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BASELINE STREAM QUALITY DATA FROM NURE GEOCHEMICAL RECONNAISSANCE IN THE SOUTHEASTERN UNITED STATES

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ABSTRACT — The United States Department of Energy is sponsoring a geochemical reconnaissance of the continental United States as part of the National Uranium Resource Evaluation (NURE) program. The Savannah River Laboratory is responsible for sample collection, elemental analyses, and data interpretation in portions of thirty-seven states.

The primary purpose of the present paper is to call attention to the potentially valuable data on water quality contained in the NURE data base. Alkalinity, conductivity, and pH measurements from over 15,000 small streams are summarized. Strong geologic control of these measurements is evident and results in rather extreme regional variations in water quality.

As these and other data from the NURE program become available, they will provide invaluable baseline data for environmental studies.

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INTRODUCTION

A hydrogeochemical and stream sediment reconnaissance (HSSR) of the continental United States is being conducted as part of the National Uranium Resource Evaluation (NURE) Program of the U.S. Department of Energy (DOE). The Savannah River Laboratory (SRL) has primary responsibility for conducting the HSSR survey in 30 eastern and 7 western states.

In the eastern United States (from Louisiana to Maine and east of the Mississippi River), small streams are being sampled at a density of about one site per 20 km^2. Field measurements made at each site include alkalinity, conductivity, and pH of the stream water. Ground water (well and spring) sites are similarly sampled. Sample collection techniques have been described[1] and include rigorous calibration of pH and conductivity meters.

The purpose of this paper is to call attention to the availability of this data base for subsequent environmental and earth science studies and to summarize some general features of the stream water quality data. Detailed results of geochemical

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sampling and analyses for uranium and related elements will be discussed elsewhere.

RANGE OF DATA

Figure 1 is a plot of pH *vs.* conductivity for 16,000 sites; predominantly from the Piedmont of Alabama through southern Virginia, but including some Valley and Ridge and upper Coastal Plain areas. The range of apparently natural pH values that can be deduced from this figure extends from about 4.2 to 9.8. Some (but not all) values outside this range have an identifiable artificial influence. Although not apparent from this figure, pH distribution is multi-modal with peaks at 5.4 (upper Coastal Plain samples), 6.0 and 7.4 (Piedmont) and 8.6 (Valley and Ridge).

Figure 2 is a plot of alkalinity *vs.* conductivity for the same stream sites included in Figure 1. These combined data approach a log-normal distribution with apparent peaks in the distribution at 0.04 meq/L (upper Coastal Plain), 0.25 to 0.45 meq/L (Blue Ridge and Piedmont), and 2.4 meq/L (Valley and Ridge and parts of Piedmont).

Conductivity ranges from less than 10 μmhos/cm to $\sim 10^4$ μmhos/cm. Apparent peaks in the log-normal distribution are at 20 (upper Coastal Plain), 40 (Blue Ridge), 80 (Piedmont), and 300 μmhos/cm (Valley and Ridge).

Details of the distribution of these measurements are taken from specific area reports.[2,3]

DISCUSSION

Very few papers in the literature discuss the variation of water quality parameters with local geology,[4,5,6] and none to our knowledge discusses systematic regional variations in water quality such as may be seen in the SRL-NURE data.

Gibbs[7] has discussed factors controlling surface water chemistry. He points out that precipitation defines the initial water quality, that equilibration with rocks (rock dominance) within the drainage basin is a second major factor, and that evaporation and crystallization form a final control on water chemistry. Mature waters may eventually approach the composition of sea water.

SRL samples are collected from small streams within 10 to 25 sq km drainage units where water quality parameters are most likely to reflect influence of specific factors in the drainage basin. Larger streams combine water from several sources, so that factors controlling the water chemistry might not be apparent.

Figure 3 shows the distribution of pH values for small streams in the Spartanburg 1° × 2° quadrangle.[2] Regional geologic divisions are also given. Note that the areal distribution is distinctly non-random. There may be many tens of contiguous square miles where the pH of small streams falls within a narrow range, including extremes of the observed total range. A close correlation between the pH values from small streams and local geology is evident. Streams draining the upper Coastal Plain (Sand Hills area) have an average pH of about 5, and few exceed a pH of 6.5.

The area of high pH values at 81°20'W, 34°20'N may correspond to an area of previously unmapped felsic volcanics and granitoids.

The data show that pH ranges quoted in standard references as "normal" may not be normal at all for some regions. For example, in his excellent geochemistry textbook, Krauskopf (Reference 8, pp. 35 and 245) implies that pH values above 9 are very exceptional and states that streams in humid regions generally show values between 5 and 6.5. However, the entire area of Figure 3 is in a humid region, and there are clearly many tens of contiguous square miles where there are many stream pH values outside the range 5 to 6.5. Indeed, in areas of the Valley and Ridge underlain by limestone (e.g., in the Winston-Salem quadrangle[3]), stream pH values and alkalinity tend to be very high, and pH values above 9 are common.

One of the most extensive compilations and discussions of stream water pH values is that of Baas-Becking, et al.,[9] who give a range of typical stream pH values of about 4 to 9.3, with higher values reported (p. 268) as the result of photosynthetic removal of carbon dioxide which causes an increase in pH values in the afternoons of sunny days. Examination of NURE data for a few counties where high pH values were measured does not reveal any consistent trends; however, most pH values above 9.5 were measured during late afternoons of sunny days. Correlations between pH and time-of-day might not be readily apparent, because the data represent a geologically and geographically heterogeneous population with many factors influencing pH.

Abnormally high conductivity (above regional background) seems to be a good indicator of contamination of stream water. In the Winston-Salem quadrangle, the highest conductivity value is for a stream draining the Saltville, Virginia, area and may reflect the natural influence of soluble materials in the rocks. Other cases of anomalously high conductivity have been related to mining or industrial activity.

An accepted value for the lower range of natural stream conductivities is about 50 micromhos/cm (Reference 10, p. 102). This value is approximately the mean for 3761 streams in this study. Many, but not all (see Reference 3, Figure B-4), of the lower conductivity readings are from Coastal Plain streams which drain surfaces of nearly pure quartz sand.

It is not practical in a broad reconnaissance survey to measure all water constituents or parameters which might have some value in a detailed appraisal of the geochemical character of samples. Such measurements (e.g., dissolved sulfate or phosphate) would be appropriate for a detailed follow-up of areas which yielded anomalous reconnaissance samples. The existing data, however, can be interpreted to circumscribe the possible range of some unmeasured parameters.

In unpolluted stream waters, the number of dissolved species which are abundant enough to influence pH, alkalinity, or conductivity measurements is rather limited. The most likely cations are sodium, calcium, potassium, and magnesium; the most likely anions are bicarbonate, chloride, and sulfate. Titrable alkalinity in this study is almost entirely due to carbonate species.

A typical alkalinity value might be 1 meq/L. If this alkalinity is due entirely to calcium bicarbonate, the expected conductivity would be: 59.5 (1/2 Ca^{++}) + 44.5 (HCO_3^-) = 104 μmho/cm.[11] Very few samples collected by SRL exhibit a conductivity value below approximately 100 times the alkalinity value. The rather sharp boundary observed on Figure 2 confirms this ratio. Conductivity in excess of (100 × alkalinity) can be attributed to other dissolved species, and maximum limits can be placed on their concentrations.

Released NURE reports are placed on open-file at DOE offices and other selected libraries throughout the country. Copies may be obtained from the Grand Junction, Colorado, office of DOE. These reports contain not only the water quality data discussed above, but analytical data for uranium and other elements in stream sediments and ground and surface waters. Data will also be available on magnetic tape through the DOE Technical Information Center in Oak Ridge, Tennessee.

REFERENCES

1. *Savannah River Laboratory Quarterly Report, April-June 1976, Hydrogeochemical and Stream Sediment Reconnaissance-Eastern United States:* USDOE Report GJBX-27 (76). Available from DOE-GJ, Grand Junction, CO 81501.

2. Heffner, J. D. and R. B. Ferguson. *Preliminary Raw Data Release, Spartanburg 1° × 2° NTMS Area, North Carolina and South Carolina:* USDOE Report GJBX-9 (78). Available from DOE-GJ, Grand Junction, CO 81501.

3. Baucom, E. I., V. Price, and R. B. Ferguson. *Preliminary Raw Data Release, Winston-Salem 1° × 2° NTMS Area, North Carolina, Virginia, and Tennessee:* USDOE Report GJBX-66 (77). Available from DOE-GJ, Grand Junction, CO 81501.

4. Bell, H., II and G. E. Siple. Geochemical Prospecting Using Water from Small Streams in Central South Carolina: *U.S. Geol. Surv. Bull.*, 1378, 26 pp., 1973.

5. Johnson, A. H. and R. L. Reynolds, Jr. Chemical Character of Headwater Streams in Vermont and New Hampshire: *Water Resour. Res. 13(2)*, 469-473, 1977.

6. Price, V. and P. C. Ragland. Ground Water Chemistry as a Tool for Geologic Investigations in the Southeastern Piedmont: *Southeastern Geol., 9(1)*, 21-38, 1978.

7. Gibbs, R. J. Mechanisms Controlling World Water Chemistry. *Sci., 170*, 1088-1090, 1970.

8. Krauskopf, K. B. *Introduction to Geochemistry:* McGraw-Hill, Inc., New York, 721 pp., 1967.

9. Baas-Becking, L. G. M., I. R. Kaplan, and D. Moore. Limits of the Natural Environment in Terms of pH and Oxidation-Reduction Potentials: *J. Geol. 68*, 243-284, 1960.

10. Hem, John D. Study and Interpretation of the Chemical Characteristics of Natural Water, 2nd Ed., *U.S. Geol. Surv. Water Supply Pap. 1473*, 363 pp., 1970.

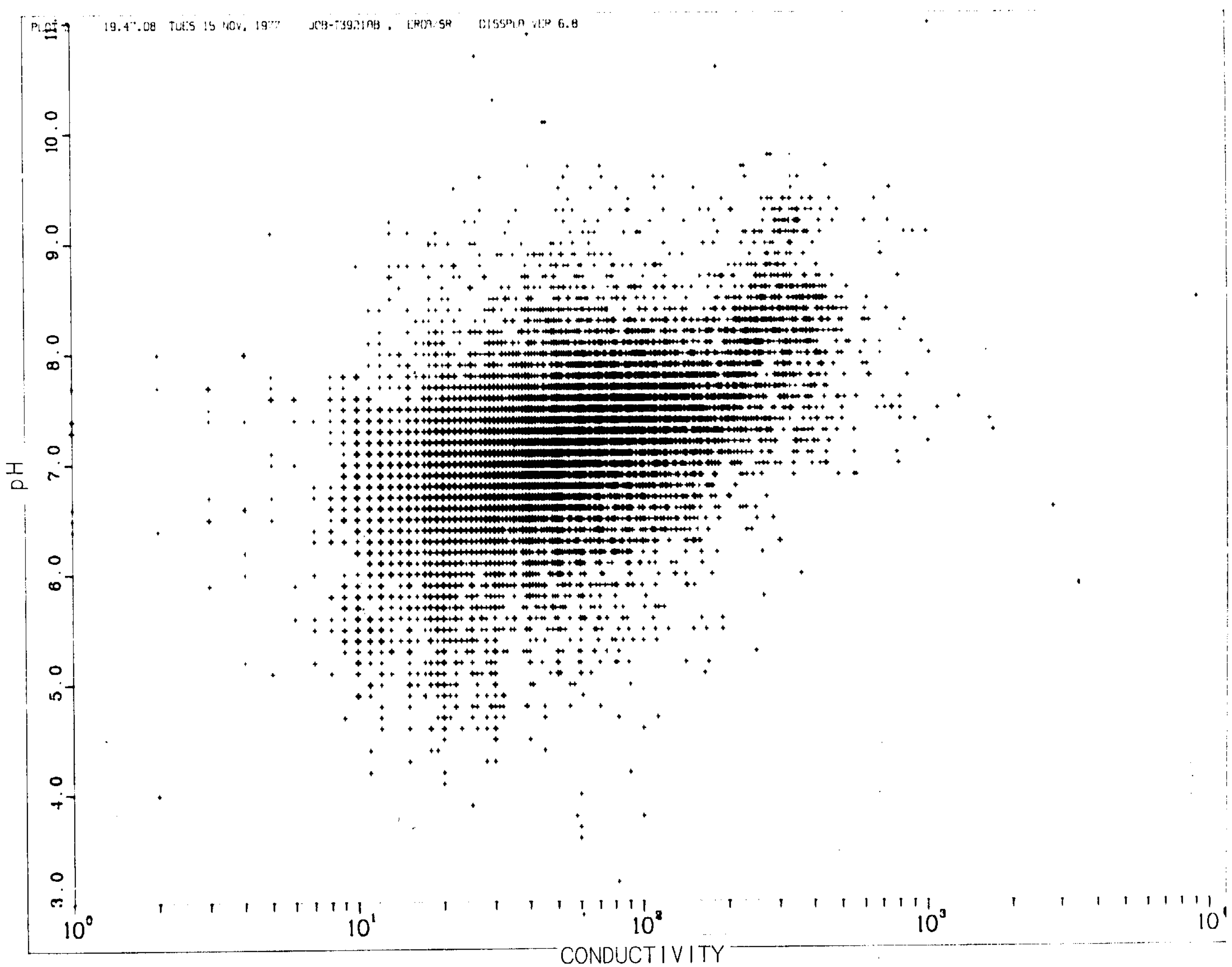
11. Moore, W. J., data from page 337 of *Physical Chemistry:* 3rd Ed., Prentice-Hall, Inc., Englewood Cliffs, NJ, 844 pp., 1962.

LIST OF FIGURES

Fig. 1. pH *versus* log conductivity

Fig. 2. Log alkalinity *versus* log conductivity

Fig. 3. Distribution of pH values in small streams of the Spartanburg 1° × 2° NTMS quadrangle



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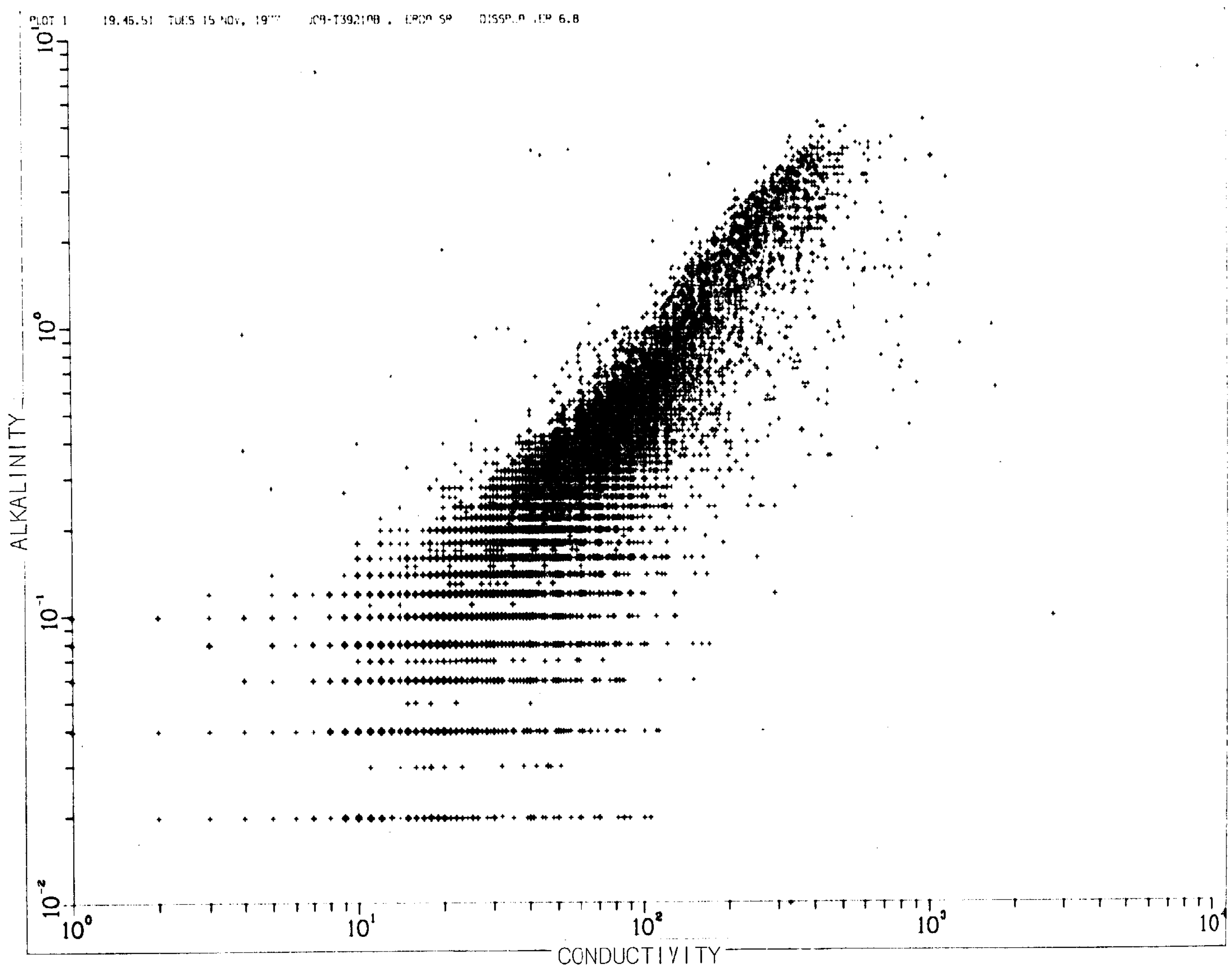
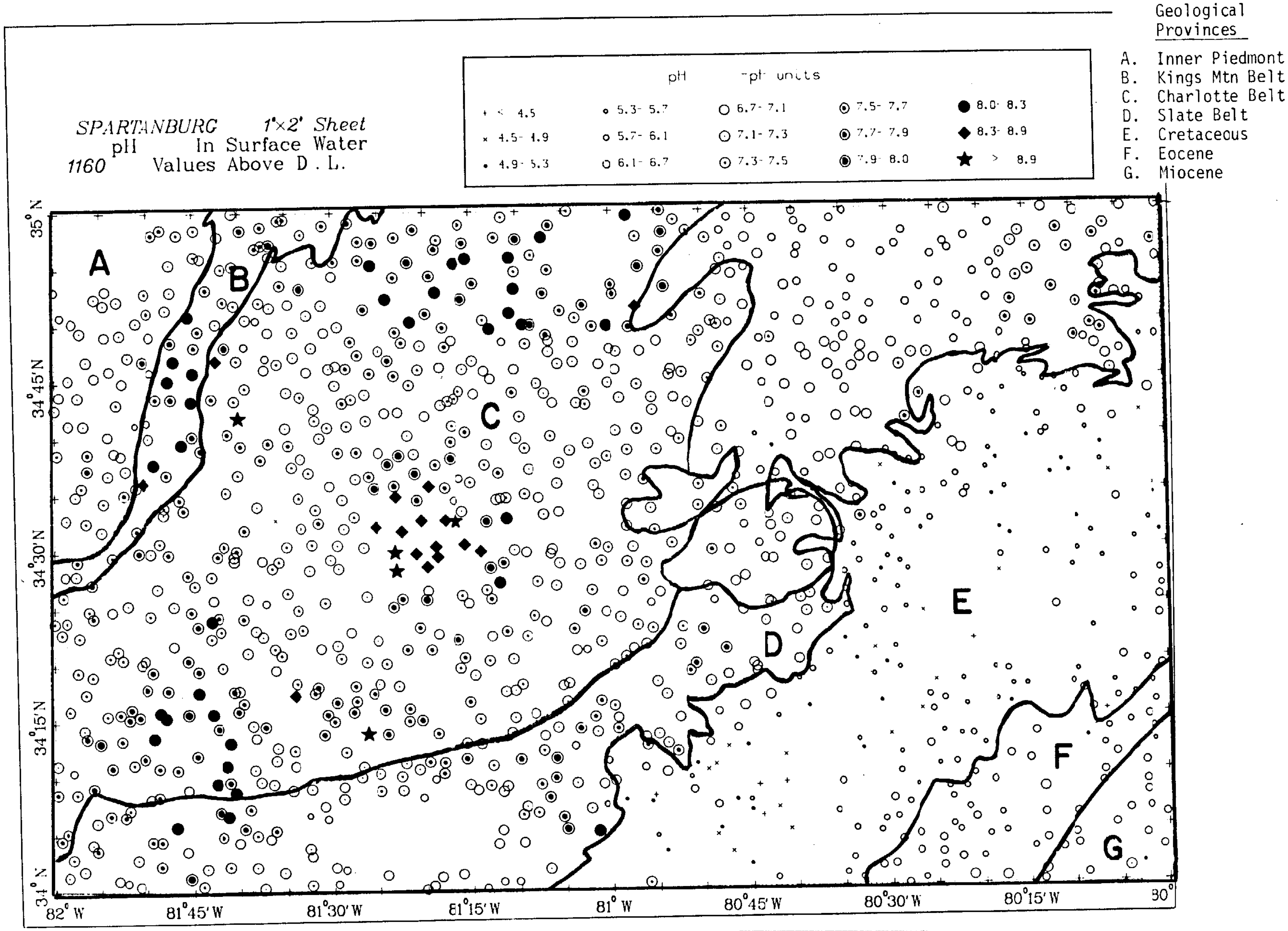


Fig. 2. Log alkalinity *versus* log conductivity



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