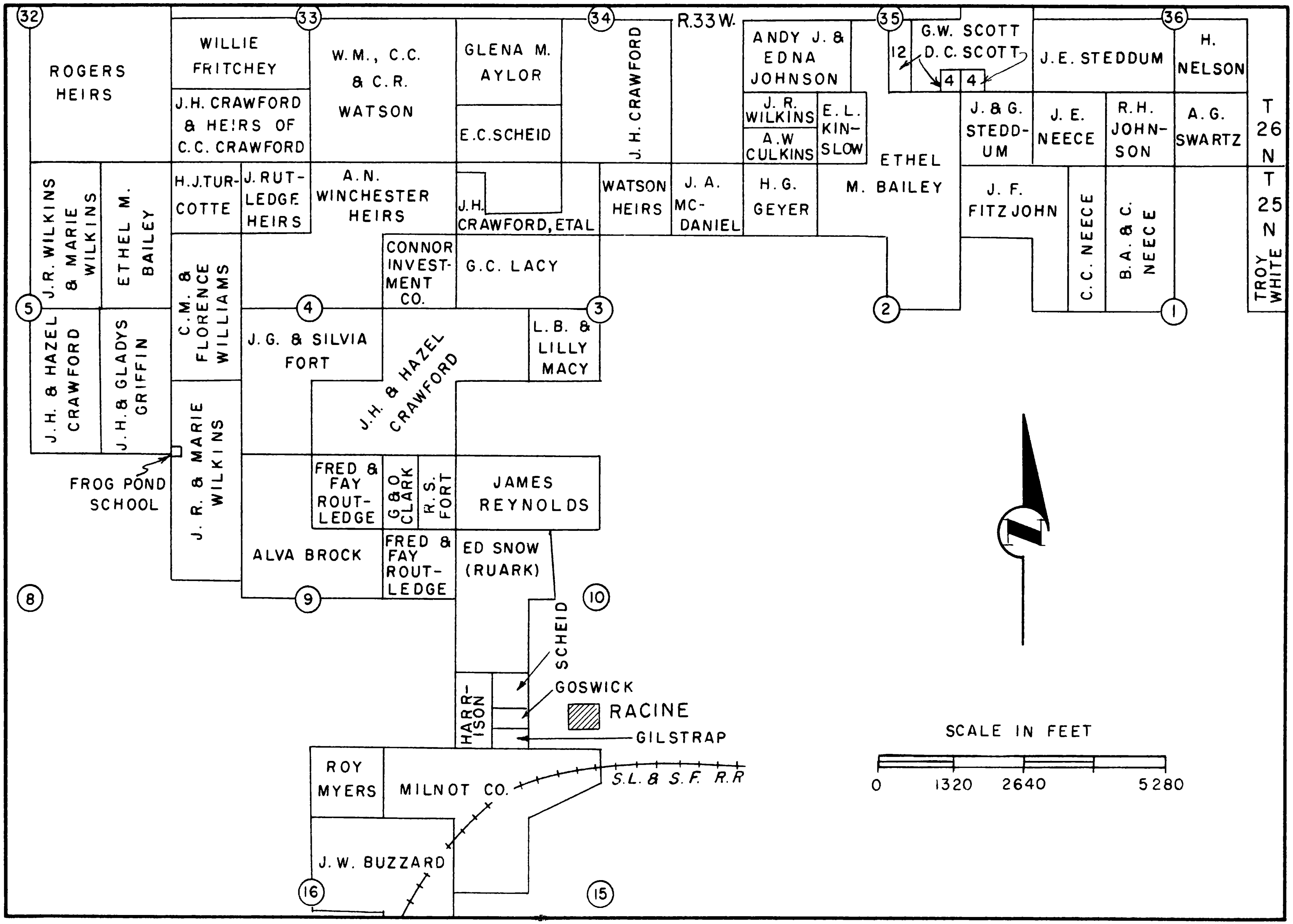

FIGURE 3. - Land Ownership, Part of Racine-Spurgeon Area.

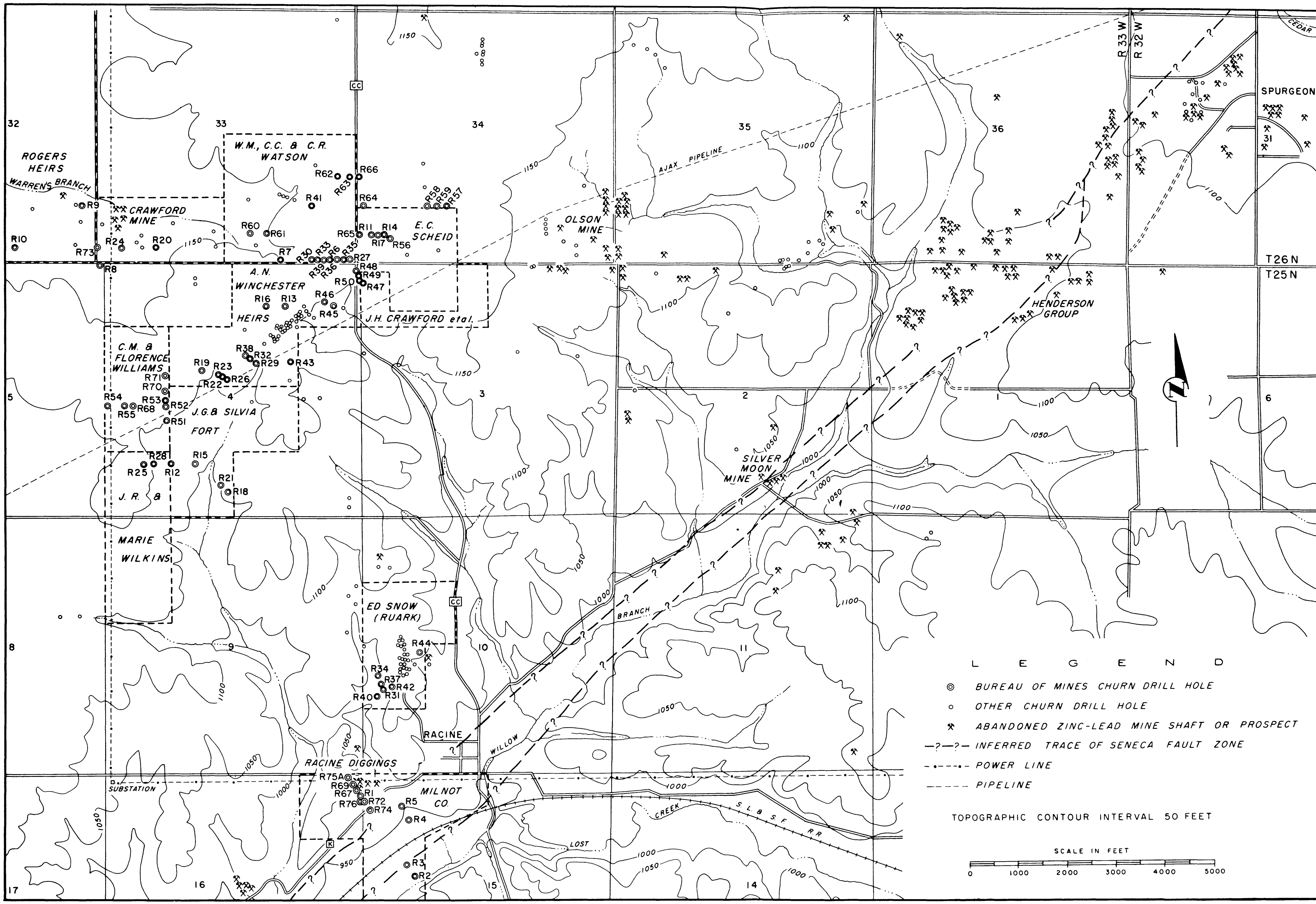

FIGURE 2. - Location of Drillholes and Mine Workings, Racine-Spurgeon Area, Newton County, Mo.

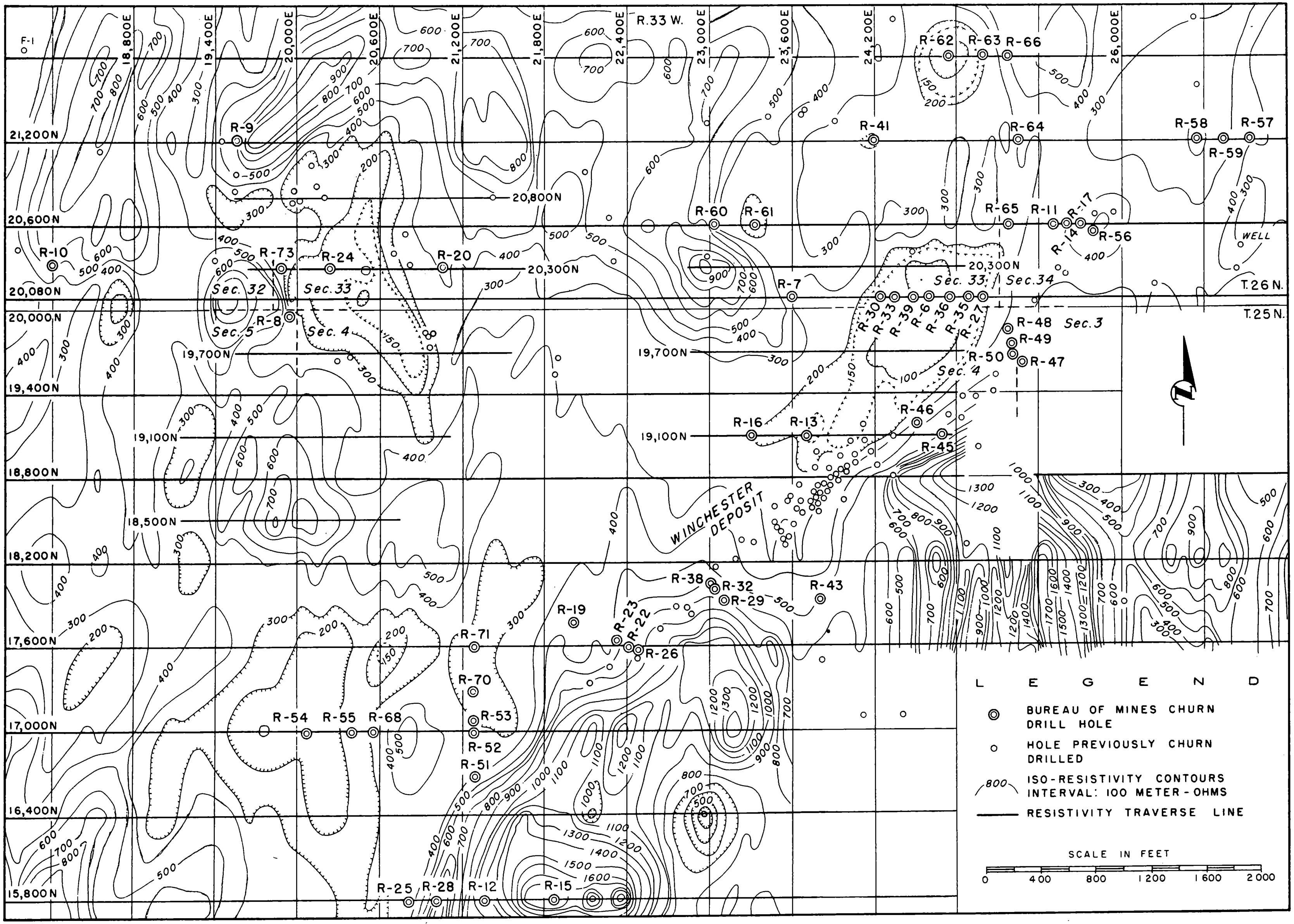

FIGURE 4. - Northwestern Part of Racine-Spurgeon Area.

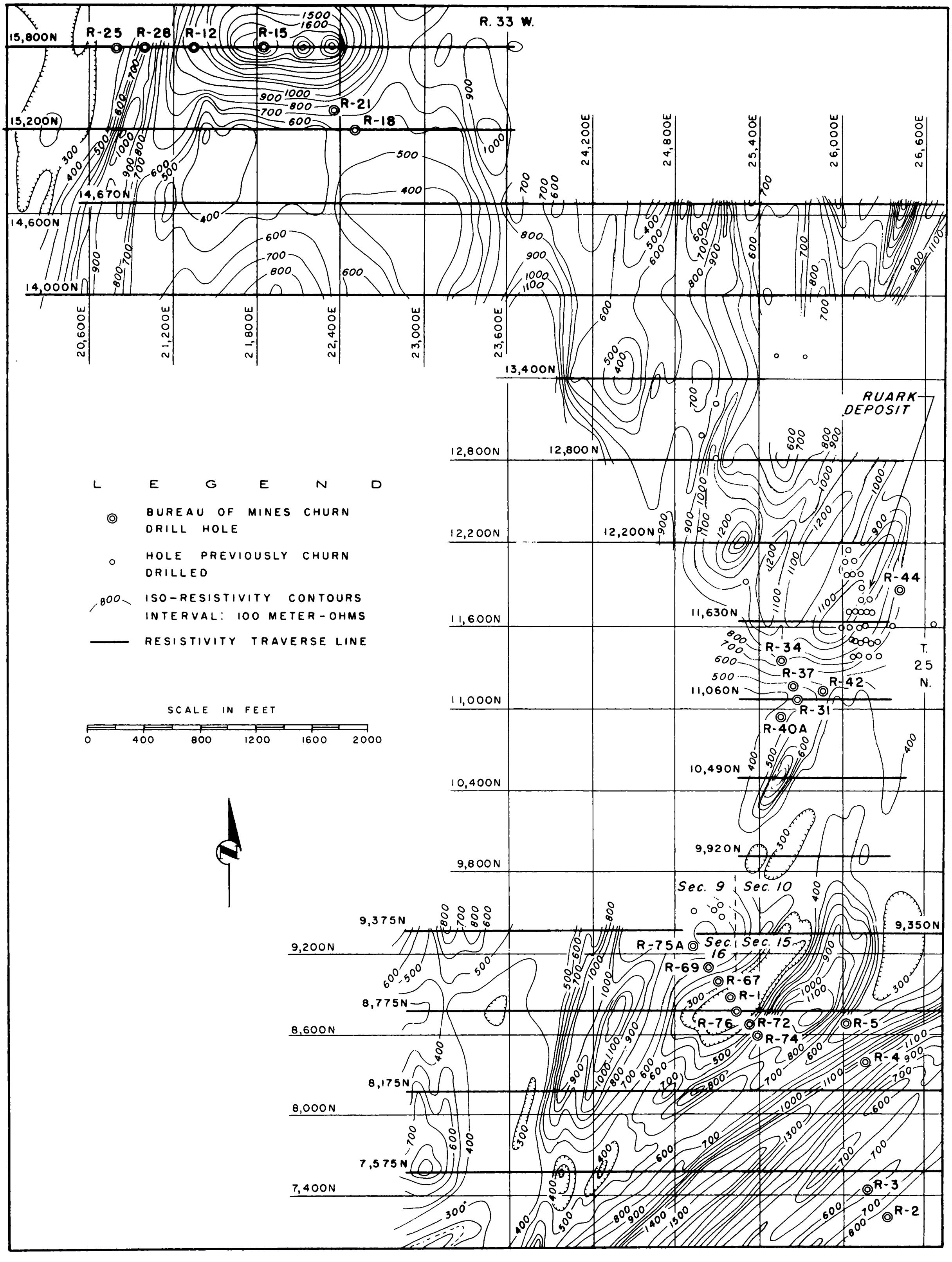

FIGURE 5. - Southwestern Part of Racine-Spurgeon Area.

Locations of sinks or potholes can be determined with relative accuracy by resistivity measurements. Such structures are favorable for exploration.

Results indicate that the electrical-resistivity survey was at least as effective as shale drilling in delineating favorable areas for exploration. Moreover, the geophysical work was done for about one-third the cost of obtaining comparable information by shale drilling.

The holes were drilled primarily to determine the relationship between resistivity anomalies and geologic structure, and not to explore for ore deposits: 23 of the 76 holes intersected minable thicknesses of ore-grade material.

Ore, as used throughout this report, is defined as material with a minimum grade of 1.5 percent of zinc within an interval at least 7.5 feet thick or its equivalent in feet-percent.

ACKNOWLEDGMENTS

The assistance and cooperation are gratefully acknowledged of American Zinc, Lead & Smelting Co., The Eagle-Picher Co., individuals, and landowners in furnishing pertinent drillhole logs, mining and geophysical data, and other information. Special acknowledgment is due the Missouri Geological Survey for the geologic logging of churn-drill cuttings and for their cooperation in making available records for the preliminary examination.

LOCATION, ACCESSIBILITY, AND PHYSICAL FEATURES

The Racine-Spurgeon area encompasses about 18 square miles in Newton County, Mo., and includes Racine in the southwest and Spurgeon in the northeast. Racine is 10 miles south of Joplin and 8 miles west of Neosho. Figure 1 shows the location of the project site and its relation to various mining camps in the Tri-State district.

All-weather graveled roads, mostly on section lines, provide access to nearly all parts of the project area and connect with paved highways leading to Joplin and Neosho. Freight-loading facilities are available at Racine, which is on a main line of the St. Louis-San Francisco Railway. Electric power is available from transmission lines of The Empire District Electric Co. and the Rural Electrification Administration that cross the area.

The project site is mainly rolling prairie land near the western boundary of the Ozark uplift. Altitudes range from approximately 925 feet near Lost Creek, southwest of Racine, to about 1,180 feet on the highest part of the upland prairie. Most of the area is drained by Lost Creek and its tributaries, including Willow Branch. Lost Creek flows southwestward to Grand Lake in Oklahoma. Cedar Creek, a tributary of Shoal Creek, drains the northeastern part; and Warrens Branch, a westward-flowing tributary of Spring River, drains the northwestern area. Figure 2 shows the topography and drainage.

The upland prairie lands have largely been cleared and are used for forage and production of small grain crops. The rest of the area is mainly rocky woodland cut by a few valleys, in which the chief occupation is dairy farming. Several parts of the project site contain groups of abandoned mine shafts, mine dumps, and mill tailing piles.

The moderate climate is suitable for year-round mining operations. The average annual precipitation is about 38 inches. Temperatures normally range from 100° on the hottest days of the summer to nearly 0° F. in the coldest time of the winter; these extremes are usually of short duration.

GEOLOGY AND ORE DEPOSITS

The geology of the Tri-State district, which includes the Racine-Spurgeon area, has been described in publications of the Missouri Geological Survey (2, 3) and the Federal Geological Survey (4-6) and by G. M. Fowler, consulting geologist (9, 10, 12), and others. Figure 1 shows the general distribution of surface rocks and the principal structural features of the Tri-State district.

The Tri-State district lies on the gently sloping northwestern flank of the Ozark uplift and contains an approximate area of 2,000 square miles in southwest Missouri, southeast Kansas, and northeast Oklahoma. Shale, sandstone, limestone, chert, and dolomite of the Pennsylvanian, Mississippian, and Ordovician systems overlie Precambrian granitic rocks. The thickness of the sediments, shown by the logs of the few deep wells that have been drilled in the district, range from 1,045 feet to 1,815. The average dip is 30 feet per mile to the northwest.

In the Oklahoma-Kansas part of the Tri-State district the Pennsylvanian Cherokee formation covers most of the surface in the productive area and lies unconformably on the Mississippian Chester formation where the Chester is present. In the Missouri part of the district, the Cherokee and Chester formations have been mostly removed by erosion. Only a few outliers and remnants survive. The surface formation is largely the Mississippian Boone, which has been eroded as deep as the OPQ beds in some places.

For closer stratigraphic correlation the Boone formation was subdivided by Fowler and Lyden (9) into 16 separate beds to the top of the Fern Glen. These beds are designated B through R, with I omitted. Except for an abnormally thick M bed, the stratigraphic section in the Racine-Spurgeon area (table 1) is comparable with that in the rest of the Tri-State district.

Most of the ore produced in the district has been mined from the Boone formation. In a few places the Chester and Cherokee formations have also been productive. Throughout the district, the GH, K, M, and OPQ beds have been the most productive. Where conditions are favorable, all beds of the Boone formation may contain ore.

TABLE 1. - General geologic section - Racine-Spurgeon area, (compiled from Bureau of Mines drillhole logs)

System	Formation	Rock character	Thickness, feet
Recent	Alluvium and residuum	Soil, clay, and gravel; chert, limestone and sandstone boulders	0 - 70
Pennsylvanian	Cherokee	Shale and a little sandstone	0 - 70
Mississippian	Chester	Limestone; a few sandstone and shale lenses	0 - 140
	Boone — Warsaw - B, C, D, E, F, G, H, and J beds	Limestone and chert	0 - 100
	Boone — Burlington — Upper — Keokuk — K and L beds	Chert and limestone	0 - 32
	Boone — Burlington — Upper — Keokuk — M bed: Short Creek oolite	Oolitic limestone Limestone and chert	0 - 12 0 - 134
	Boone — Burlington — Upper — Grand Falls N, O, P, and Q beds	Chert and a little limestone	0 - 110
	Boone — Burlington — Lower — Reeds Springs R bed	Limestone and chert	25 - 140
	Boone — Fern Glen	Shaly limestone, dolomite	9 - 84
	Northview	Shale	0 - 23
	Compton	Limestone	0 - 15
Ordovician	Cotter (Jefferson City)	Dolomitic limestone	-

The ore is further localized within the Boone formation in the more pervious zones usually associated with structural features. Two major structural features can be observed in the district. The first of these (and probably the oldest) is a series of northwestward-trending, gentle folds, which include the Bendelari trough, the Joplin anticline, and the Webb City-Duenweg syncline. This system was later cut by a series of northeastward-trending faults; the best known examples are the Miami trough and the Seneca fault. The Seneca fault is the major structural feature in the Racine-Spurgeon area.

The fractures and joints associated with these major structural features and parallel to them have apparently increased the permeability of the rock; the fractures and joints allowed more circulation of ground waters and solutions and have provided conditions that favored deposition of ore.

Sphalerite and galena are the principal ore minerals in the Tri-State district. A large part of the production from the Racine-Spurgeon area and other mining camps in Newton County, Mo., was made up of the oxidized lead and zinc minerals calamine, smithsonite, cerussite, and pyromorphite. Chert, limestone, jasperoid, dolomite, shale, and calcite are the principal gangue minerals.

There is no general agreement among geologists regarding the origin of the ore deposits. Various authors have ascribed the origin to ascending hot solutions, to descending ground water, and to artesian circulation. Regardless of origin, the deposits do bear some relation to the structural features of the district - a fact that can be used as a guide in exploration.

HISTORY AND PRODUCTION

Information on early mining activities in the Racine-Spurgeon area is meager, and records of ore production are incomplete. It was common practice in some years to lump production from several adjacent areas and report the data by subdistricts; records of individual mines therefore were not preserved.

The first significant production of lead ore in the district was from the Mosely mine, 3 miles east of Spurgeon, in the early 1850's. Although zinc occurs with the lead in nearly all mines of the district, production of zinc ore was not economically feasible until after 1870, when completion of a railroad through southwest Missouri provided transportation to zinc smelters in Illinois. The Mosely mine was one of the earliest producers of zinc ore and was worked sporadically for over 100 years.

Following discovery of ore at the Mosely mine, other mines were developed near Spurgeon and along the Seneca fault to the southwest. Much of the recorded production came from mines near Spurgeon, but other contributors were the Olson mine, about 2 miles west of Spurgeon; the Crawford mine, about 4 miles west; the Silver Moon mine and Racine Diggings, southwest of Spurgeon; the Gallimore and Potwin-Holmes mines near Seneca; and the Canyon Diggings, 2 miles east of Spurgeon (figs. 1 and 2). The most recent recorded production from the Racine-Spurgeon area was in 1952, when about 100 tons of ore from the Olson mine was hauled to a small custom mill near Joplin for treatment.

In the early days ore was usually upgraded by hand cobbing, sorting, and hand jigging. Later, when methods were developed for concentrating the lower grade ores, small milling plants were built at several mines in the area, as well as in other parts of the district.

Few maps or other pertinent data showing the extent of mine workings are available. Many mine dumps and mill-tailing piles have been removed or leveled; however, available evidence indicates that the productive mines of the Racine-Spurgeon area were small and shallow and operated intermittently.

Table 2 shows the recorded outputs of zinc and lead ores from 1850 to 1893 and concentrates from 1905 to 1950, inclusive.

TABLE 2. - Zinc-lead ore production, Racine-Spurgeon-Seneca area, Newton County, Mo. (1, 2, 7)

Year	Zinc ore (tons)	Lead ore (tons)
1850-54	-	281
1886	1,500	25
1891	171	603
1892	200	45
1893	2,000	100
Total	3,871	1,054

Year	Zinc concentrate (tons)		Lead concentrate (tons)	
	Sulfide 1/	Carbonate and silicate 2/	Sulfide 3/	Carbonate 4/
1905	608	-	-	-
1907	1,939	514	608	-
1908	1,993	959	606	161
1909	1,706	953	658	94
1910	224	589	757	40
1911	80	400	868	106
1912	593	33	580	69
1913	1,671	1	146	-
1914	1,223	7	144	-
1915	1,291	2	78	3
1916	2,240	311	240	-
1917	2,702	419	138	5
1918	957	105	95	-
1919	650	-	304	-
1926	-	-	21	-
1937	120	-	31	-
1939	203	-	14	-
1940	950	-	116	-
1947	-	25	62	51
1948	120	-	34	-
1949	61	2	68	10
1950	22	-	6	-
Total	19,351	4,320	5,574	539

1/ Assumed average, about 60 percent metal.
2/ Assumed average, about 40 percent metal.
3/ Assumed average, about 80 percent metal.
4/ Assumed average, about 60 percent metal.

PREVIOUS EXPLORATORY CHURN DRILLING

Various companies and individuals have explored parts of the project area intermittently since 1919. In 1919-20 American Zinc, Lead & Smelting Co. drilled 17 holes aggregating 5,705 feet of bore on the Winchester property in sec. 4, T. 25 N., R. 33 W. In 1924 A. N. Winchester drilled six holes aggregating approximately 2,430 feet of bore on the property. In 1937 and 1942 St. Louis Smelting & Refining Co. drilled an additional nine holes aggregating 3,191 feet (14). Figure 6 shows the locations of the holes. Table 1 of the Appendix summarizes pertinent data on the holes, many of which penetrated zinc ores.

In 1926, Grasselli Chemical Co. drilled 31 holes aggregating 5,179 feet of bore on the Snow Property (Ruark) in sec. 10, T. 25 N., R. 33 W. Minable thicknesses of zinc-lead sulfide ore were penetrated in eight of the holes. Figure 7 shows the locations of the holes. Table 2 of the Appendix summarizes pertinent data on these holes.

Available data on other recorded exploratory churn drilling in the project area during the period 1919-42, covering approximately 17,470 feet of bore in 59 holes, are summarized in table 3 of the Appendix.

In 1945-46 the Bureau of Mines drilled 17 holes aggregating 6,353 feet of bore on the Winchester property (14) to delineate more fully a zinc deposit indicated by previous private drilling. Twelve of these holes penetrated zinc ore. Table 4 of the Appendix gives pertinent data abstracted from the logs of these holes.

BUREAU OF MINES EXPLORATION RESEARCH

The Racine-Spurgeon area was selected as a suitable site for exploration research because it appeared to be representative of the southeastern part of the Tri-State district. Geologic structure and stratigraphic conditions were considered to favor zinc-ore deposition, and much of the area had not been explored. Considerable information on ore occurrences and related geologic features was available from records of exploratory drilling. This information facilitated correlation of geophysical data with geologic data disclosed by drilling.

The various methods of exploration that have been used during the past 100 years in the search for zinc and lead ores in the Tri-State district have been studied. These procedures, which ranged from "hunch" drilling to some of the latest geophysical methods, have had varying degrees of success.

Many of the ore finds in the district are credited to accidental discovery in the course of drilling water wells. Some early prospectors became quite proficient in inferring the subsurface structure from the limited topographic features. Direct observation and correlation are precluded by the thick mantle of alluvium and residuum.

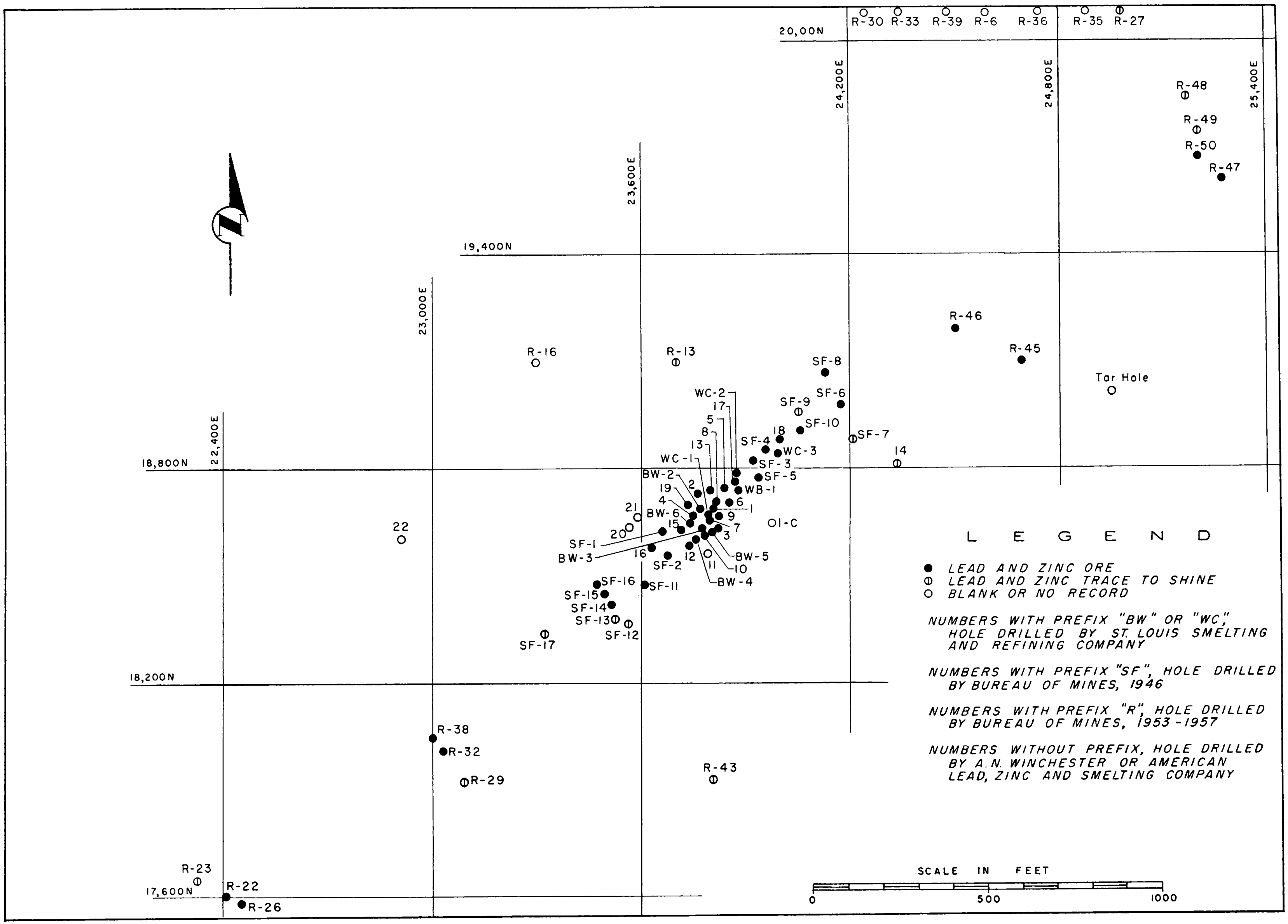

FIGURE 6. - Detail of Hole Locations, Winchester Deposit.

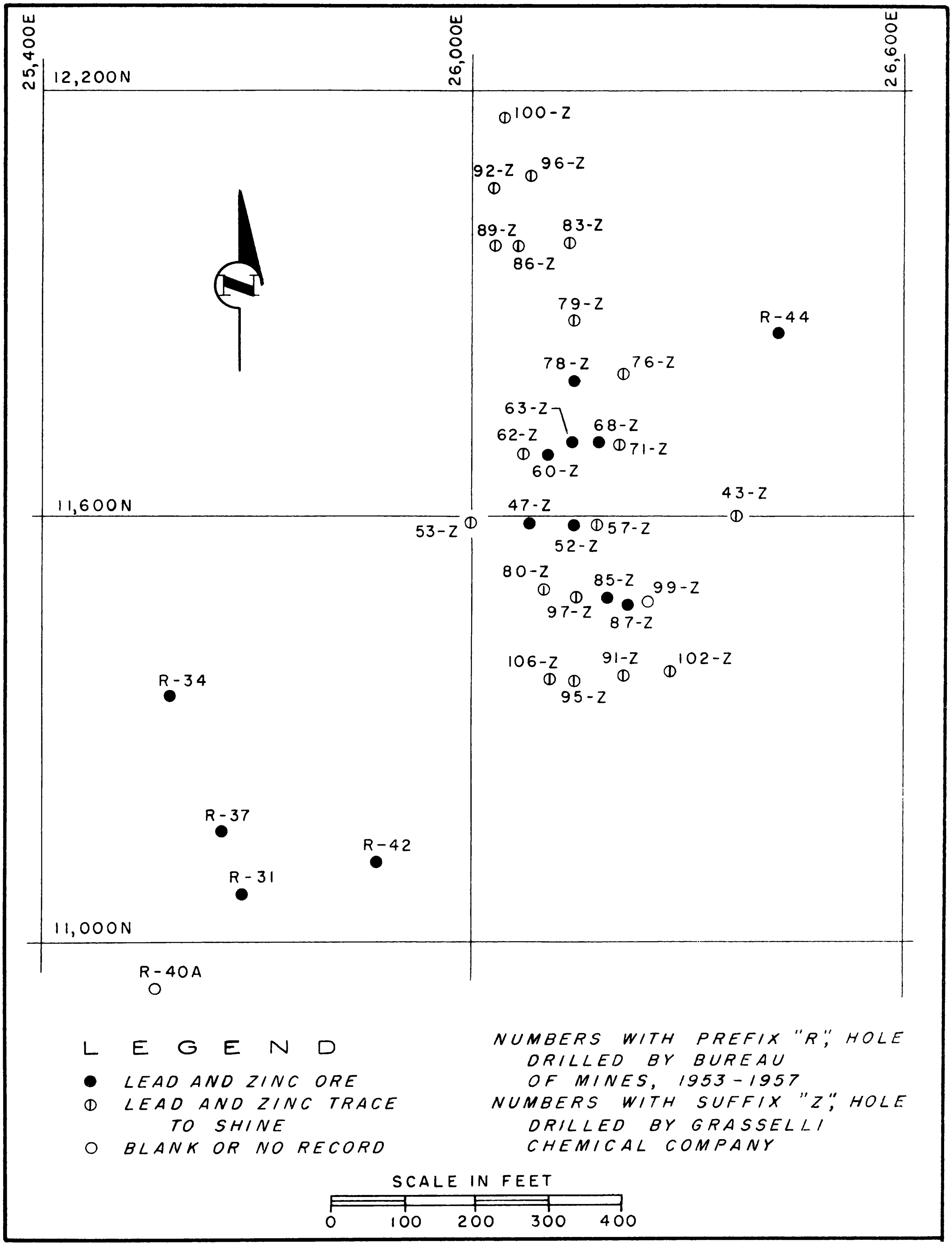

FIGURE 7. - Detail of Hole Locations, Ruark Deposit.

Several operators used a system of "shale drilling" to evaluate large tracts of land. This consisted of a pattern of holes drilled through the overburden and shale into the underlying "hard" formations. A contour map was then constructed on the "hard." This was not a true structural contour on the top of the Boone formation, as no allowance was made for erosion of some of the upper beds of the Boone. It was accurate enough to show erosion channels and other structural features masked by overburden.

In recent years several of the various geophysical methods have been used. The electrical-resistivity techniques employed by the Bureau of Mines in the course of this project differ little from those used by private operators in the district. Emphasis was placed on correlation with surface and subsurface features, the search for new interpretations of anomalies, and an overall evaluation of the effectiveness of the method. It was felt that results surpassing those by "shale drilling" could be obtained at much reduced cost.

Electrical-resistivity surveys covered about 4 square miles. These surveys were conducted by Sherwin F. Kelly Geophysical Services, Inc., under two separate contracts completed in December 1953 and May 1954. Resistivity measurements were taken along parallel lines, usually spaced 600 feet apart. Survey lines were oriented west to east, except in the northeastern part of the area, where they were oriented normal to the inferred trace of the Seneca fault. Electrodes were spaced for a theoretical depth penetration of 100 feet. In a few places, where more detailed resistivity data were desired to define certain anomalies, measurements were taken along parallel traverse lines 300 feet apart. One area was tested by taking resistivity measurements with electrodes spaced for a theoretical 300-foot depth penetration. One line was surveyed with 100-, 200-, and 300-foot depth penetrations. In addition, several depth determinations were made. The contractor prepared isoresistivity contour maps and furnished interpretative data for use in locating test drillholes and for correlating geologic features.

The combined traverse length covered by resistivity measurements was 53 miles. In preparation for the geophysical surveys, 56 miles of base and grid traverses was brushed and staked; a base map of the area was prepared showing pertinent topographic, geologic features, development, and mine openings. Test drilling totaled 23,986 feet in 76 holes; 8,312 feet in 28 holes was drilled under contract; and 15,674 feet in 48 holes was drilled by the Bureau of Mines on force account. Table 5 of the Appendix shows pertinent data abstracted from the logs of these drillholes.

All drilling was done with churn drills, using standard drilling techniques. Samples of cuttings were taken at 5-foot intervals in barren ground and at 2-1/2-foot intervals in mineralized zones. The samples were taken with a "flapper-valve" bailer. This type of bailer was used instead of the "dart-valve" bailer, because it was considered superior in its ability to clean the hole, and so minimized salting or contamination of cuttings.

Samples from mineralized zones were reduced in bulk with a Jones-type riffle sampler. After drying, the samples were taken to a commercial laboratory for chemical analyses. Bulk samples, representative of each interval of each hole, were bagged and stored for reference until the project was completed.

Accurate cost records were kept on all phases of the project. Comparison of the actual cost of the electrical-resistivity survey with an estimated cost of shale drilling shows a decided advantage in favor of the electrical-resistivity method. Computations indicate that shale drilling on the standard pattern of 16 holes per 40-acre tract would have cost about three times as much as the electrical-resistivity survey in the Racine-Spurgeon area.

The project was under the immediate supervision of Clinton C. Knox, Bureau mining engineer, from its inception until April 1957. The research work was then supervised by the author. Logging of drillholes and all surveying were conducted by J. L. Woolsey, engineering technician, of the Bureau of Mines.

CORRELATION OF GEOPHYSICAL AND TEST-DRILLING DATA

Isoresistivity contours form many and various patterns in the project area. The more pronounced anomalies are: (1) Long, benchlike anomalies, (2) domelike highs, (3) large lows, (4) small pothole lows, (5) noselike highs intruding lows, and (6) saddlelike anomalies between areas of high-resistivity readings. Representative anomalies of each type were tested by drilling to determine their relationship to lithologic conditions, structure, and favorability for ore deposition. The results of these tests are summarized below.

Milnot Property (Figs. 2, 3, 5, 8)

An elongated area of high resistivity, with readings up to 1,500 meter-ohms, crosses the Milnot property in a northeast direction. A smaller area of low resistivity, with readings down to 100 meter-ohms, lies on the northwest flank of this long high (fig. 5). This pattern of anomalies was interpreted to be the resistivity expression of the Seneca fault.

The first test hole drilled in the project area was near the center of the low-resistivity area, near a group of shallow shafts and prospect pits. This hole, R-1, penetrated a thick section of Chester limestone, which apparently had dropped below its normal position owing to solution action, faulting, or both. The only indications of ore minerals here were faint traces of sphalerite in the depth interval of 390- to 415 feet.

Holes R-2, R-3, R-4, and R-5 were drilled primarily to obtain a stratigraphic cross section of Lost Creek Valley. This valley is believed to be the topographic expression of the Seneca fault. These widely spaced holes did not establish the location of the fault or its relationship to the dropped block disclosed by hole R-1.

In order to obtain more information relative to the dropped block and test a benchlike anomaly between the areas of high- and low-resistivity readings, holes R-67, R-69, R-72, R-74, R-75A, and R-76 were drilled in a line on either side of hole R-1 (figs. 5 and 8). These holes disclosed that all the beds, including those of the Cotter formation, were displaced downward. The thinning of R bed and the probable absence of Fern Glen and Northview beds indicate some dissolution, but displacement of the Cotter formation by as much as 120 feet is strong evidence of faulting. Considerable solution activity in the beds penetrated by the eight drillholes was indicated by the highly altered condition of the rock and by the many openings encountered.

Concentrations of zinc minerals of ore grade were found in holes R-67, R-72, and R-74. The ore encountered in R-67 is largely oxidized and therefore is not now of economic value, whereas sulfides predominate in holes R-72 and R-74. The latter two holes were drilled on the edge of a benchlike anomaly that resembles the one on the Winchester property. This similarity suggests that the anomaly on the Milnot property might be a favorable area for further explorations.

The structural profile determined by holes R-75A, R-69, R-67, R-1, R-76, R-72, and R-74 matches very closely the resistivity profile (fig. 8), thus correlation in this area is excellent.

Snow Property (Ruark) (Figs. 2, 3, 5, and 9)

Isoresistivity contours indicated that the previously discovered Ruark ore deposit might be associated with a domelike anomaly of high-resistivity readings and that a fracture zone existed between this high and a smaller domelike anomaly to the southwest (fig. 5). Holes R-31, R-34, R-37, R-40A, and R-42 were drilled to test the saddlelike anomaly between the two highs, and R-44 was drilled on the east flank of the Ruark high. All these holes, except R-40A, penetrated ore sections. Most of the zinc was in nonsulfide form. The presence of oxidized zinc minerals and open, altered strata tends to confirm the inference of a fracture zone roughly parallel to the Seneca fault.

The resistivity profile of the section through holes R-40A, R-31, 80, 52, 57, and R-44 (fig. 9) bears a general resemblance to the profile of the top of the M-bed. The correlation here was not as good as that in the section on the Milnot property. Extension of the resistivity survey farther to the east and west might change the overall pattern of anomalies and permit broader correlation.

Williams Property (figs. 2-4, 10, 11)

Holes R-54, R-55, and R-68 were drilled to test a large area of low resistivity wherein readings ranged from 100 to 300 meter-ohms. The low resistivity here was tentatively interpreted as indicating a slump in the strata, but test drilling did not substantiate this (fig. 10). A slight dip of strata into the low is indicated, but the pattern of resistivity here is apparently related to the difference in alteration of the rock rather than to structure.

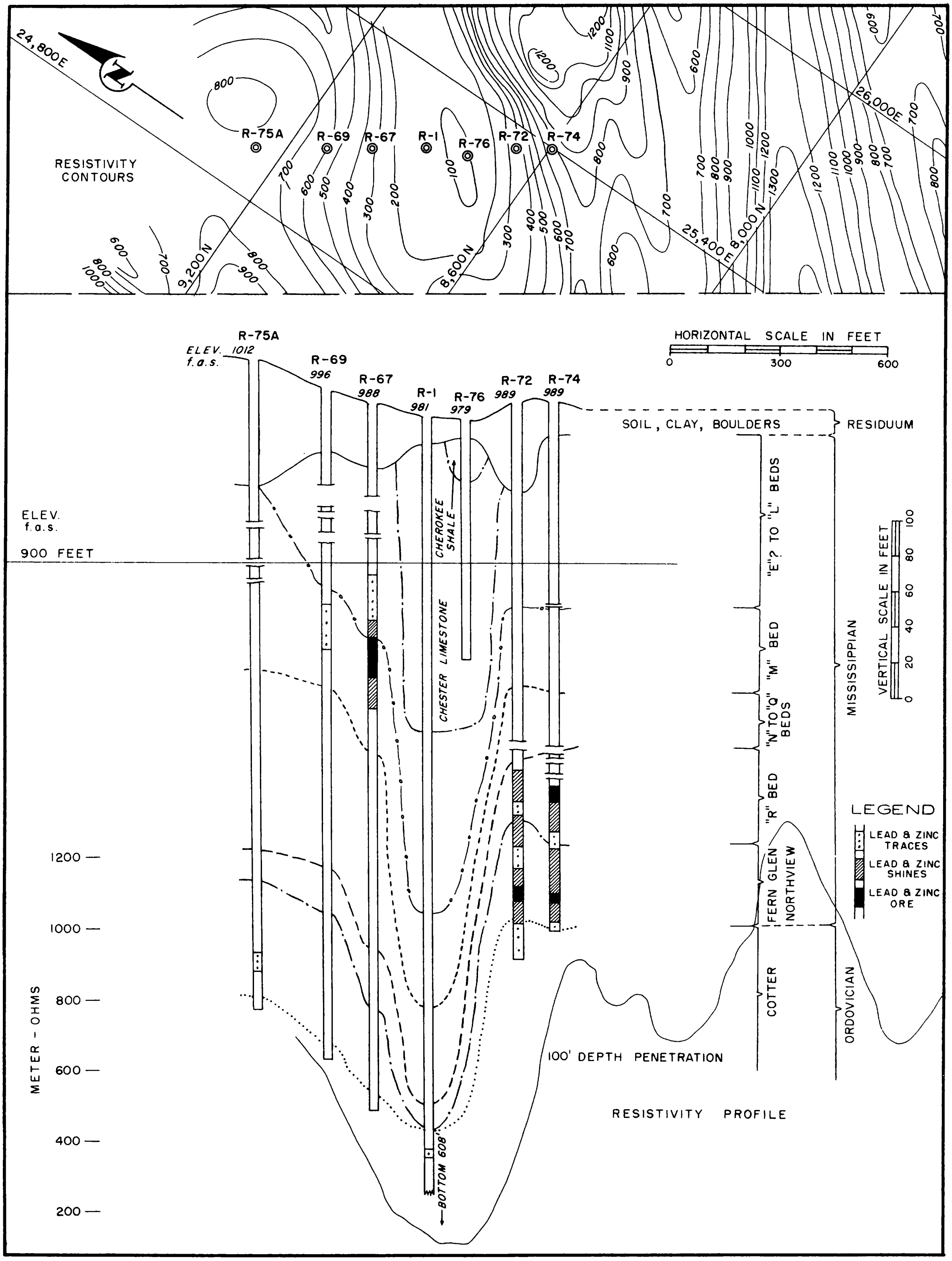

FIGURE 8. - Plan and Vertical Cross Section Through Drillholes R-75A–R-74, Milnot Tract.

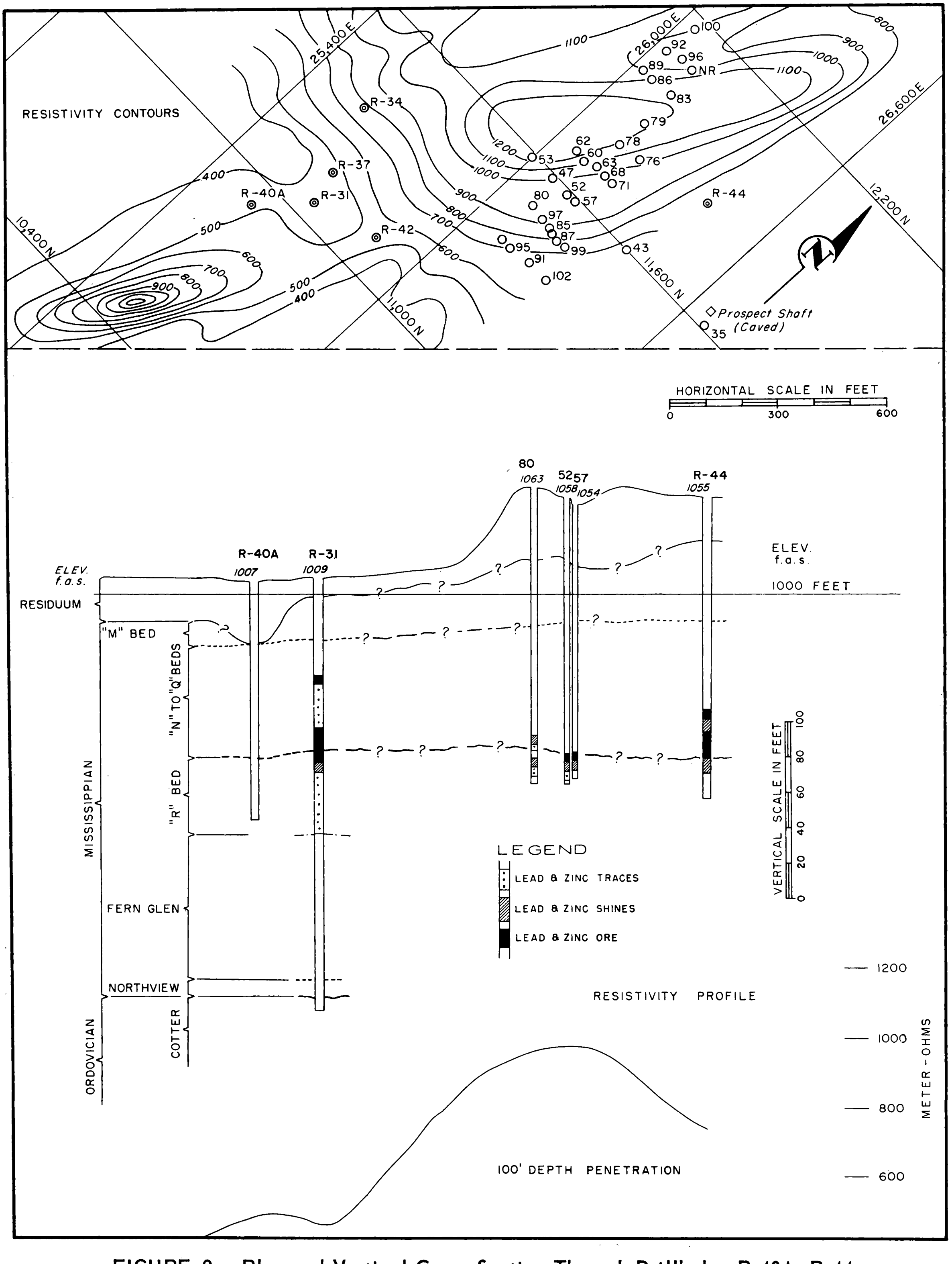

FIGURE 9. - Plan and Vertical Cross Section Through Drillholes R-40A–R-44, Snow Tract (Ruark).

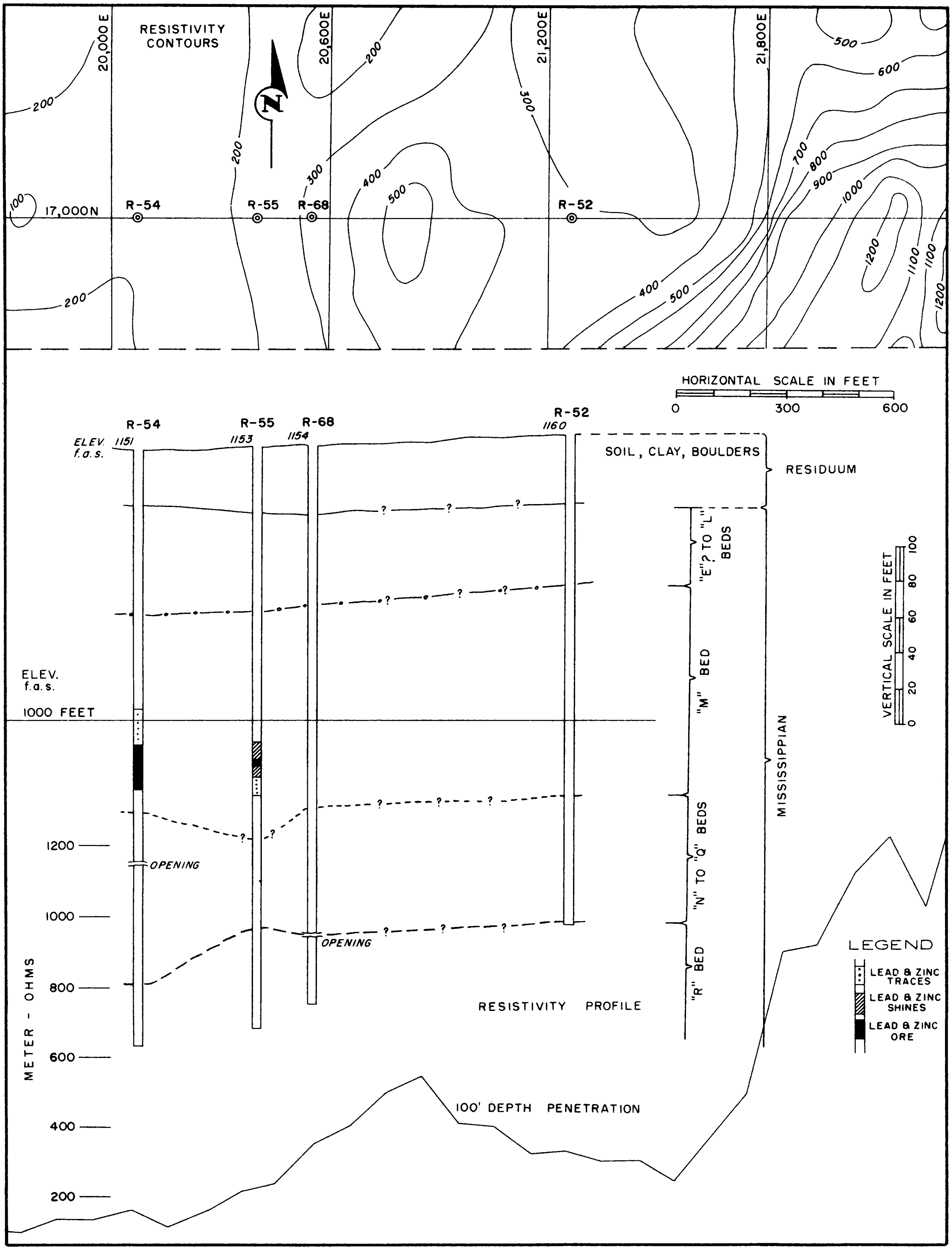

FIGURE 10. - Plan and Vertical Cross Section Through Drillholes R-54–R-52, Williams Tract.

During the interval of 165 to 190 feet below the surface, hole R-54 penetrated highly altered beds of oxidized zinc ore. Hole R-55 penetrated somewhat less altered beds and a section of oxidized zinc ore from 172 to 180 feet. The beds in R-68 were only slightly altered and showed no trace of zinc minerals.

Holes R-51, R-52, and R-53 were drilled to test another low-resistivity area and the indicated southwest extension of the benchlike anomaly associated with the Winchester ore deposit. The rock strata penetrated in these holes were firm and relatively unaltered - a condition considerably different from that which had been expected. The structural configuration here bears no apparent relationship to the resistivity pattern (fig. 11). Holes R-70 and R-71 were drilled in the area of lowest resistivity, northward along this line of holes (fig. 4), in an attempt to determine the reason for the lack of correlation. These holes also penetrated firm, relatively unaltered strata. The surface here is flat, poorly drained, and swampy, so the resistivity readings probably reflect the swampy surface residuum rather than subsurface conditions.

Crawford Mine Property and Bailey Property (figs. 2-4, 12)

A large area of low resistivity (200-300 meter-ohms) in secs. 4, 5, 32, and 33 (fig. 2) and the presence of Cherokee shale on mine dumps indicated the existence of a sink structure. This interpretation was confirmed by test holes R-8, R-20, R-24, and R-73. Comparison of the resistivity profile with the cross section through holes R-20, R-24, and R-73 (fig. 12) shows good correlation between resistivity and structure.

Hole R-8 showed traces of oxidized zinc minerals and galena from 210 to 240 feet in depth; R-20 showed traces of sphalerite in several intervals; R-24 penetrated a mineralized zone from 250 to 255 feet in depth containing 1.47 percent of zinc; and R-73 penetrated several mineralized zones including one from 195- to 235 feet in depth with an average zinc content of 2.24 percent, mostly in nonsulfide form.

Fort-Wilkins Properties (Figs. 2-5, 13, 14)

Holes R-12, R-15, R-18, R-21, R-25, and R-28 were drilled to test a domelike anomaly of high resistivity, with readings ranging from 400 to 2,100 meter-ohms (figs. 4 and 5). The cross section through holes R-15, R-12, R-28, and R-25 shows only a vague relationship between structure on the top of M bed and the resistivity profile (fig. 13). The most significant disclosure is that the domelike pattern of resistivity here was not the reflection of a structural dome, as might have been inferred. All holes penetrated predominantly firm and relatively unaltered beds, and only R-25 encountered an appreciable thickness of soft material.

The soil cover at hole R-25 is much thicker than at R-15, and the ground near R-15 is very rocky. These conditions probably influenced the resistivity readings to as great or greater degree than did the structure. The section through R-15, R-18, and R-21 (fig. 14) further supports this conclusion. The soil cover at R-18 is about the same as the cover at R-25.

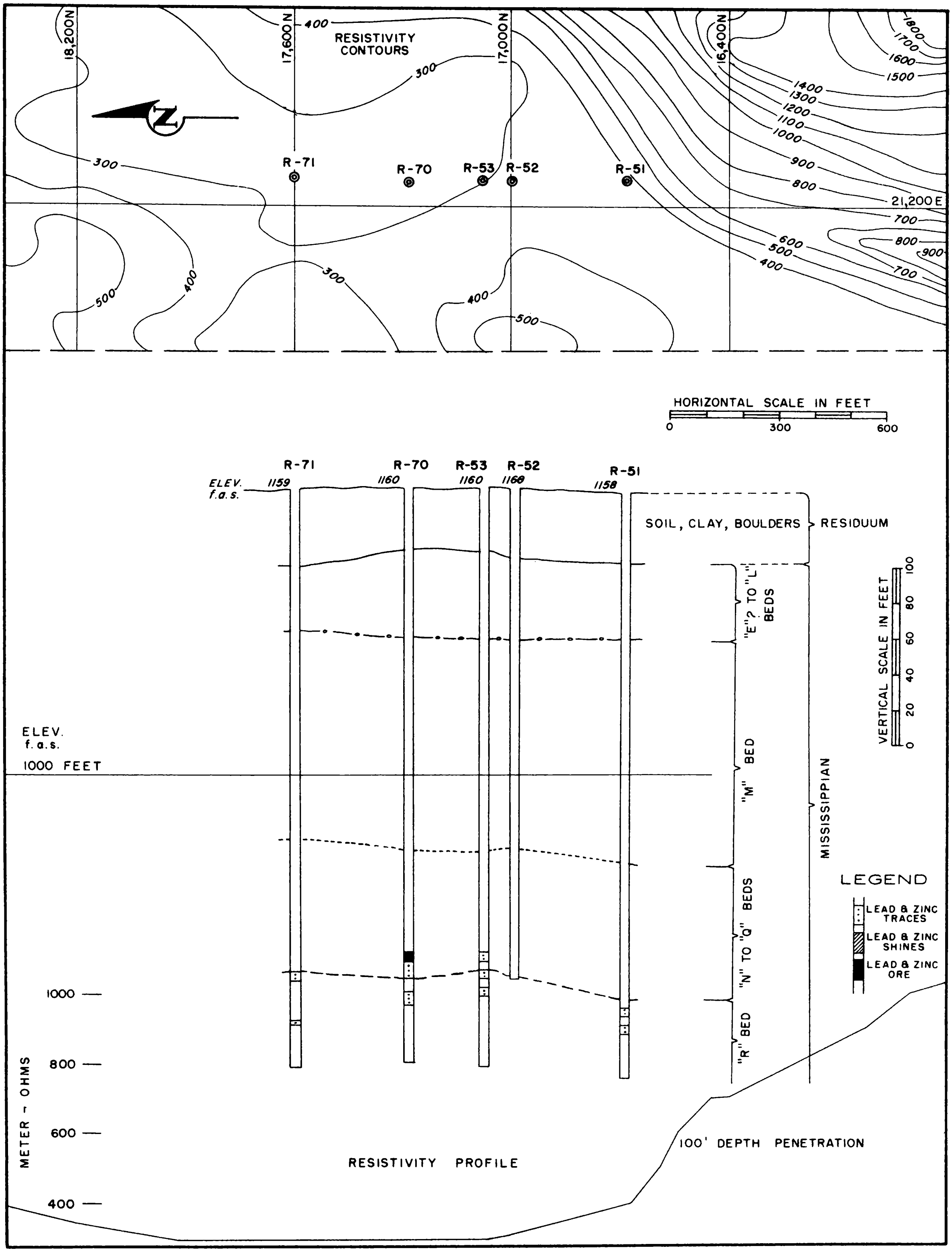

FIGURE 11. - Plan and Vertical Cross Section Through Drillholes R-71–R-51, Williams Tract.

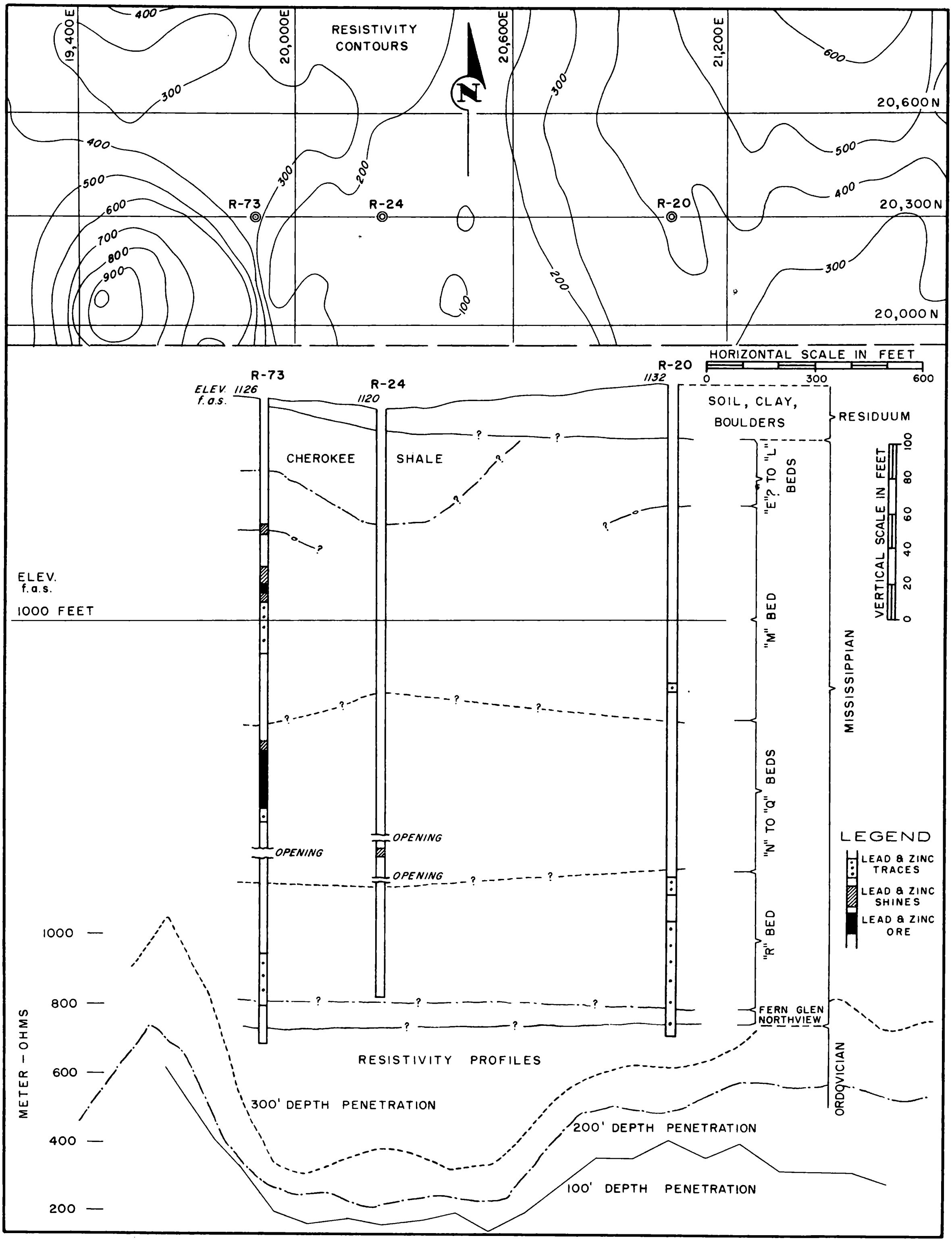

FIGURE 12. - Plan and Vertical Cross Section Through Drillholes R-73–R-20, Crawford Tract.

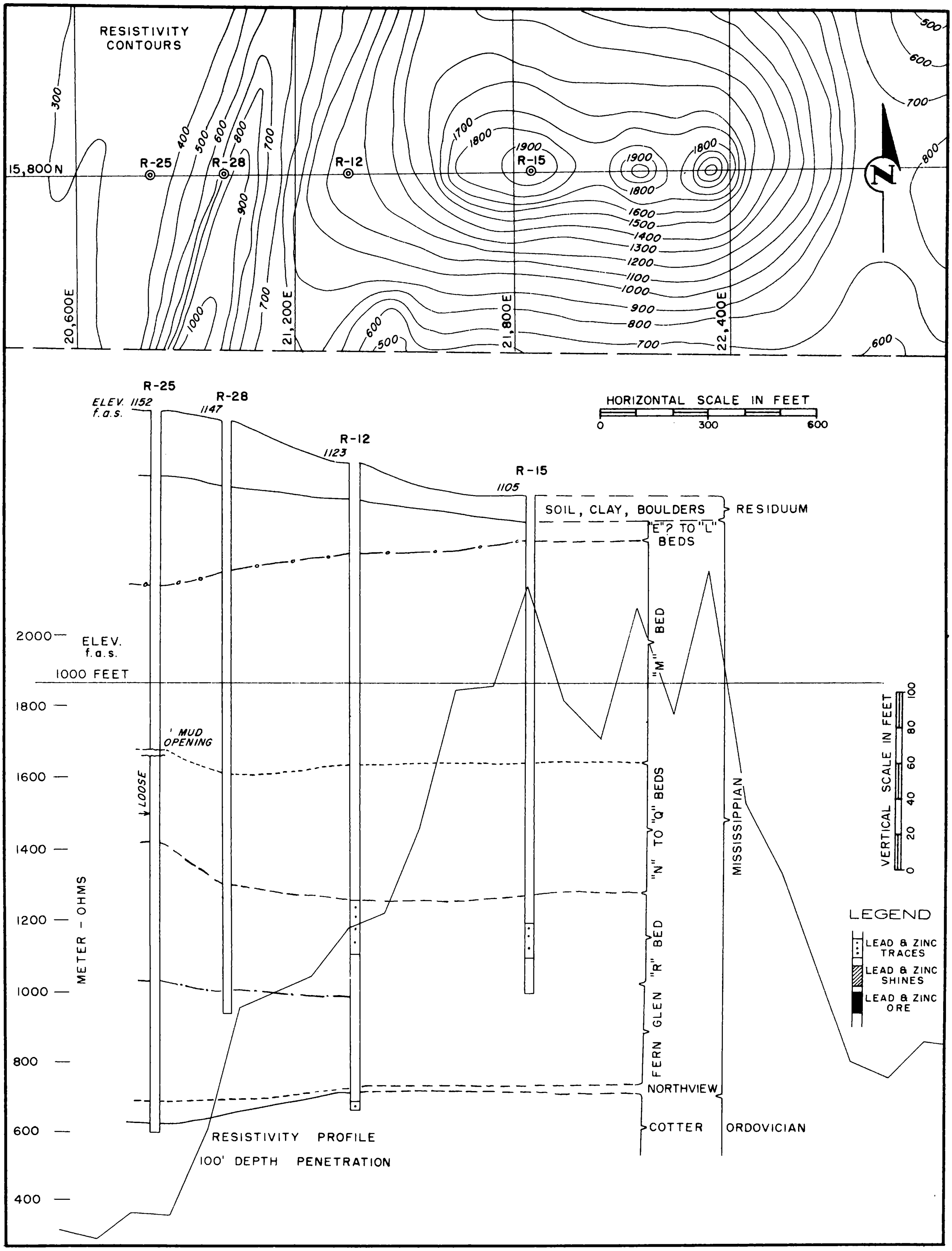

FIGURE 13. - Plan and Vertical Cross Section Through Drillholes R-25–R-15, Fort-Wilkins Tracts.

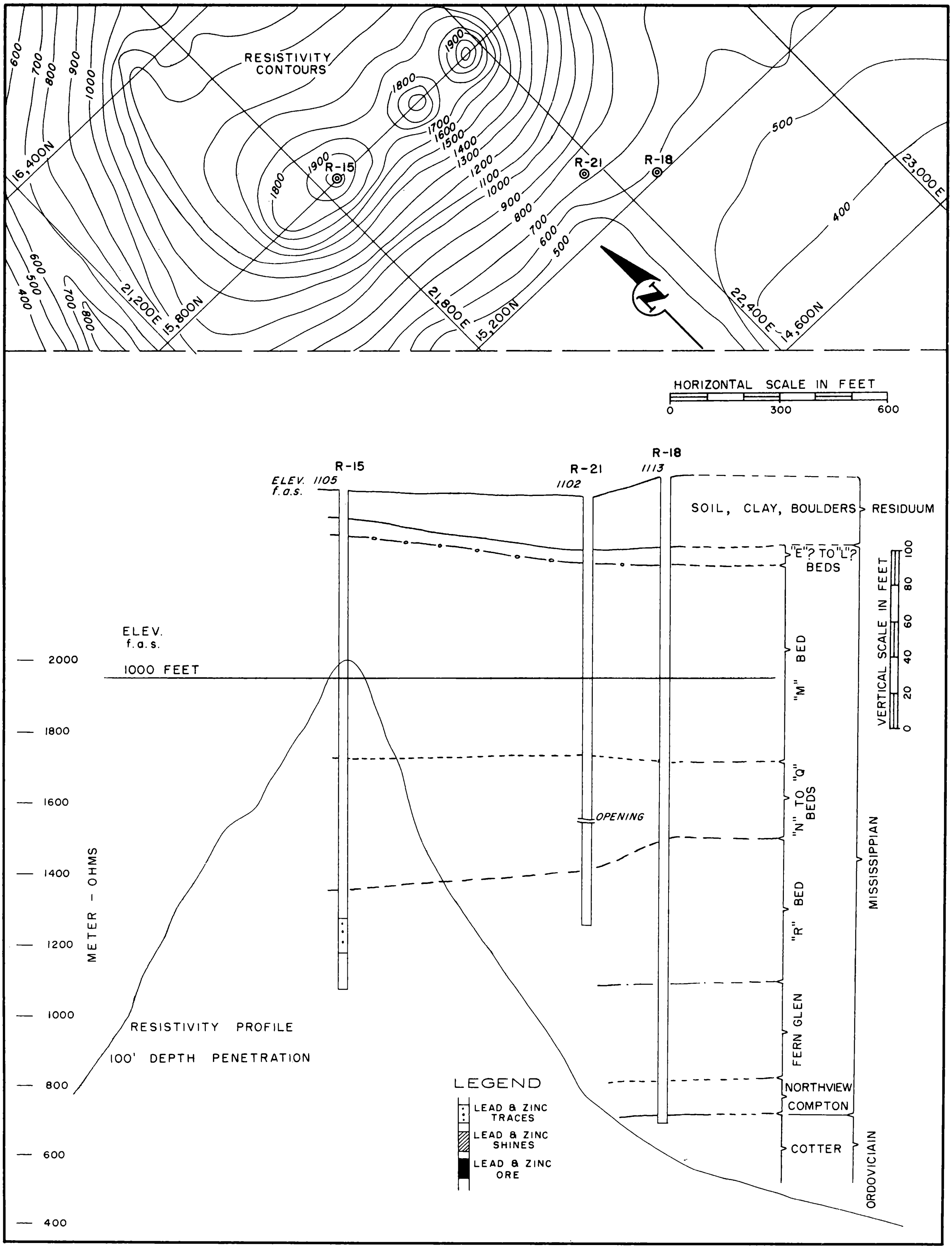

FIGURE 14. - Plan and Vertical Cross Section Through Drillholes R-15–R-18, Fort Tract.

Watson Property (Figs. 2-4, 15, 16)

The northern end of a large area of low resistivity readings (100-200 meter-ohms) is in the southern part of this property (figs. 2-4). The nose of a pattern of higher resistivity intrudes the low from the west. Test holes R-7, R-30, R-33, R-39, R-6, R-36, R-35, and R-37 confirmed the inferred relationship between the resistivity readings and structure. R-7 confirmed the presence of a structural nose, and the other holes confirmed the presence of a sink structure containing a block of highly porous Chester limestone (fig. 15). No significant mineralization was indicated by these holes, but correlation between the resistivity profile and structure is good.

Holes R-60 and R-61 (fig. 16), drilled on a flank of the nose further confirmed the presence of a structural nose but the short section through these holes is not conclusive as to the relationship between resistivity and structure or alteration.

Watson-Scheid Properties (Figs. 2-4, 17)

The small, almost circular area of low resistivity readings (100-200 meter-ohms) in the northeast section of the Watson property was interpreted as an expression of a pothole or sink structure. Hole R-62, which was drilled in the center of this anomaly, penetrated highly altered beds and oxidized zinc ore. Hole R-63 unexpectedly penetrated a greater thickness of residuum than R-62 and greater thinning in the M-bed. R-63 also disclosed intervals of oxidized zinc ore. Hole R-66, drilled on a line with and east of the other two holes (fig. 4), penetrated relatively unaltered beds.

The structure shown by the cross section through the three holes correlates fairly well with the resistivity profile, except for being offset (fig. 17).

Scheid Property (Figs. 2-4, 18-20)

Holes R-65, R-11, R-17, R-14 and R-56 were drilled to test a weak "high" on the Scheid property (figs. 2-4). All the holes except R-65 showed indications of zinc mineralization; R-17 cut through a thick section of submarginal ore, and R-56 a 7-1/2-foot section that contains 2.15 percent of zinc. The test drilling was encouraging with respect to mineralization; however, the correlation between geology and geophysics is not clear. No structural features can be recognized at the depths expected that might account for the differences in resistivity readings. A suggestion of doming is shown on the top of the N-bed and also on the top of R-bed (fig. 18), but these features are thought to be too deep to influence the 100-foot depth penetration of resistivity. The relative alteration in the rocks does not appear to bear any relation to resistivity.

Test drilling of holes R-57, R-58, R-59, and R-64 across a broad, relatively shallow "low" north of the weak "high" on the Scheid property produced good results (fig. 19). Residuum was the deepest at the center of the low, a structural low was evident through all the beds penetrated, and alteration was greatest in the center of the low. Hole R-58 cut a 7-1/2-foot interval containing 1.56 percent zinc. The zinc occurs as sphalerite in the OPQ beds at a depth of 260-267-1/2 feet.

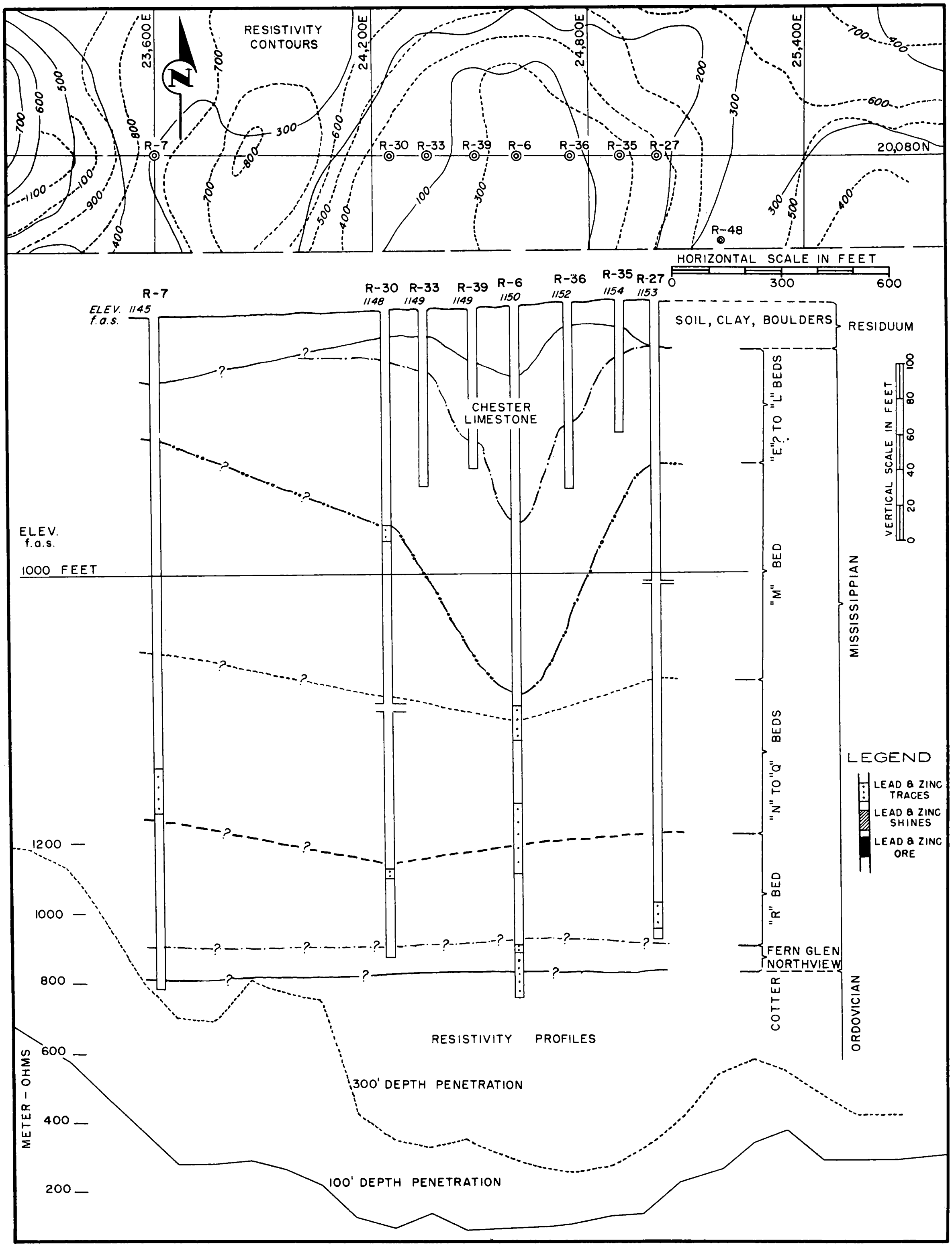

FIGURE 15. - Plan and Vertical Cross Section Through Drillholes R-7–R-27, Watson Tract.

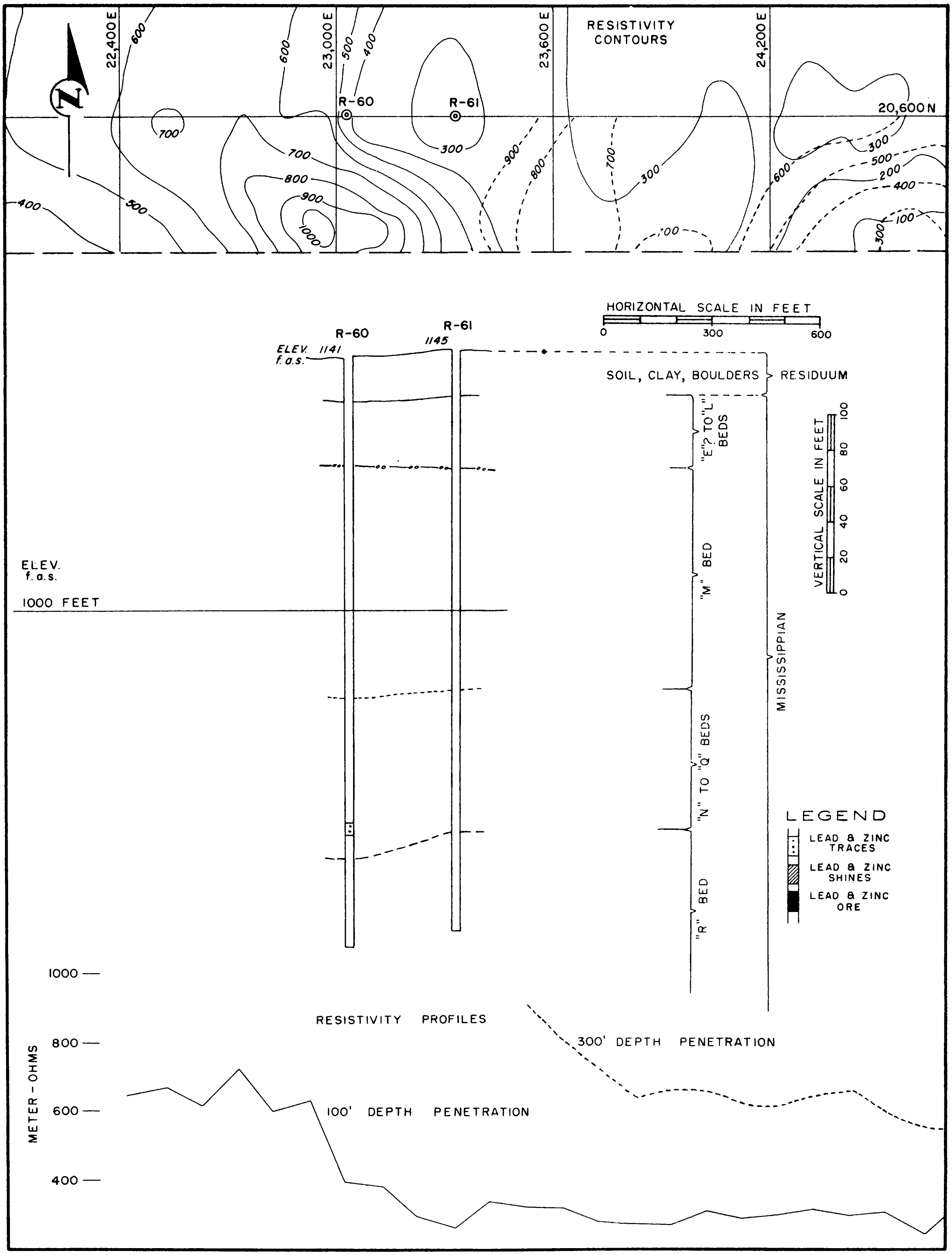

FIGURE 16. - Plan and Vertical Cross Section Through Drillholes R-60 and R-61, Watson Brothers Tract.

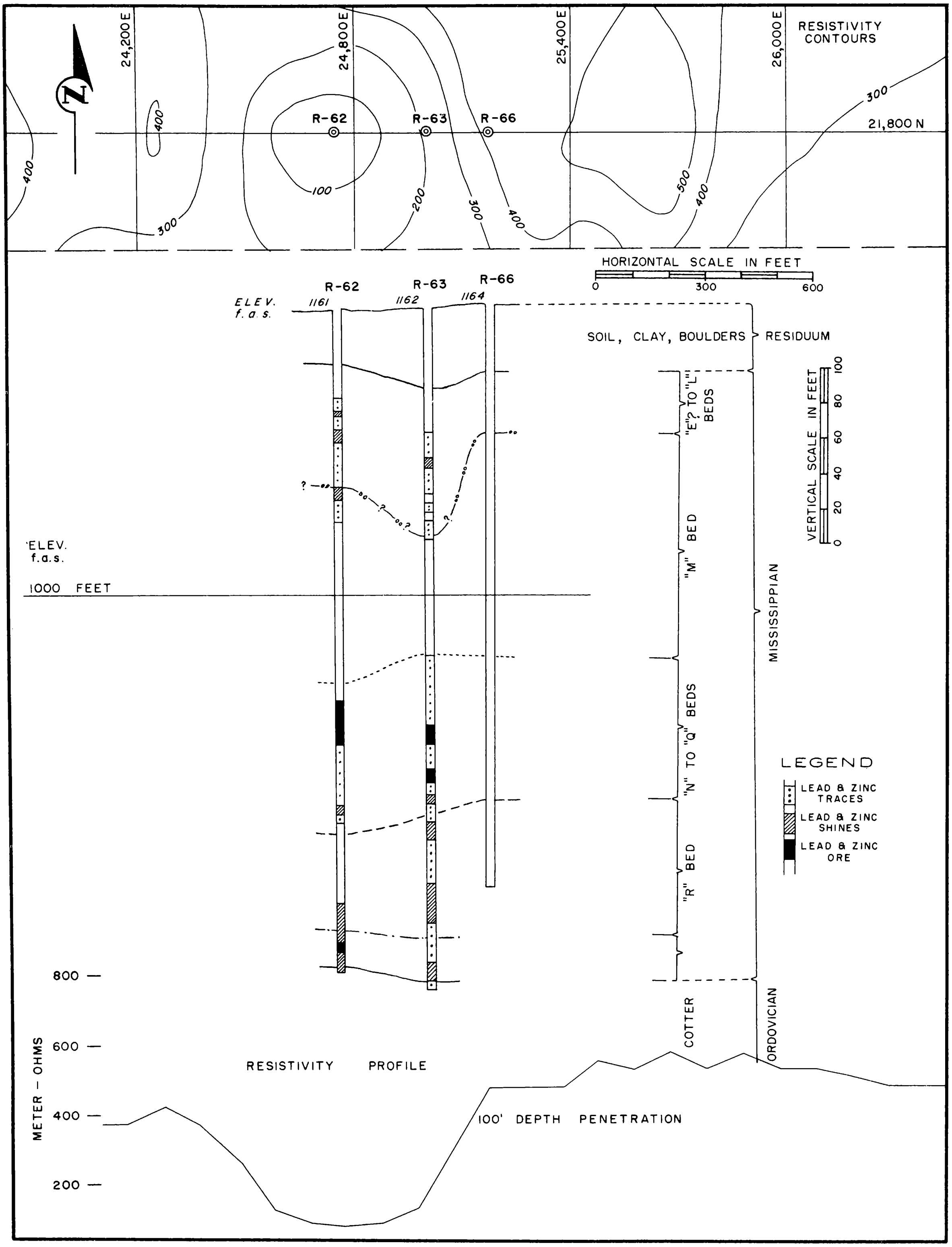

FIGURE 17. - Plan and Vertical Cross Section Through Drillholes R-62–R-66, Watson-Scheid Tracts.

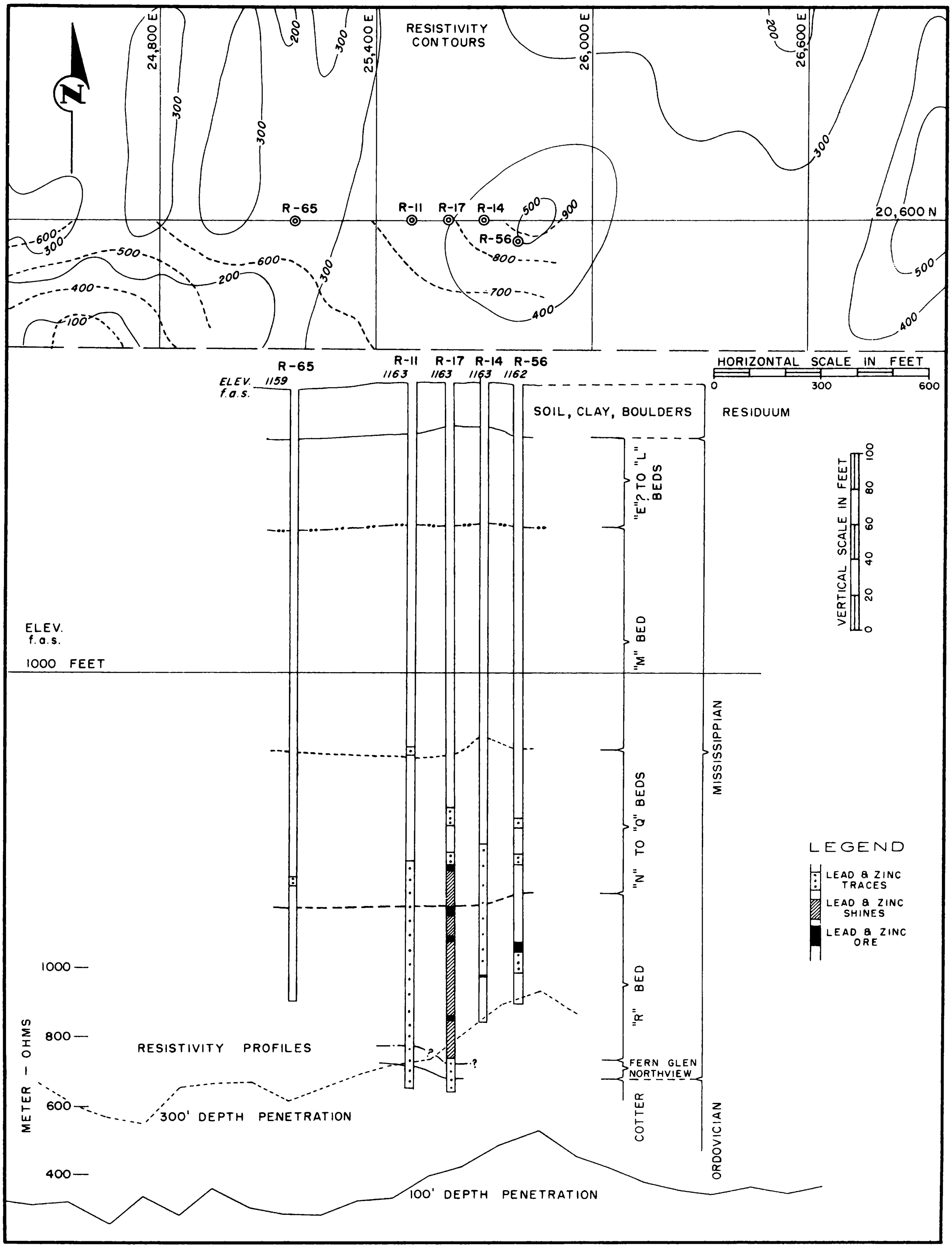

FIGURE 18. - Plan and Vertical Cross Section Through Drillholes R-65–R-56, Scheid Tract.

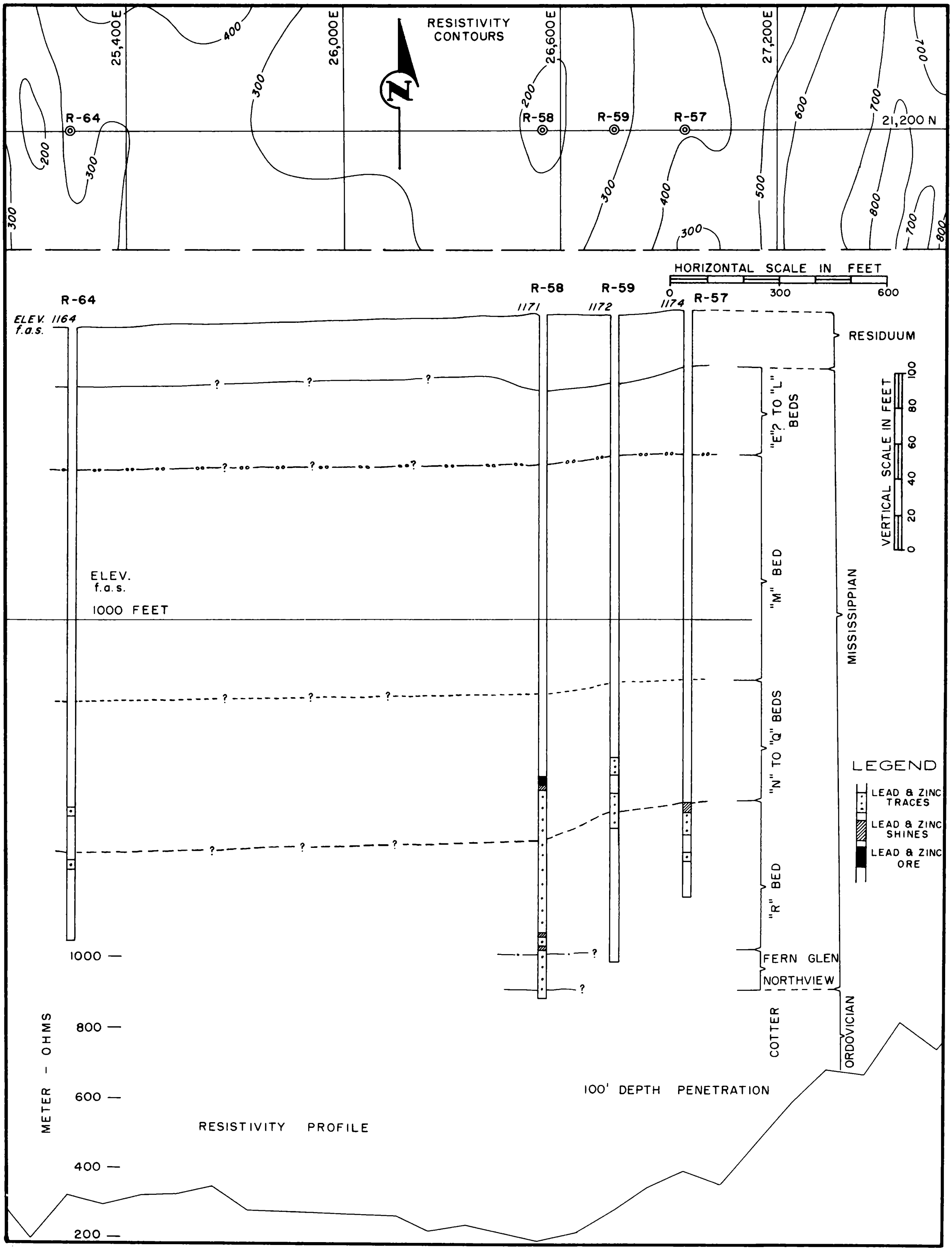

FIGURE 19. - Plan and Vertical Cross Section Through Drillholes R-64–R-57, Scheid Tract.

A north-south section consisting of holes R-48, R-65, R-64 and R-66 produced expected results (fig. 20). The holes are widely spaced and at about the same resistivity. The information is consistent with what was expected, but the holes are spaced too widely for any but broad correlation.

Rodgers Property (Figs. 2-4)

Holes R-9 and R-10 were drilled to test two separate noselike highs on the Rodgers property. The results appear to confirm the presence of structural "noses" but the limited drilling does not permit more specific correlation. Neither hole showed more than faint traces of ore minerals.

Winchester Property (Figs. 2-4, 21-25)

Five sections were drilled across the long, benchlike anomaly with which the Winchester ore deposit is associated. These sections are composed of (1) holes R-27, R-48, R-49, R-50, and R-47 (fig. 21); (2) holes R-45 and R-46 (fig. 22); (3) holes R-16, R-43, and SF-11 (fig. 23); (4) holes R-29, R-32, and R-38 (fig. 24); and (5) R-19, R-22, R-23, and R-26 (fig. 25). The finding of ore in holes R-22, R-26, R-32, R-38, R-45, R-46, and R-50 has greatly enlarged the previously indicated size of the ore deposit. All sections show good correlation. Differences in both structure and alteration conform with interpretations made from resistivity measurements.

CONCLUSIONS

The results obtained by using electrical-resistivity measurements in conjunction with test drilling indicate that resistivity determinations adequately reflect structure and alteration, in most instances, in the test area. The 600-foot spacing between lines of resistivity readings and the 100-foot depth penetration are adequate here for reconnaissance work.

Fair to good correlation was obtained between drillhole data and electrical-resistivity determinations in most of the tests. Overlays of topographic contours and structural contours on the tops of M, N, and R-beds were compared with the isoresistivity contour map. In most of the area the topography and resistivity are unrelated, but the structural contours show definite relationship with resistivity. The relationship of the M bed is clearest (figs. 26 and 27), the N bed is slightly less clear (figs. 28 and 29), and the R bed is a little more vague (figs. 30 and 31). Many parts of the project could not be structurally contoured because of widely spaced drilling, so the relationship of structure to resistivity there is obscure. In other places more definite interpretations would be possible by extending the lines of resistivity readings farther to the east and west.

Too many factors may influence the resistivity readings to permit definite prediction of structure or degree of alteration on the basis of the absolute reading. It is the relationship between a reading and its adjacent readings that is important in interpreting subsurface conditions. Toward the close of the project it was possible to predict, with fair accuracy, the condition of the subsurface rocks in a specific locality before a test hole was drilled.

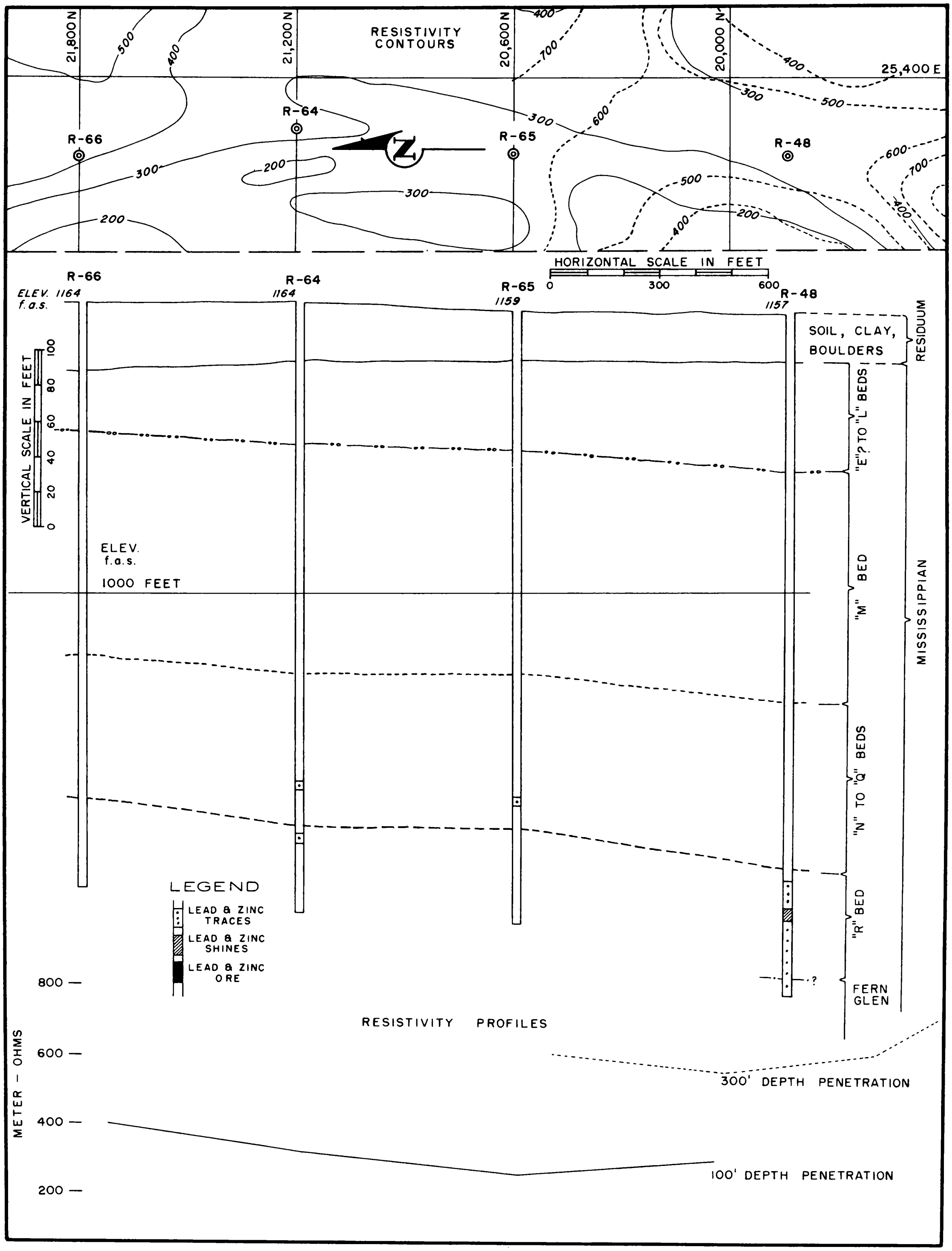

FIGURE 20. - Plan and Vertical Cross Section Through Drillholes R-66–R-48, Scheid-Winchester Tracts.

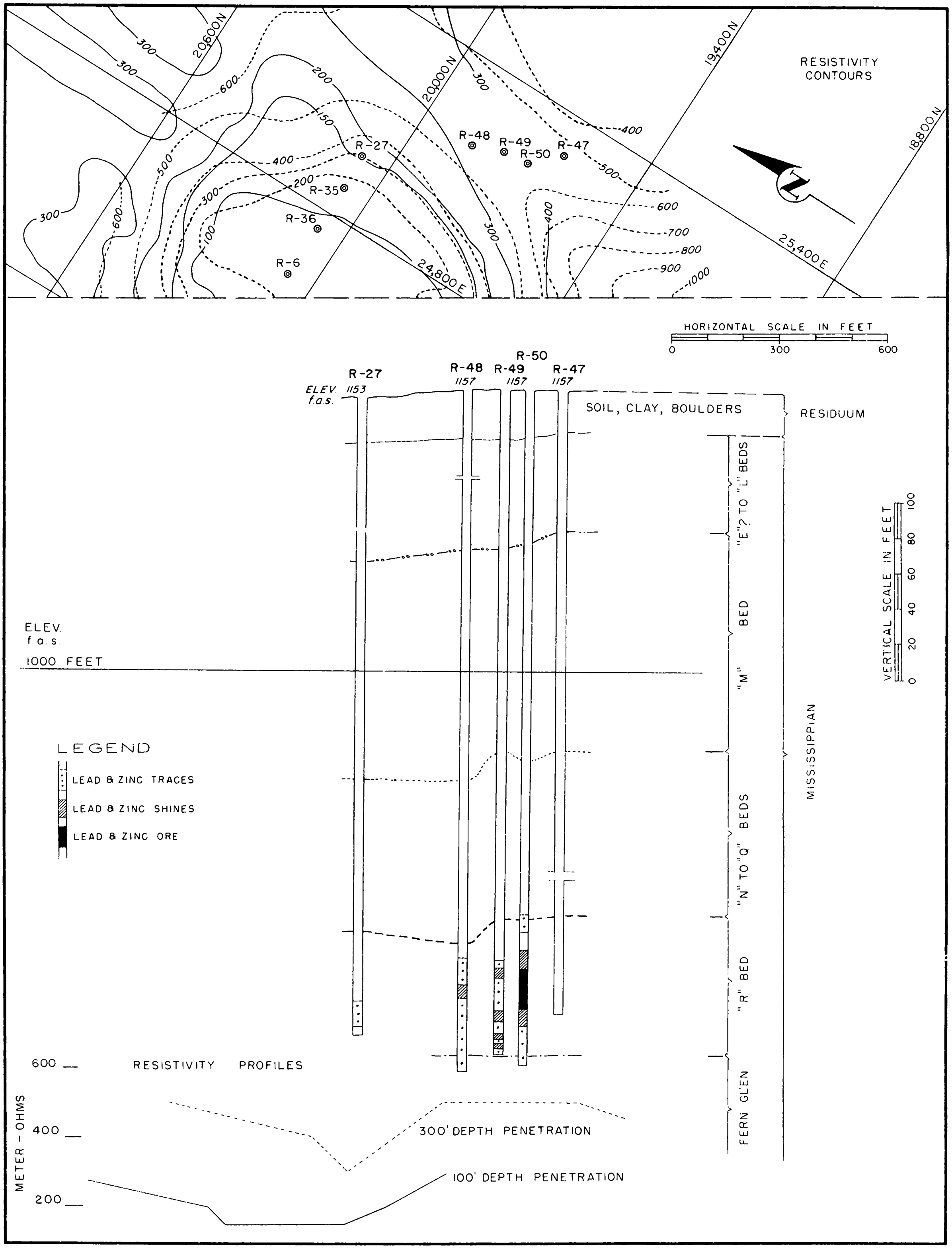

FIGURE 21. - Plan and Vertical Cross Section Through Drillholes R-27–R-47, Watson, Winchester, and Crawford Tracts.

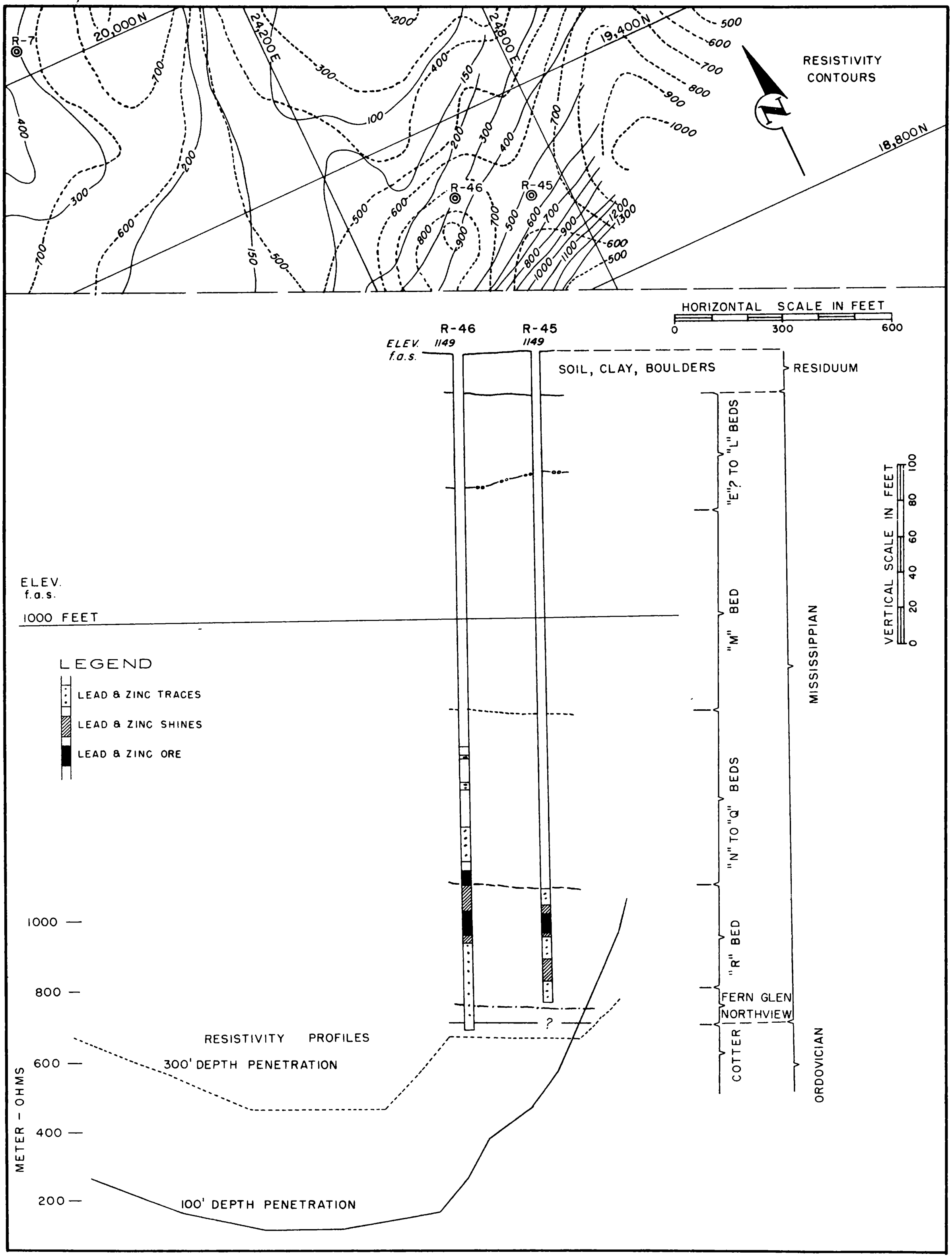

FIGURE 22. - Plan and Vertical Cross Section Through Drillholes R-45–R-46, Winchester Tract.

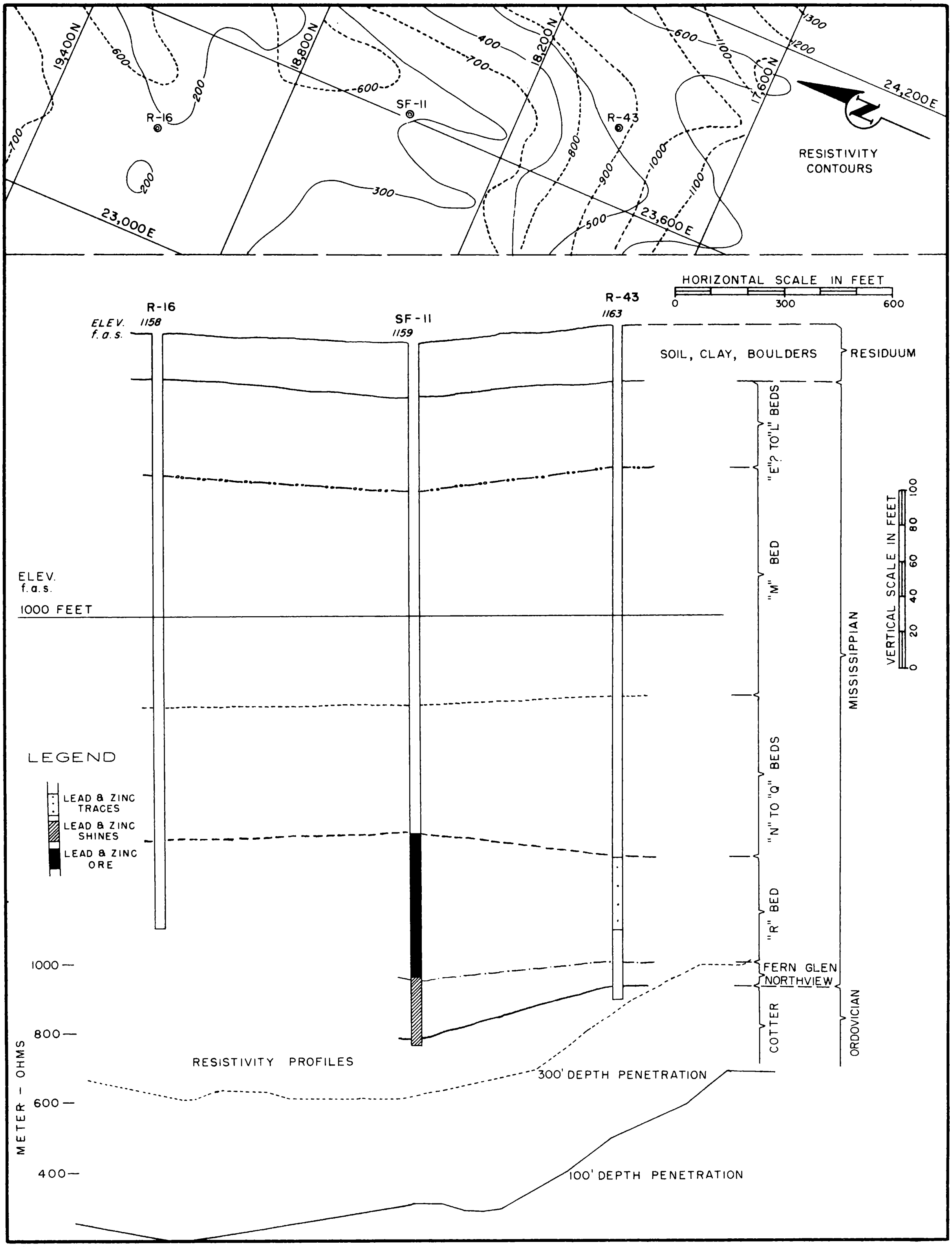

FIGURE 23. - Plan and Vertical Cross Section Through Drillholes R-16–R-43, Winchester Tract.

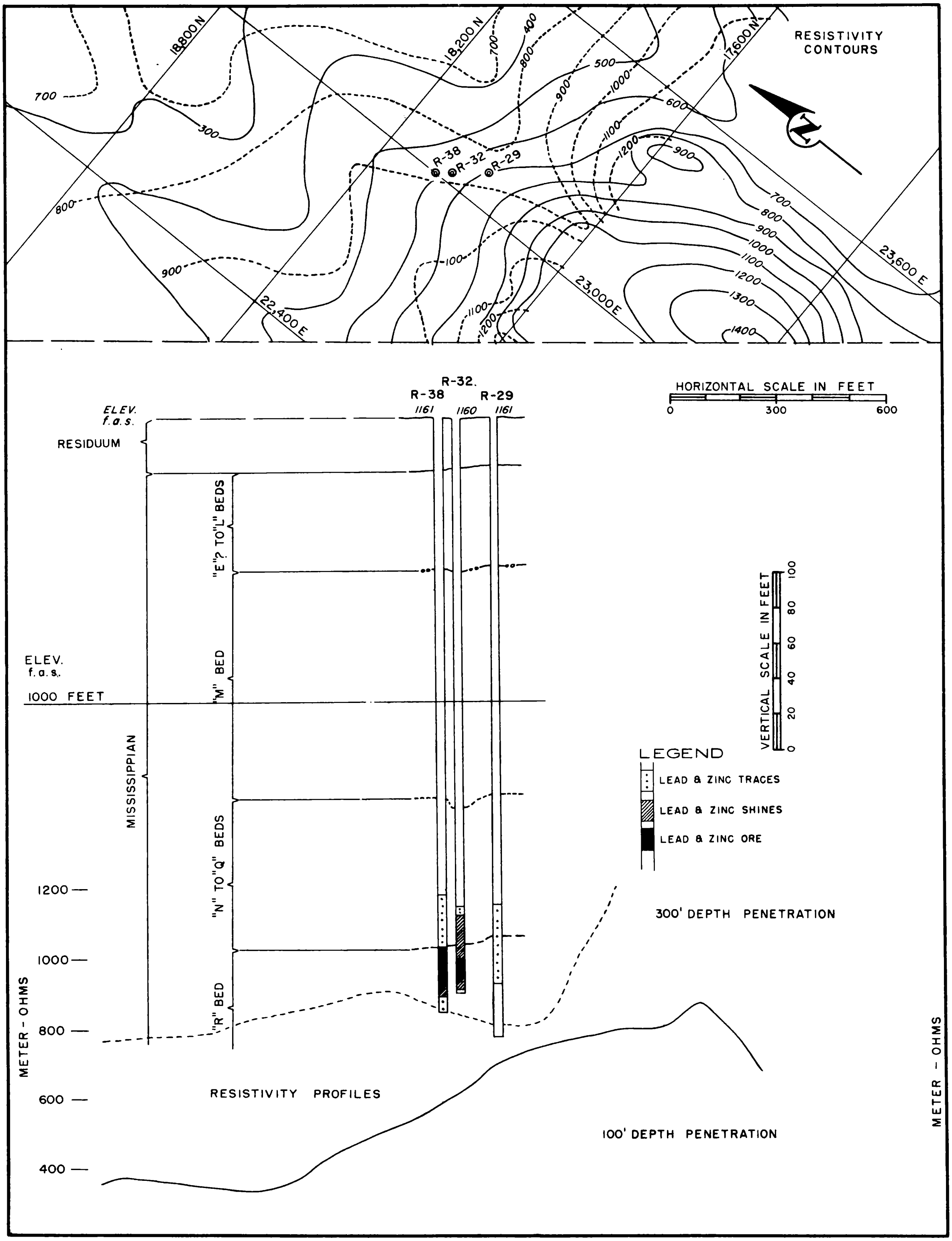

FIGURE 24. - Plan and Vertical Cross Section Through Drillholes R-38–R-29, Winchester Tract.

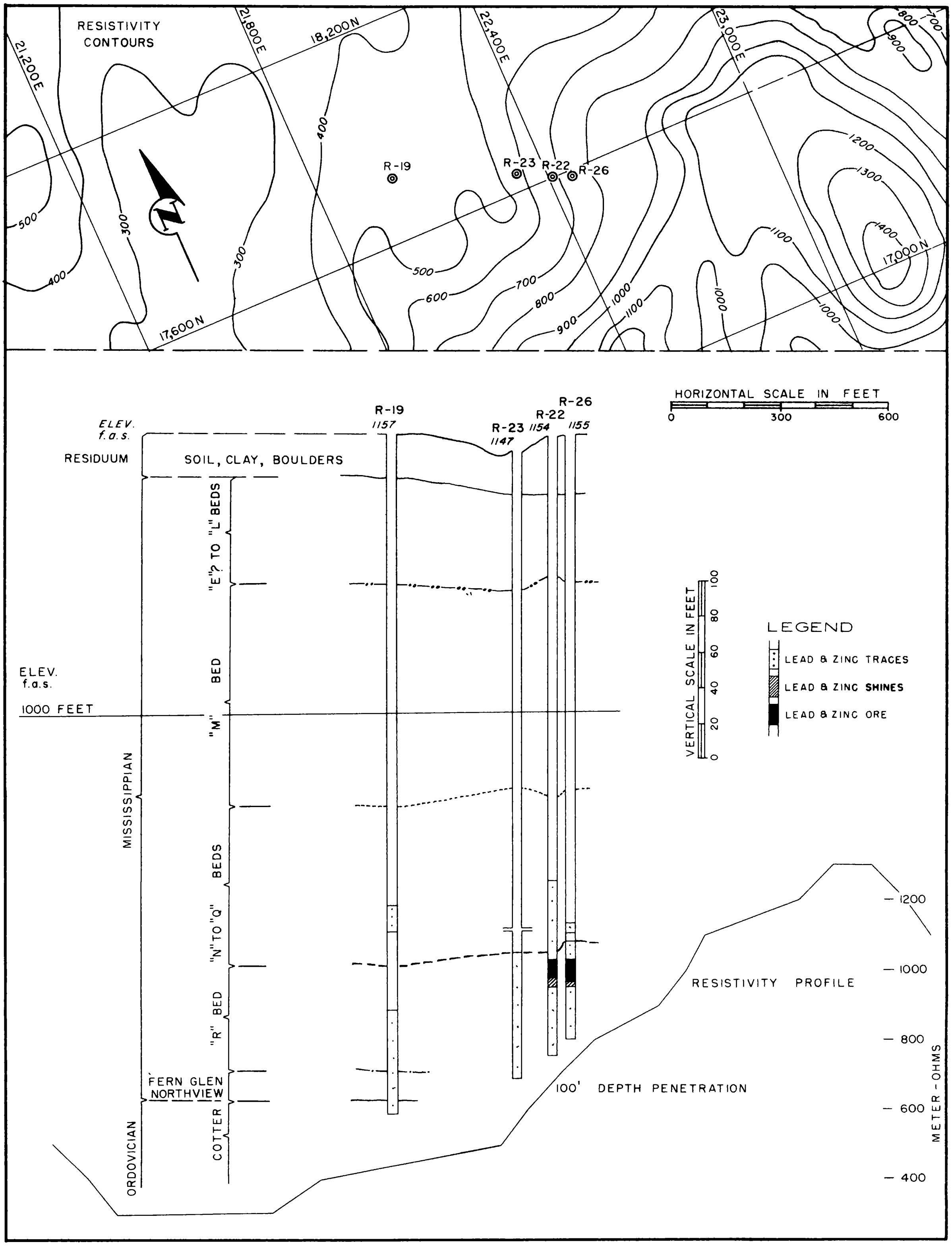

FIGURE 25. - Plan and Vertical Cross Section Through Drillholes R-19–R-26, Winchester Tract.

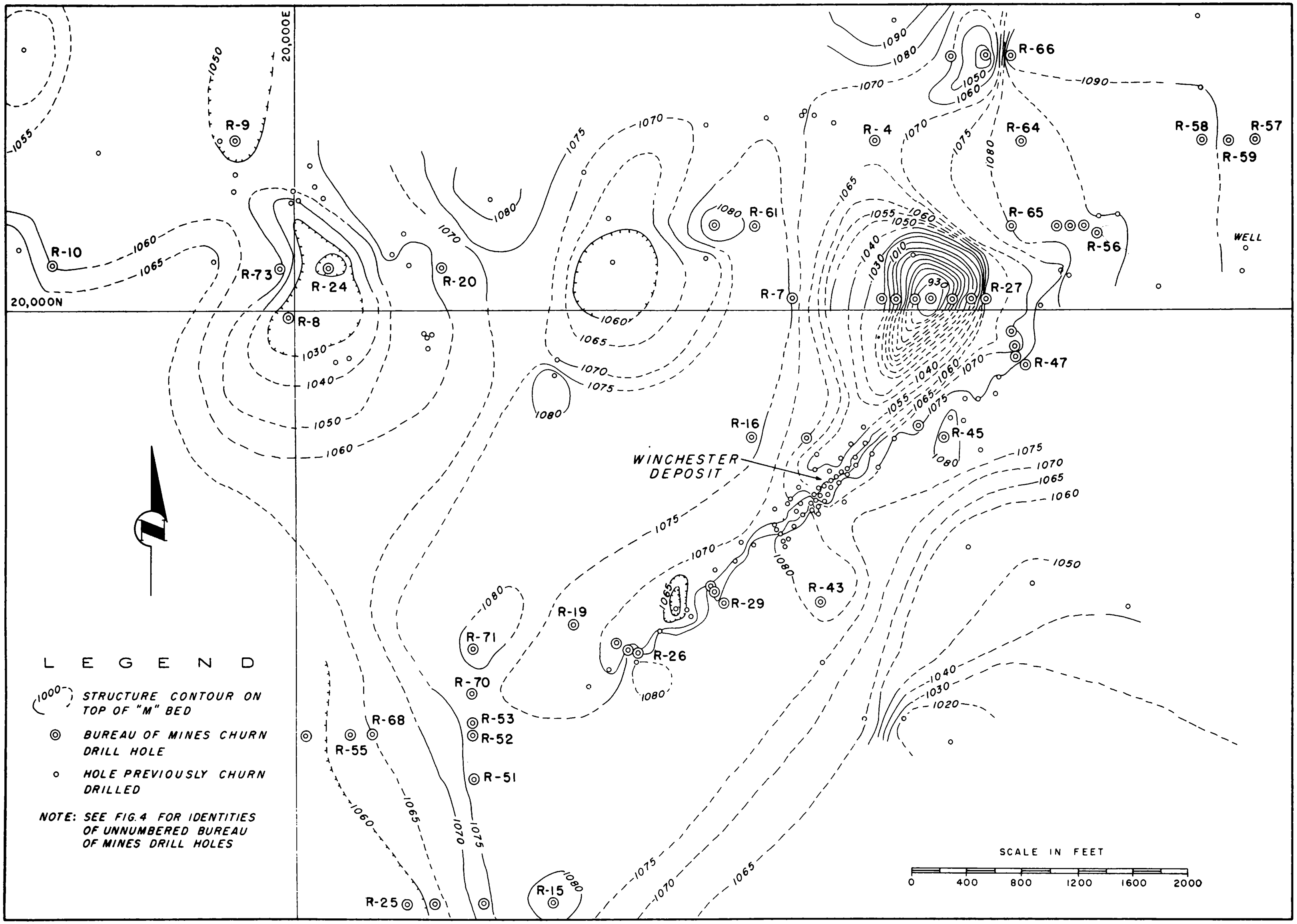

FIGURE 26. - Structure Contours on Top of M Bed, Northwestern Part of Racine-Spurgeon Area.

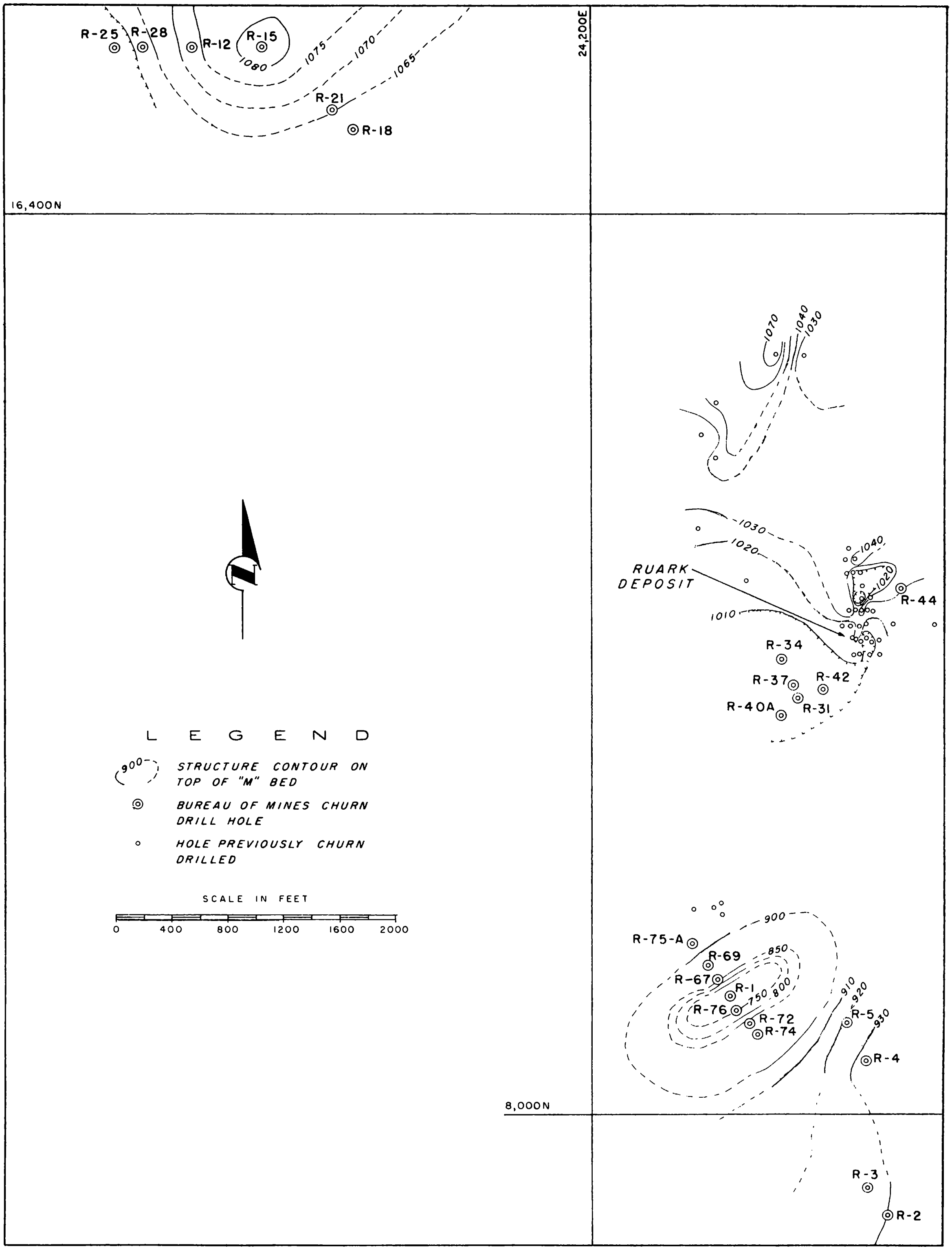

FIGURE 27. - Structure Contours on Top of M Bed, Southwestern Part of Racine-Spurgeon Area.

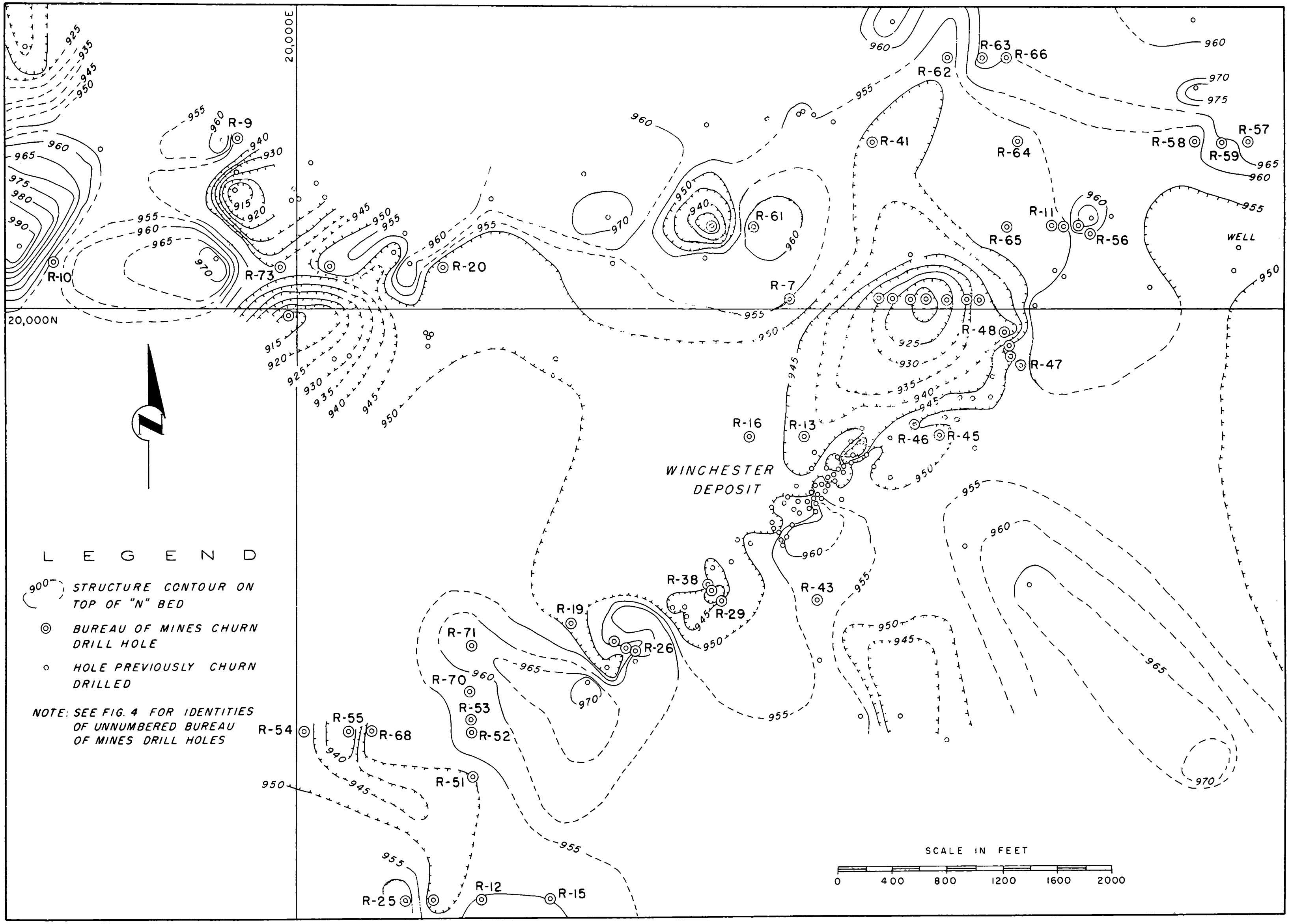

FIGURE 28. - Structure Contours on Top of N Bed, Northwestern Part of Racine-Spurgeon Area.

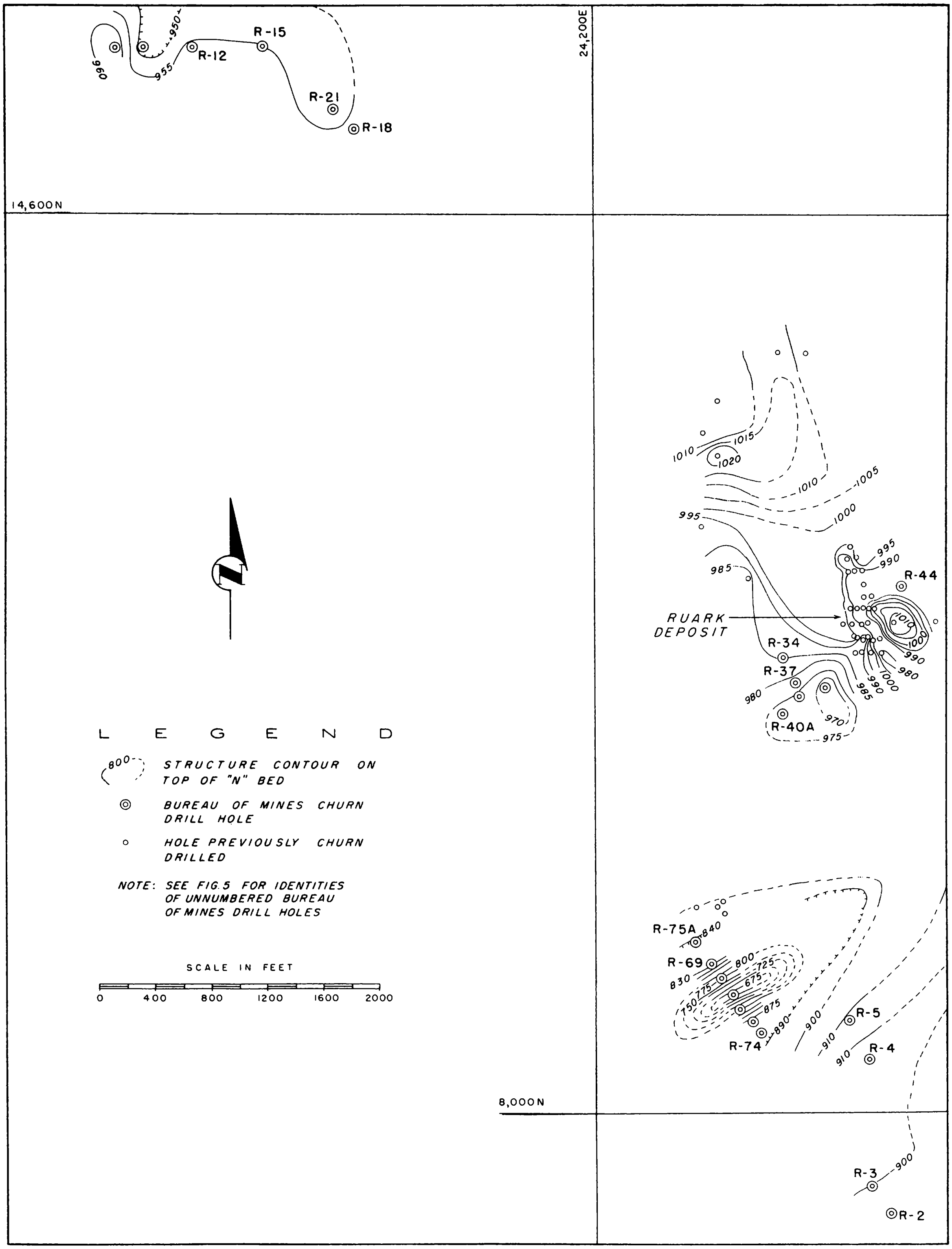

FIGURE 29. - Structure Contours on Top of N Bed, Southwestern Part of Racine-Spurgeon Area.

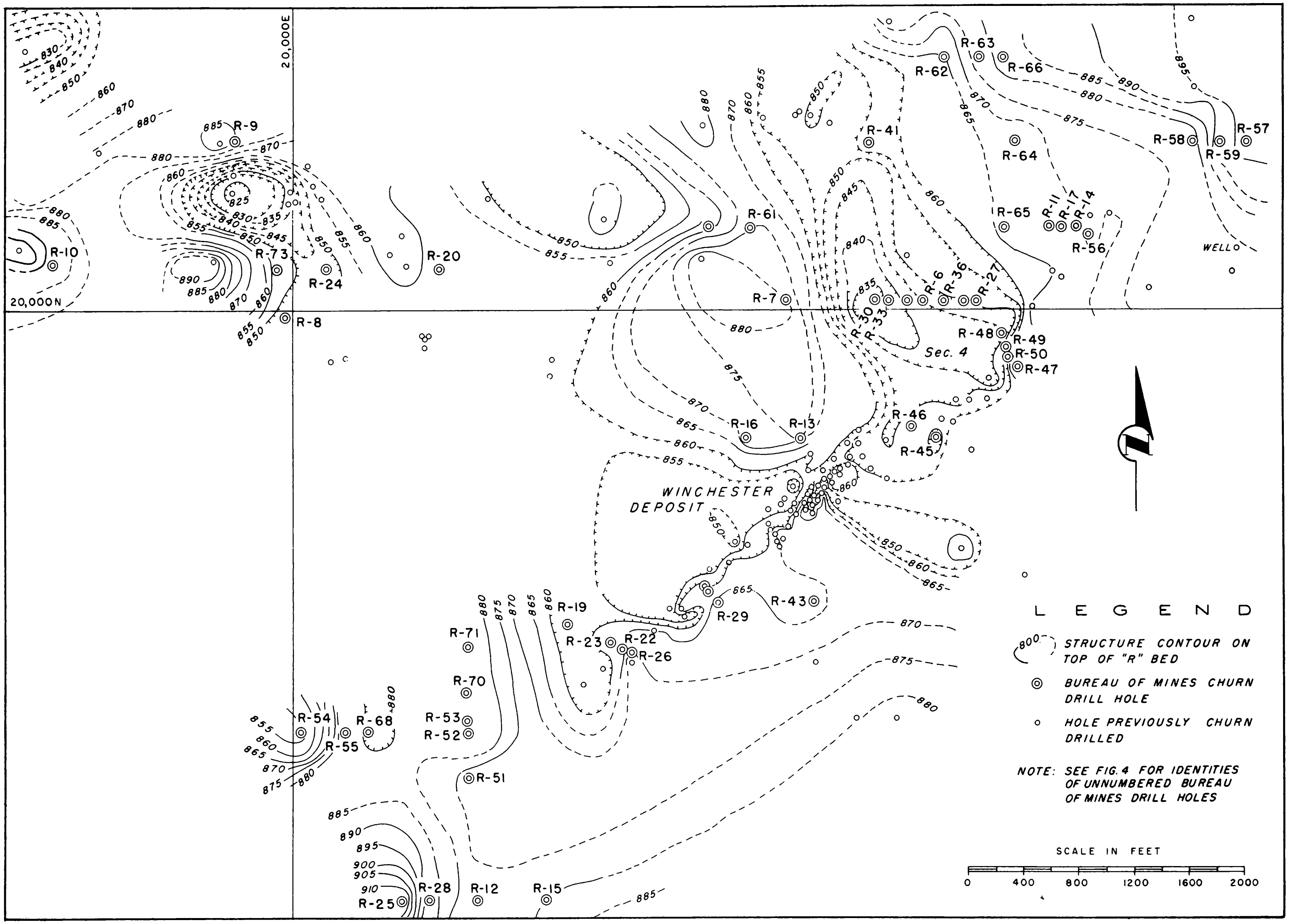

FIGURE 30. - Structure Contours on Top of R Bed, Northwestern Part of Racine-Spurgeon Area.

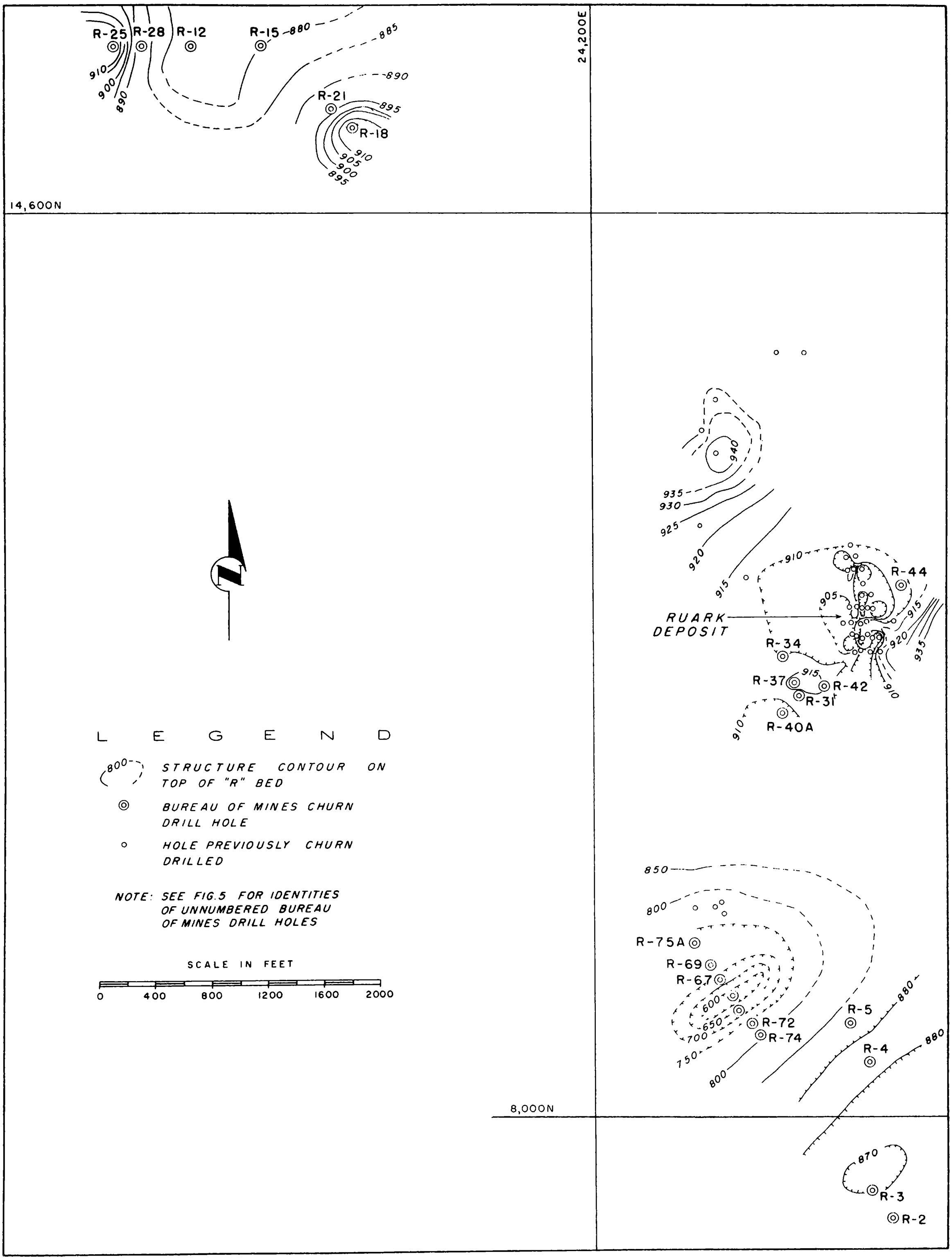

FIGURE 31. - Structure Contours on Top of R Bed, Southwestern Part of Racine-Spurgeon Area.

Highly altered beds were found in areas where resistivity readings ranged from 75 to 700 meter-ohms. Firm to only slightly altered beds were found where readings ranged from 270 to 2,140 meter-ohms. Test drilling indicated that, in the project site, most areas with readings above 800 meter-ohms are unfavorable for ore deposition. Very little evidence of ore mineralization was found in these areas.

Test drilling of various patterns of resistivity readings indicated that certain types of anomalies are much better indexes to ore deposition than others. The long, benchlike type of anomaly is apparently one of the best indicators of a sulfide ore deposit. The Winchester ore body is associated with an anomaly of this type. Although test drilling was not sufficient to be conclusive, the locations of two ore holes adjacent to an area of low resistivity on the Milnot property suggest that this ore may also be associated with a benchlike anomaly.

Sink structures indicated by low-resistivity readings are favorable sites for oxidized ore deposits and in some instances for sulfide deposits near the outer limit of the sink.

This project demonstrated that an electrical-resistivity survey can be a valuable tool in the search for zinc-lead deposits. As a method of indicating favorable areas for exploratory drilling, eliminating unfavorable areas, the electrical-resistivity survey is probably more effective than shale drilling, and can be done at about one-third the cost.

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APPENDIX

TABLE 1. - Pertinent data abstracted and interpreted from logs of holes churn-drilled by various private interests on Winchester property N1/2 sec. 4, T. 25 N., R. 33 W.

Hole*	Location coordinates		Collar elevation	Depth drilled	Depth below collar (feet)			Zinc-lead horizons			
								Interval, feet		Content, percent	
	North	East	(f.a.s.)	(feet)	Base of residuum	Top of M bed	Top of N bed	From-	To-	Zinc	Lead
1	18,680	23,800	1,154	339	16	?	?	258	330	5.36	-
								330	339	1.14	0.07
2	18,725	23,755	1,154	360	26	?	215?	298	310	2.40	.03
								310	340	.80	.03
3	18,625	23,815	1,155	391	25	80?	200?	262	271	2.19	.09
								271	289	.71	.14
								289	298	2.17	.10
								298	344	.61	.06
4	18,665	23,745	1,155	350	28	77	210	265	272	.42	.12
								272	284	2.26	.12
5	18,745	23,830	1,152	360	25	80	200	316	319	.90	.03
								319	331	3.84	.07
								331	356	1.02	.07
6	18,695	23,850	1,154	354	26	85	205	300	316	.91	.08
								316	325	2.73	.04
								325	346	.58	.07
7	18,655	23,790	1,154	358	25	75	196	265	273	3.41	-
								273	309	1.61	-
								309	345	4.87	-
								345	358	.51	-
8	18,700	23,810	1,153	366	25	85	200	303	328	2.97	-
								328	343	1.16	-
								343	366	"Shines"	-
9	18,660	23,820	1,154	371	25	85	200	282	321	.58	-
								321	330	2.95	-
								330	353	.77	-
10	18,610	23,775	1,154	365	30	85	200	265	276	2.04	-
								291	302	1.22	-
								302	333	3.02	-
								333	354	.89	-

TABLE 1. - Pertinent data abstracted and interpreted from logs of holes churn-drilled by various private interests on Winchester property, N1/2 sec. 4, T. 25 N., R. 33 W. (Con.)

Hole*	Location coordinates		Collar elevation (f.a.s.)	Depth drilled (feet)	Depth below collar (feet)			Zinc-lead horizons			
	North	East			Base of residuum	Top of M bed	Top of N bed	Interval, feet		Content, percent	
								From-	To-	Zinc	Lead
11	18,555	23,790	1,156	350	25	80	200	275	325	"Trace"	"Trace"
12	18,580	23,740	1,156	350	27	75	200	270	280	.77	0.04
								300	309	2.61	.02
								309	330	1.22	-
								330	339	.55	-
13	18,740	23,795	1,153	361	30	90	188?	302	334	1.06	-
14	18,805	24,330	1,140	340	?	?	?	273	277	"Trace"	-
15	18,625	23,715	1,156	350	25	85	205	270	278	2.03	-
								300	303	.57	-
								303	312	2.17	-
								312	321	.78	-
								321	333	2.06	-
								333	342	1.11	-
16	18,575	23,625	1,157	350	27	85	205?	270	300	2.16	-
								315	334	1.48	-
17	18,765	23,865	1,151	350	24	85	195?	300	321	2.52	-
								321	324	.23	-
18	18,880	23,995	1,151	340	Log not available			300	325	2.34	-
								325	340	.70	-
19	18,690	23,725	1,154	330		do.		280	300	1.68	-
20	18,635	23,560	1,156			do.		310	330	.59	-
21	18,665	23,585	1,157			do.					
22	18,600	22,910	1,156			do.					
23	17,495	23,810	1,160			do.					
WC-1	18,665	23,790	1,154	360	26	85	205	265	280	3.58	0.03
								280	302	.91	.02
								302	335	2.74	.04
								335	340	1.05	.02
WC-2	18,790	23,885	1,151	340	24	?	205	305	310	.60	-
								310	320	2.03	-
								320	325	.52	-

TABLE 1. - Pertinent data abstracted and interpreted from logs of holes churn-drilled by various private interests on Winchester property, N1/2 sec. 4, T. 25 N., R. 33 W. (Con.)

Hole*	Location coordinates		Collar elevation	Depth drilled	Depth below collar (feet)			Zinc-lead horizons			
								Interval, feet		Content, percent	
	North	East	(f.a.s.)	(feet)	Base of residuum	Top of M bed	Top of N bed	From-	To-	Zinc	Lead
WC-3	18,840	23,990	1,149	340	23	80	205	297	305	1.13	-
								305	317	3.49	-
								317	325	1.13	-
BW-1	18,735	23,875	1,153	375	24	85	200	312	332	1.76	-
								340	348	2.91	-
BW-2	18,680	23,760	1,154	356	25	90?	200	265	277	2.76	-
								295	312	1.55	-
BW-3	18,630	23,770	1,155	365	26	?	195?	265	275	2.33	0.04
								290	330	5.11	.03
BW-4	18,600	23,750	1,156	355	27	79	200	265	275	1.27	-
								295	315	2.49	-
								315	330	1.34	-
								340	347	1.18	-
BW-5	18,615	23,800	1,155	350	27	80	200	265	275	4.21	"Trace."
								275	280	.90	.28
								290	310	1.01	-
								310	340	2.19	-
BW-6	18,645	23,740	1,155	350	27	80	195?	295	312	1.56	-
								312	320	.65	

* Numbers with prefix WC and BW designate holes drilled by St. Louis Smelting & Refining Co.; all others were drilled by American Zinc, Lead & Smelting Co. and A. N. Winchester.

TABLE 2. - Pertinent data abstracted and interpreted from logs of holes churn-drilled by Grasseli Chemical Co. on Snow (Ruark) property, sec. 10, T. 25 N., R. 33 W.

Hole	Location coordinates		Collar elevation	Depth drilled	Depth below collar (feet)			Zinc-lead horizons			
								Interval, feet		Content, percent	
	North	East	(f.a.s.)	(feet)	Base of residuum	Top of M bed	Top of N bed	From-	To-	Zinc	Lead
35-Z	11,610	26,670	1,023	181	10	10*	?	40	45	"Shines"	
43-Z	11,605	26,370	1,036	142	20	20*	?	100	130	do.	
47-Z	11,590	26,080	1,067	196	35	35*	70	150	160**	2.20	-
52-Z	11,580	26,140	1,058	162	34	34*	65	145	155**	1.19	1.23
53-Z	11,590	26,000	1,076	190	29	29*	75	150	165	"Shines"	-
57-Z	11,590	26,170	1,054	155	35	35*	65	140	145	1.44	.12
60-Z	11,690	26,100	1,067	173	28	28*	70	150	165**	2.51	-
62-Z	11,690	26,070	1,069	171	30	30*	75	157½	162½	1.30	-
63-Z	11,700	26,140	1,065	172	25	25*	80	142½	165**	1.41	-
68-Z	11,700	26,175	1,063	164	30	30*	70	150	160**	3.03	-
71-Z	11,700	26,200	1,060	163	25	25*	50?	135	160	"Shines"	-
76-Z	11,800	26,205	1,070	170	35	35*	80	142½	157½	do.	"Shines."
78-Z	11,785	26,135	1,073	174	25	25*	85	160	170**	2.40	-
79-Z	11,880	26,140	1,077	181	42	42*	90	142½	175	"Shines"	"Shines."
80-Z	11,495	26,100	1,063	167	40	40*	65?	140	162½	do.	Do.
83-Z	11,985	26,130	1,082	185	50	50*	90	167½	177½	1.32	.10
85-Z	11,485	26,190	1,054	157	40	40*	50?	125	152½**	.87	1.03
86-Z	11,975	26,065	1,083	183	40	40*	95	120	132½	"Shines"	1.29
87-Z	11,475	26,215	1,052	165	30	30*	60?	115	142½**	.99	.51
89-Z	11,975	26,030	1,083	181	33	33*	90	165	172½	1.44	-
91-Z	11,380	26,210	1,058	160	30	30*	50	140	145	"Shines"	-
92-Z	12,065	26,030	1,085	184	30	30*	95	125	165	do.	"Shines."
95-Z	11,365	26,140	1,060	154	10	10*	50	125	135	-	1.40
96-Z	12,075	26,080	1,085	180	28	28*	95	165	175	"Shines"	"Shines."
97-Z	11,490	26,145	1,066	160	45	45*	75	135	145	-	Do.
99-Z	11,480	26,245	1,056	151	40	40*	60	None	None	-	-
100-Z	12,160	26,040	1,088	181	30	30*	90	120	140	-	"Shines."
102-Z	11,375	26,275	1,056	150	45	45*	75	115	120	"Silicate"	-
103-Z	11,920?	25,310?	1,029?	136	13	13*	30	105	125	0.69	-
106-Z	11,370	26,110	1,067	163	45	45*	75	135	145	"Shines"	"Shines."
107-Z	12,028?	25,125?	1,029?	128	19	19*	45	115	125	"Fair jack"	-

* Upper part of M bed removed by erosion.

** Contains a section of zinc-lead sulfides of ore grade 7 feet or more in thickness.

TABLE 3. - Pertinent data abstracted and interpreted from logs of holes churn-drilled by private interests on various properties

Hole	Location coordinates		Collar elevation (f.a.s.)	Depth drilled (feet)	Depth below collar (feet)			Zinc-lead horizons			
					Base of residuum	Top of M bed	Top of N bed	Interval, feet		Content, percent	
	North	East						From-	To-	Zinc	Lead
1-C	18,640	24,975	1,156	350	25	80	205	*		-	-
2-C	18,260	25,030	1,150	375	24	70	160?	320	365	Fair Zn	
1-H	17,030	22,980	1,140	350	35	105	185?	*		-	-
1-R	19,530	21,870	1,164	365	25	85	225	*		-	-
2-R	19,640	21,880	?	353	18	75	210	*		-	-
113A1	17,100	24,050	1,138	326	15	?	180?	275		0.41	-
113A2	17,100	24,600	1,128	295	15	?	185?	*		-	
113F1	14,830	24,970	1,133	376	28	83	180?	*		-	-
113F2	15,050	24,960	1,128	348	26	80	190?	*		-	-
1-T	17,865	25,060	1,105?	315	15	?	155?	268	289	1.34	-
K-1	18,110	28,430	1,130?	265	25	34?	?	211	265	"Trace"	
K-2	18,030	29,640	1,095	312	22	170?	197?	*			
W-1	19,890	28,810	1,145?	82	15	-	-	*			
W-2	19,930	28,850	1,145?	95	60	?	-	*			
123B1	20,190	29,620	1,120?	341	55	?	155	*			
123B2	20,370	29,630	1,122	326	50	?	140	*			
123B3	20,480	29,370	1,130?	314	62	?	?	*			
123A1	21,630	29,800	1,129	306	50	?	150?	*			
K-1	20,830	28,980	1,135?	150	?	?	141?	80	98	"Trace"	
K-2	20,620	28,980	1,135?	150	30	?	149?	139	150	"Shines"	
K-3	20,930	28,980	1,135?	150	50?	130?	130?	*			
122A1	21,580	26,580	1,175	338	31	85	205	*			
122A2	22,060	26,560	1,176	336	32	80	210?	*			
122C1	20,150	26,240	1,168	327	34	80	210?	*			
122D1	20,260	26,850	1,166	352	38	75	210	*			
1	20,395	24,475	1,151	385	28	?	208	359	366	Few "shines"	
2	20,370	22,985	1,139	363	22	70	?	267	286	do.	
3	21,325	22,985	1,142	360	15	65	?	245	250	"Shines"	
4	21,340	23,905	1,154	380	?	?	?	251	264	"Silicate"	
5	21,390	23,780	1,154	377	25	83	195?	314	362	"Shines"	"Shines."
6	21,410	23,690	1,152	367	22	77	195?	296	342	1.07	-
7	21,370	23,430	1,150	385	22	70	198?	290	360	"Shines"	
8	22,060	24,340	1,166	340	38	65	195?	*			

TABLE 3. - Pertinent data abstracted and interpreted from logs of holes churn-drilled by private interests on various properties (Con.)

Hole	Location coordinates		Collar elevation	Depth drilled	Depth below collar (feet)			Zinc-lead horizons			
								Interval, feet		Content, percent	
	North	East	(f.a.s.)	(feet)	Base of residuum	Top of M bed	Top of N bed	From-	To-	Zinc	Lead
1	20,340	22,300	1,156	292	28	95?	195?	240	292	"Shines"	
2	20,650	22,270	1,144	360	30	70	195	*		do.	
3	20,820	21,420	1,126	339	20	40	185	*			
4	20,550	20,790	1,130		Log not available.						
5	20,410	20,700	1,132	350	35	70	185	*			
6	20,340	20,820	1,134	325	65	83	170	*			
105H1	21,170	19,460	1,115	367	35	65	150?	135	150	7.02	-
105H2	20,960	19,560	1,125	319	27	70	190?	*			
105H3	20,840	19,550	1,136	316	28	70	165?	*			
105H4	21,110	18,540	1,117	275	17	?	165?	*			
105C1	22,830	17,580	1,128	277	30	?	145?	*			
105G1	20,440	17,890	1,134	301	35	65	140?	*			
105F1	21,850	17,960	1,104	297	30	60?	130?	*			
112A1	19,810	17,270	1,149	345	35	75	220?	*			
112A2	19,510	17,310	1,153	355	35	75	?	*			
112A3	18,910	17,310	1,156	367	40	75	180?	*			
112O1	18,520	17,310	1,154	366	30	80	180	*			
AZ-1	12,600	19,180	1,115?	256	20	120	210?	*			
AZ-2	12,600	19,530	1,110?	216	20	140	-	*			
				(Cherokee shale and sandstone, 20 to 45 feet)							
AZ-3	12,750	19,875	1,110?	237	15	122	205?	*			
				(Cherokee shale and sandstone, 15 to 40 feet)							
				(Chester limestone and shale, 40 to 80 feet)							
1	13,040	25,070	1,075?	151	28	28**	55?	140	143	"Shines"	
2	12,980	25,180	1,070?	143	28	28**	55?	115	135	do.	
3	12,340	25,060	1,052	132	30	30**	50?	115	120	"Trace"	
4	13,280	25,170	1,090?	170	25	25**	75?	155	165	do.	
5	13,600	25,630	1,104?	169	30	30**	80?	*			
6	13,570	25,820	1,104?	143	60	60**	102?	*			

* No zinc or lead mineralization in log.
** Upper part of M bed removed by erosion.

TABLE 4. - Pertinent data abstracted from logs of holes churn-drilled by Bureau of Mines in 1946 on Winchester property, N1/2 sec. 4, T. 25 N., R. 33 W.

Hole	Location coordinates		Collar elevation (f.a.s.)	Depth drilled (feet)	Depth below collar (feet)			Zinc-lead horizons			
					Base of residuum	Top of M bed	Top of N bed	Interval, feet		Content, percent	
	North	East						From-	To-	Zinc	Lead
SF-1	18,630	23,655	1,156	360	29	85	210	280	295	2.14	-
								295	342	.70	-
SF-2	18,550	23,670	1,157	395	25	80	205	275	282	1.35	-
								282	305	.42	-
								305	322	2.54	-
								322	360	.80	-
SF-3	18,815	23,920	1,151	365	25	85	210	305	322	2.29	-
								322	330	.81	-
SF-4	18,850	23,955	1,152	370	25	87	210	300	310	.89	-
								310	322	1.97	-
								322	340	.87	-
SF-5	18,770	23,935	1,152	375	20	80	205	330	347	1.04	-
								347	360	2.21	-
								360	365	.52	-
SF-6	18,970	24,165	1,153	370	15	80	210	295	330	1.38	-
SF-7	18,880	24,205	1,143	379	19	68	195	290	340	"Traces"	-
SF-8	19,060	24,125	1,154	380	29	93	215	305	345	1.05	-
SF-9	18,955	24,050	1,153	380	30	90	220	330	340	.59	-
SF-10	18,900	24,050	1,152	380	20	87	215	305	317	1.00	-
								317	325	2.06	-
								325	345	.66	-
SF-11	18,475	23,605	1,159	395	20	83	203	275	330	4.21	-
								330	357	1.80	-
								357	395	.84	-
SF-12	18,370	23,560	1,159	365	25	78	195	305	335	"Traces"	-
SF-13	18,385	23,530	1,161	370	20	80	210	310	370	do.	-
SF-14	18,420	23,515	1,160	376	20	80	210	290	362	.77	0.18
SF-15	18,450	23,490	1,160	370	30	85	215	280	295	0.43	-
								310	325	2.24	-
								325	330	.43	-
SF-16	18,480	23,465	1,160	370	20	85	215	285	310	.77	-
								310	327	2.35	-
								327	355	.89	-
SF-17	18,340	23,320	1,162	363	20	83	210	295	330	.55	0.08

TABLE 5. - Pertinent data abstracted from logs of holes churn-drilled by Bureau of Mines, 1954-57

Hole	Location coordinates		Collar elevation (f.a.s.)	Depth drilled (feet)	Depth below collar (feet)				Zinc-lead horizons			
	North	East			Base of residuum	Top of M bed	Top of N bed	Top of R bed	Interval, feet From-	To-	Content, percent Zinc	Lead
R-1	8,880	25,196	981	608	16	277	330	385	390	415	Trace	-
R-2	7,237	26,336	942	233	12	12*	45	70	-	-	-	-
R-3	7,451	26,188	945	260	17	17*	45	75	45	60	Trace	-
									250	260	do.	-
R-4	8,390	26,173	952	260	15	15*	45	70	-	-	-	-
R-5	8,687	26,038	957	255	35	35*	45	80	-	-	-	-
R-6	20,080	24,600	1,150	390	40	172	235	305	225	245	"Specks."	
									280	320	Do.	
									360	390	"Specks and traces."	
R-7	20,080	23,600	1,145	380	38	70	190	265	255	280	Do.	
R-8	19,950	19,950	1,127	307	(Unconsolidated)		215?	270	210	240	0.06	0.26
R-9	21,200	19,570	1,113	230	25	66	169	-	-	-	-	-
R-10	20,325	18,200	1,128	378	35	68	170	240	225	230	-	"Trace."
									305	315	"Trace"	-
R-11	20,600	25,500	1,163	400	29	80	210	295	380	387½	.12	-
									387½	400	"Specks."	
R-12	15,800	21,350	1,123	365	20	50	170	245	245	275	Do.	
									360	365	"Trace."	
R-13	19,100	23,700	1,156	371	29	91	213	280	305	320	"Specks."	
									363	371	Do.	
R-14	20,600	25,700	1,163	362	25	79	200	295	260	325	Do.	
									325	332½	.18	.04
R-15	15,800	21,850	1,105	280	15	25	150	225	240	260	"Specks."	
R-16	19,100	23,300	1,158	335	25	80	210	285	-	-	-	-
R-17	20,600	25,600	1,163	402	25	80	210	295	240	270	"Traces."	
									270	385	.71	.03
R-18	15,200	22,500	1,113	365	39	49	160	203	-	-	-	-
R-19	17,775	22,000	1,157	385	25	85	210	300	265	280		"Trace."
									325	385	"Specks"	
R-20	20,300	21,050	1,132	370	30	68	175	275	280	290	"Trace"	
									305	370	"Specks"	-
R-21	15,388	22,351	1,102	241	30	37	145	210	-	-	-	-

R-22	17,600	22,410	1,154	350	33	79	203	290	250	295	"Specks"	"Specks."
									295½	307½	1.40	0.01
									307½	312½	.40	.01
									312	350	"Specks"	
R-23	17,648	22,322	1,147	355	25	79	190	283	283	355	"Traces"	
R-24	20,300	20,240	1,120	335	8	?	162?	272	250	255	"Trace"	
R-25	15,800	20,800	1,152	406	36	97	190	242	-	-	-	-
R-26	17,576	22,453	1,155	341	33	82	200	285	275	295	"Specks"	
									295	310	2.62	.41
R-27	20,080	24,985	1,153	360	27	93	215	302	340	355	"Specks"	"Specks."
R-28	15,800	21,000	1,147	333	36	85	198	260	-	-	-	-
R-29	17,925	23,090	1,161	350	27	84	213	293	293	320	"Trace"	"Specks."
R-30	20,080	24,250	1,148	365	15	122	218	313	122	130	"Specks"	-
									315	320	-	"Specks."
R-31	11,060	25,675	1,009	245	10	10*	35	98	55	60	1.13	1.45
									85	100	2.56	.07
									100	110	.93	"Trace."
									120	135	.27	Do.
R-32	18,002	23,024	1,160	324	28	86	220	297½	280	305	.55	.04
									305	315	3.23	-
									315	322	.67	-
R-33	20,080	24,350	1,149	100	29	Not reached			-	-	-	-
R-34	11,343	25,576	1,015	141	10	10*	30	105	60	67½	2.37	.09
									85	107½	.87	-
									107½	141	"Trace"	
R-35	20,080	24,885	1,154	75	15	Not reached			-	-	-	-
R-36	20,080	24,750	1,152	105	13	do.			-	-	-	-
R-37	11,157	25,648	1,011	124	12	12*	33	95	40	110	1.70	.02
R-38	18,041	22,992	1,161	336	30	86	215	300	300	327½	2.40	-
R-39	20,080	24,485	1,149	90	30	Not reached			-	-	--	-
R-40A	10,930	25,560	1,007	135	35	*	35?	100	-	-	-	-
R-41	21,200	24,200	1,157	340	37	89	210	300	200	207½	0.15	0.10
									252½	260	1.44	"Trace."
									305	320	.29	.04
R-42	11,118	25,865	1,015	125	10	10*	45	100	85	107½	1.95	.07
R-43	17,930	23,800	1,163	381	32	81	210	300	300	340	"Specks"	
R-44	11,855	26,426	1,055	170	25	25*	70	147½	120	155	1.75	-
									155	170	"Trace"	-

TABLE 5. - Pertinent data abstracted from logs of holes churn-drilled by Bureau of Mines 1954-57 (Con.)

Hole	Location coordinates		Collar elevation (f.a.s.)	Depth drilled (feet)	Depth below collar (feet)				Zinc-lead horizons			
	North	East			Base of residuum	Top of M bed	Top of N bed	Top of R bed	Interval, feet		Content, percent	
									From-	To-	Zinc	Lead
R-45	19,100	24,690	1,149	365	25	68	203	300	305	315	0.43	-
									315	325	1.65	-
									325	357½	.38	-
R-46	19,184	24,507	1,149	380	23	75	200	297½	220	227½	-	0.21
									275	290	.41	-
									290	300	1.55	-
									300	310	.77	-
									310	327½	1.71	-
									327½	347½	.38	-
R-47	19,615	25,276	1,157	350	24	79	203	295	-	-	-	-
R-48	19,840	25,173	1,157	385	28	89	220	313	325	335	.05	-
									335	352½	.41	-
									352½	385	"Specks"	-
R-49	19,746	25,205	1,157	375	28	89	203	297	325	370	.44	-
R-50	19,673	25,210	1,157	380	27	85	208	297	315	360	1.78	-
									360	380	"Trace"	-
R-51	16,681	21,273	1,158	330	40	82	208	285	290	305	"Specks"	-
R-52	17,000	21,272	1,160	275	38	84	202	273?	-	-	-	-
R-53	17,080	21,271	1,160	325	35	84	203	270	260	285	"Specks"	-
R-54	17,000	20,070	1,151	335	31	92	203	300	165	190	2.59	-
R-55	17,000	20,400	1,153	327	37	92	220?	270	165	185	1.10	.23
R-56	20,541	25,793	1,162	350	28½	79½	195?	288	315	327½	1.36	-
R-57	21,200	26,950	1,174	330	32	81	208	277½	277½	285	.41	-
									285	310	"Trace"	
R-58	21,200	26,550	1,171	385	32	84	213	295	260	267½	1.56	-
									330	360	.26	-
R-59	21,200	26,750	1,172	365	39	80	208	280	250	285	"Trace"	-
R-60	20,600	23,030	1,141	330	24	60	190	280	260	267½	do.	-
R-61	20,600	23,330	1,145	325	25	66	178	270	-	-	-	-
R-62	21,800	24,750	1,161	374	30	100?	210	296	75	85	.75	.43
									100	107½	1.09	-
									220	245	2.18	-
									280	285	1.32	-
									340	367½	.80	-

R-63	21,800	25,000	1,162	385	45	128?	195	285	85	95	0.49	0.09
									235	245	1.60	-
									260	267½	1.60	-
									267½	280	.71	-
									290	300	.53	-
									325	347½	.50	-
									370	380	.50	-
R-64	21,202	25,251	1,164	345	33	80	210	296	270	305	"Trace"	-
R-65	20,599	25,174	1,159	346	28	79	205	292	275	280	-	"Trace."
R-66	21,803	25,169	1,164	330	38	72½	199	280	-	-	-	-
R-67	9,003	25,110	988	396	25	?	193	303	70	75	.18	-
									95	120	.40	-
									120	165	2.21	-
R-68	17,000	20,550	1,154	314	39	89½	203	275	-	-	-	-
R-69	9,105	25,040	996	375	35	110?	165?	265?	120	145	.18	-
R-70	17,280	21,269	1,160	323	34	83	203	275	260	267½	1.77	-
									282½	290	-	.10
R-71	17,600	21,283	1,159	324	42	78	195	270	270	300	"Specks"	-
R-72	8,675	25,339	989	311	50	?	115?	200	205	267½	.61	-
									267½	280	1.72	-
									280	300	.47	-
R-73	20,300	19,890	1,126	367	40	75?	185	275	72	77½	.22	.41
									100	115	1.02	-
									195	235	2.24	-
									320	330	.15	-
R-74	8,591	25,394	989	295	20	?	100?	194	215	232½	1.72	-
									232½	240	.67	-
									250	272½	.67	-
									272½	280	1.52	-
									280	290	.53	-
R-75A	9,270	24,933	1,012	362	70?	70?	173	273	330	340	"Specks"	-
R-76	8,775	25,249	979	134	10	Not penetrated			-	-	-	-

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