Geology
GJBX-(80)-97

GJBX- 97 '80

Bendix Subcontract: 79-308-E

World Class Uranium Program

INVESTIGATIONS OF THE URANIUM POTENTIAL ALONG THE PROTEROZOIC UNCONFORMITY IN THE VAN HORN AREAS, TEXAS

FINAL REPORT

Donald M. Davidson, Jr.
Principal Investigator

Mr. Gerald Edwards
Dr. Philip C. Goodell
Dr. G. Randy Keller
Co-Investigators

Department of Geological Sciences
University of Texas at El Paso
El Paso, Texas 79968

April 1980

GEOLOGICAL SURVEY OF WYOMING

PREPARED FOR U.S. DEPARTMENT OF ENERGY
Assistant Secretary for Resource Applications
Grand Junction Office, Colorado

metadc958476

This report is a result of work performed by Science Applications, Inc., through a Bendix Field Engineering Corporation Subcontract, as part of the National Uranium Resource Evaluation. NURE is a program of the U.S. Department of Energy's Grand Junction, Colorado, Office to acquire and compile geologic and other information with which to assess the magnitude and distribution of uranium resources and to determine areas favorable for the occurrence of uranium in the United States.

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

ABSTRACT

A 350 km^2 area was examined and systematically sampled in the vicinity of Van Horn, Texas for purposes of assessing the potential for non-sandstone type uranium deposits in the Precambrian units exposed there. In addition four anomalous areas previously identified in the NURE program were critically evaluated for resource potential.

Over 300 rock samples were prepared and chemically analyzed for 30 elements, including U, Th, and K. Three areas rendered anomalous values of radioactive elements (3x-10x background) and may be seriously considered as potential sites of "Proterozoic-type" uranium mineralization. Examination of anomalies related to the NURE program proved negative.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

INTRODUCTION

Purpose

The purpose of this study was to investigate an area in the vicinity of Van Horn, Texas in order to assess the potential for non-sandstone type uranium mineral resources (Fig. 1). This research effort focused on geological units of Precambrian age which were remapped (in part), selectively sampled, and chemically analyzed. Results of the present study together with available geological, geophysical and geochemical data were then compiled and compared with standard criteria of recognition which are presently accepted and utilized in the exploration for such deposits.

The Van Horn area was selected not only because the Precambrian rocks there have proven mineral resources (King and Flawn, 1953), but because the lithologies and structural relationships exhibited by these Proterozoic units indicated considerable potential for the occurrence of non-sandstone type uranium anomalies. "World-class" Proterozoic unconformity-type deposits (Kalliokoski, et al., 1978; Hegge and Rountree, 1979; Dahlkamp, 1978; Hoeve and Sibbald, 1978), were of particular interest although volcanic regimes (Goodell, 1979) were also considered. Moreover, this present investigation provided detailed ground truth data necessary for the evaluation of anomalies detected in a previous gamma-ray and aerial magnetic survey of the Van Horn 2° quadrangle conducted as part of the NURE Programm (Geometrics, 1978).

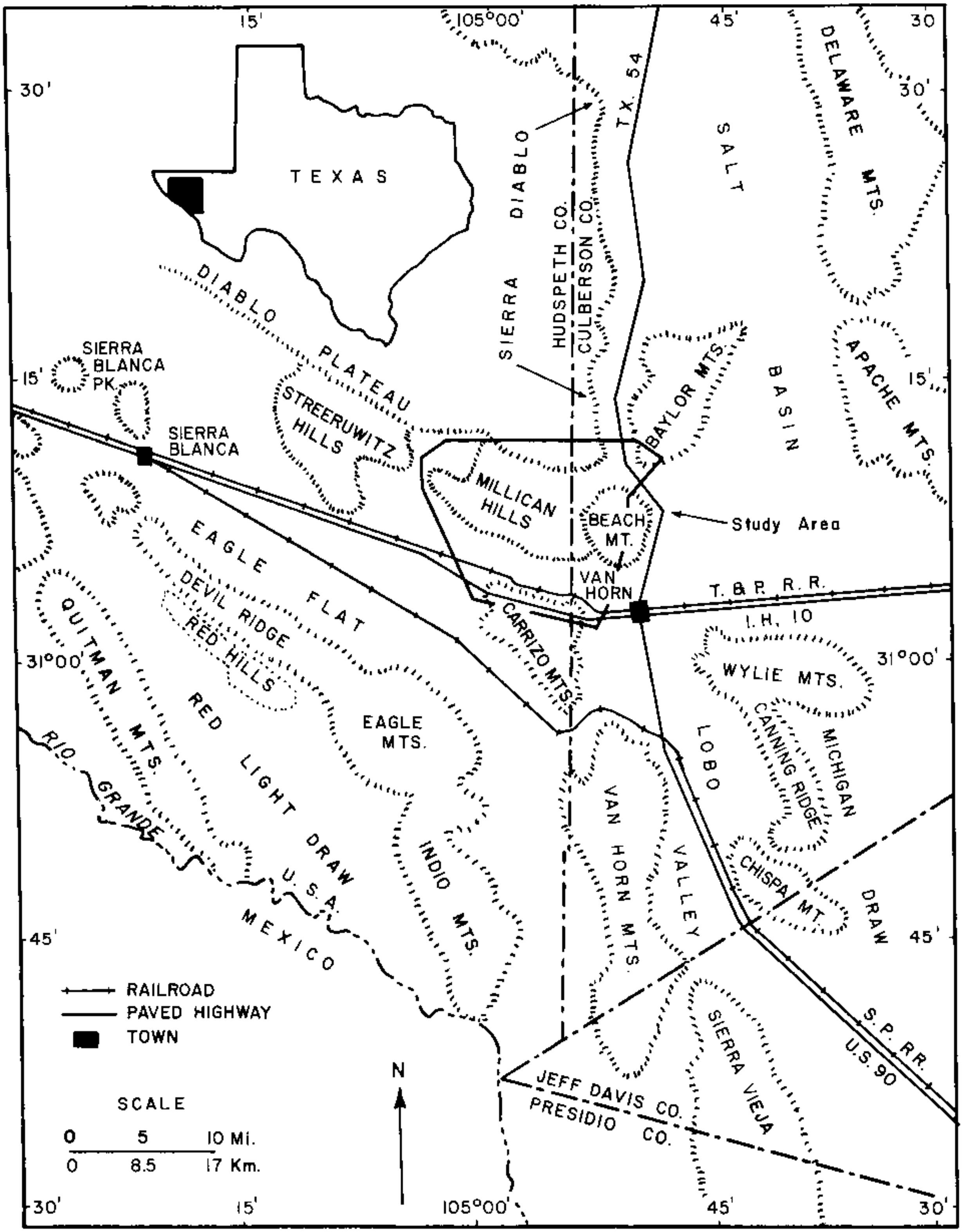


Figure 1. Physiographic map of part of Trans-Pecos, Texas (after Wylie, 1970).

Area of Investigation

The study area is trapezoidal in shape and comprises approximately 360 square km (225 square mi) within the Trans-Pecos region of west Texas (Fig. 1). The northern boundary of the area extends from 24 km (15 mi) northwest of the city of Van Horn and west of state highway 54 in a west-south westerly direction along the foothills of the Sierra Diablo Plateau, a distance of some 24 km (15 mi). The southern boundary extends from 5 km west southwest of Van Horn and south of Interstate Highway 10 approximately 11 km (7 mi) due west.

Model Deposits

Two idealized "type" or "model" uranium deposits can be utilized in exploration for uranium in the Van Horn area. The first type is the "Proterozoic-unconformity" or "vein-breccia" model (Kalliokoski, et al., 1978) and the second is in direct association with volcanic rocks (Goodell, et al., 1979).

The first type of deposit, the Proterozoic unconformity or vein-breccia type, occurs in or near breccia zones within fractured, carbon-rich basement rocks near unconformities with overlying unmetamorphosed fluvial strata of Proterozoic age (Deery, 1973). Examples of this class of deposit are world renowned and include those in western Saskatchewan (Rabbit Lake, Key Lake, Cluff Lake and Beaver Lodge) and in the Northern Territory of Australia (Rum Jungle, Pine Creek, Alligator River). These deposits consist dominantly of pitchblende and exhibit a fair degree of structural control along fault zones togther with extensive wallrock alteration (Fig. 2).

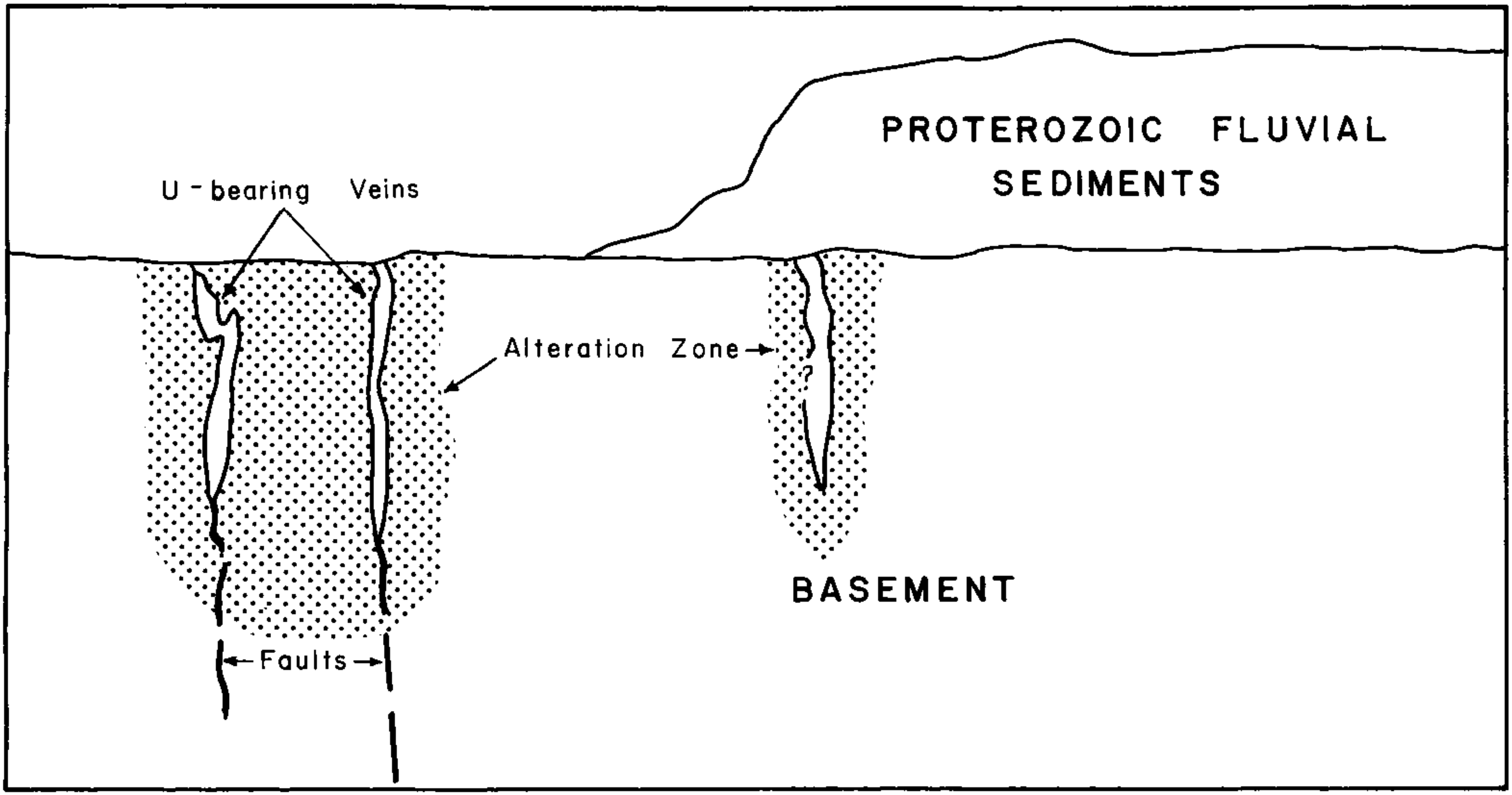


Figure 2. Idealized representation of the occurrences of "Proterozoic - unconformity" type uranium deposits.

The origin of this class of deposit is somewhat controversial. Some such deposits have been interpreted as being of primary, epigenetic, "hydrothermal" origin (Deery, 1973) whereas other deposits are interpreted as being syngenetic in origin. The latter deposits are explained by the *in situ* leaching of uranium by oxidizing solutions in porous, fluvially-derived cover rocks of Proterozoic age). Uranium is ultimately precipitated along fractures in basement rocks where reducing conditions are prevalent (Kalliokoski, et al., 1978).

The application of this model to the Van Horn project resulted in close-spaced (1/4 mile) geochemical sampling and gamma-spectrometer field analysis at, above and below, the unconformity between the Van Horn Sandstone and older units in hopes of detecting distinctive anomalies.

The second type of deposit is that in which uranium mineralization is found to occur as a direct result of concentration through volcanic activity. Specifically such deposits occur in ash-flow tuff sheets, frequently associated with rhyolite, of peralkaline composition. Noted examples include Pena Blanca, Chihuahua City, Mexico (Goodell, et al., 1979) the McDermitt Caldera Complex, Nevada (Rytuba and Conrad, 1979), and Marysvale, Utah (Cunningham et al., 1980), and elsewhere world-wide.

Such deposits are commonly associated with caldera formation and attendant ring fracture development, and resurgance. In many cases uranium appears to have been deposited from fluorine-rich solutions. Alteration may be present, and is generally of low intensity and variable degree of development.

The consideration of volcanogenic uranium deposits of Precambrian age as a valid target for the development of resource potential is emphasized by the recent report of significant occurrences of commerical grade deposits in Proterozoic tuffs in Labrador (Gandhi, 1978). The Carrizo Mountain Group in the Van Horn area appears to be a part of a widespread Precambrian ignimbrite province, including the Franklin Mountains, west Texas, and perhaps as far east as the St. Francoise Mountains of Missouri.

The application of this model to the Van Horn project results in closed-space (1/4 mile) geochemical sampling and gamma spectrometer field analysis of units of the Carrizo Mountain Group, including rhyolite volcanics to determine whether anomalies exist.

Logistics

Field work on this project required six weeks of intensive effort and involved minor remapping of the geology (1:62,500), geochemical sample collection and field readings of geophysical data. Three hundred and forty (340) samples (3 kg) were collected at not less than one quarter mile intervals along, below or at the unconformity underlying the Van Horn Sandstone for purposes of obtaining analyses on selected trace or major elements. Because of the excellent control on sample location and bedrock lithology it was not necessary to sample either stream sediment or ground waters in the area. Pre-existing geologic maps (King and Flawn, 1973) were used for sample location and the geologic information on them was ammended during the collection process as deemed necessary. In addition, readings on equivalent U, Th and K values were obtained at all sample locations using a Geometrics Model CP x-21, portable gamma spectrometer and Model Gr-40 recorder. A gravity survey was completed in and adjacent to the northeast corner of the area for purposes of completing the gravity data file for that portion of the Trans Pecos area using a Lacoste-Romberg Model G gravity meter (Number: G-376).

The laboratory phase of this project required six weeks of effort and involved sample preparation for geochemical analysis as well as data organization. This phase commenced prior to the end of field work and was completed by the tenth week of the project.

Samples were prepared for various chemical and gamma spectrometer analyses by grinding, splitting, pulverizing and seiving each sample to -100 mesh size. Samples were chemically analyzed for selected elements at Oak Ridge National Laboratories, Tennessee utilizing neutron activation (U-NT), fluorinetry (U-Fl) or plasma source emission spectrometry (all others except As, Se). In addition 330 samples were analyzed for U, K, and Th values at the University of Texas, El Paso using a 113 cubic inch NaI-Tl activated gamma spectrometer together with a Nuclear Data Series pulse height analyzer in the 128 channel mode and a data reduction program using a Hewlett-Packard Model 9845A computer. Sample location coordinates were digitized and various specific area and base maps were constructed during this time period as well.

The interpretive phase of the project was delayed as preliminary results of the chemical analyses were not received until week 17 (of 26) and final results in week 22 (of 26). Preliminary results were coded for computer analysis using the IBM 360/65 computer at the University of Texas, El Paso. Data were treated using standard statistical routines (SPSS) including determination of means, standard deviations and factor analysis.

Acknowledgements

We would like to express our appreciation to various land owners and managers in the Van Horn area for their cooperation in this project. Specifically we would like to express our gratitude to Messrs. D. Garren, Jr., W. McVay, T. Frank, C. Dees, J. Tabor, and G. Roan III.

The chemical analyses of rock samples were performed at the Oak Ridge National Laboratory, Oak Ridge, Tennessee, and the excellent cooperation provided by R. Helgerson in this effort is noted.

In addition we would like to note the excellent assistance provided by Messrs. D. Ray and G. McDonald. Mrs. D. Wood aided in drafting certain diagrams and Mrs. S. Ladewig typed the manuscript.

GEOLOGICAL SETTING

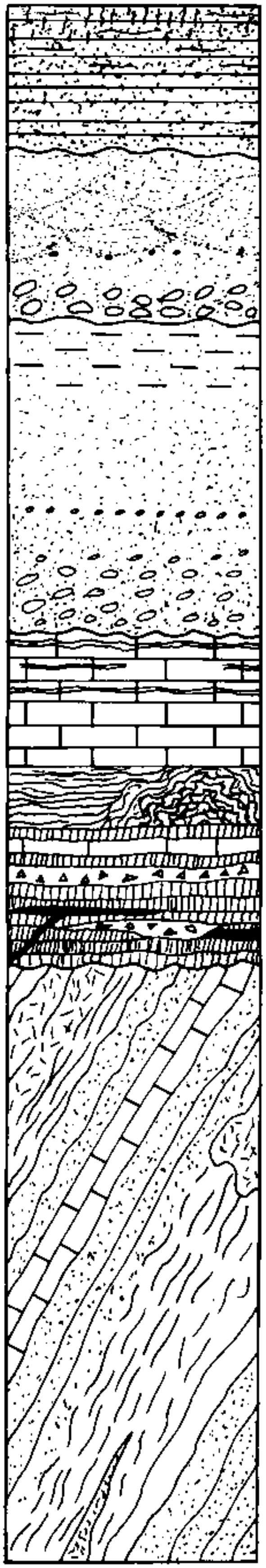
Introduction

Precambrian rocks are exposed in the Van Horn, Texas area (Plate I) as a result of block faulting of a number of adjacent, but spatially disconnected mountain ranges. The area has been referred to as the Van Horn Dome (King and Flawn, 1953), but can be considered domical only in the sense that it has tended to be a positive structural element during Phanerozoic time.

This domical physiographic structure consists of two distinctive geological terrains of Precambrian (Proterozoic) age (Fig. 3). The southern third of the area is composed of a thick (6000-7000 m) sequence of older, low- to medium-grade metamorphic rocks, while the northern two-thirds contains a thinner (3000 m) assemblage of younger, relatively unmetamorphosed sedimentary and volcanic units.

A major structural discontinuity, the Streeruwitz overthrust, forms the boundary between these two terrains and movement along this surface placed the presumably older, southern metamorphosed units over portions of the younger lithologies, locally folding them at 950-1000 m.y. (Denison and Hetherington, 1969).

Erosion and incisement of the area occurred prior to the deposition of a late Precambrian (?) clastic unit some 300 m thick the Van Horn Sandstone. The region underwent tilting prior to deposition of younger Paleozoic and Mesozoic sedimentary units which, together with the older Precambrian rocks, have been offset by faults of Tertiary age.



BLISS SANDSTONE: brown thin-bedded noncalcareous sandstone, with *Scolithus* tubes; overlain by calcareous sandstone; 105 - 125 ft. thick

Ordovician

UNCONFORMITY

VAN HORN SANDSTONE: red arkosic sandstone and conglomerate; crossbedded and unfossiliferous; 1200^{+} ft. thick

Precambrian (?)

UNCONFORMITY

HAZEL FORMATION: red fine-grained sandstone overlying and interbedded with conglomerate principally formed of fragments derived from Allamoore Fm.; 5000 ft. thick

UNCONFORMITY

ALLAMOORE FORMATION: thin- to thick-bedded cherty limestone; talcose phyllite; basaltic lava, breccia, tuff, and shallow intrusive rocks; 2500^{+} ft. thick

UNCONFORMITY

CARRIZO MOUNTAIN FORMATION: quartzite and arkosic quartzite, slate, schist, limestone, metarhyolite: cataclastically altered and in part mylonized, and greenstone: largely altered to amphibolite; 19,000^{+} ft. thick

Late Precambrian

BASE CONCEALED

Figure 3. Generalized stratigraphic column of the Precambrian and the oldest overlying Ordovician rocks, Van Horn area, Texas.

Regional Geology

Carrizo Mountain Group

The Carrizo Mountain group constitute the oldest assemblage of Precambrian rocks within the study area. These Proterozoic units occur in the southern part of the area under investigation and have been dated at 890-1090 m.y. (Wasserberg, et al., 1962).

The sequence consists of meta-arkose, metaquartzite, schist, phyllite and marble units which have been intruded by rhyolite and diorite magmas. These latter intrusive rocks have subsequently been metamorphosed to meta-rhyolite and amphibolite, respectively. The sequence is at least 6300 m thick and displays moderate homogeneity within lithologic units, yet exhibits variable metamorphic intensity as well as type of metamorphism. Regional metamorphic facies vary northward from amphibolite to greenschist. Moreover, dynamic (cataclastic) metamorphism appears superimposed upon both the earlier regional and thermal events producing retrograde and cataclastic assemblages in the vicinty of Streeruwitz overthrust zone (King and Flawn, 1973; Dennison and Heatherington, 1969).

Foliation is well developed in these units and trends predominantly N40-50E with a southeast dip. Folded foliation patterns have been noted in the high grade rocks to the south (King and Flawn, 1953) and interference fold patterns were observed in the lower grade units. According to King and Flawn (1953), lineations are developed only in metarhyolite units from the northwest part of the area where they plunge southward at 30-60°.

Pegmatites and various quartz veins appear to have intruded these units both before and after regional metamorphism (King and Flawn, 1953).

Allamore Formation

The oldest unit exposed in the northern terrian is the Allamore Formation which consists of 8000 m of volcanics, talcose phyllite and carbonate rocks. These units have been tilted and locally complexly folded and faulted. Determination of the stratigraphic sequence is therefore difficult and an estimate of total thickness is nearly impossible.

Volcanic rocks constitute from one quarter to one half of the total volume of the Allamore Formation and are often interbedded with limestone. These massive, mafic volcanic rocks apparently formed as subaerial or subaqueous lava flows while the thicker bodies which occur less frequently may represent hypabyssal intrusives. Additional volcanic units are of either pyroclastic or sedimentary origin and often include pebbly sandstones and interbedded volcanic conglomerates (King, 1965).

Phyllite occurs interbedded with or spatially associated with volcanic rocks; this suggests that the phyllite may have a volcanic origin. Bedding, as indicated by alternation of gray, black (apparently graphitic) and calcareous varieties, is extremely contorted and is crossed by well-developed slaty cleavage which parallels the axial planes of folds.

Since 1952 talc has been mined from this phyllite unit; talc content within the unit varies locally from 10-80%. The mineral may have formed as a result of chemical alteration of an original fine-grained, magnesium-bearing tuff as adjacent carbonate units contain little magnesium (King and Flawn, 1953).

The upper limestone beds are characterized by interbedded seams of chert, which parallel bedding and are spaced over intervals of a few centimeters. The chert is either primary or diagenetic and antedates folding and faulting as chert seams are sliced and broken where the rocks are strongly deformed. The limestone is thin-bedded, compact, evenly laminated, often dolomitic and frequently contains a wavy structure similar to that of stromatoporoids.

Hazel Formation

The Hazel Formation unconformably overlies the Allamore Formation and consists of more than 1700 m of interbedded conglomerate, arkosic sandstone, and limestone. The basal portion contains a thick, coarse conglomerate composed almost wholly of angular rock fragments derived from the Allamore. Near the top the conglomerate is interbedded with and eventually succeeded by a thick section of fine-grained, silty, red sandstone interbedded with well laminated, algal-bearing carbonate rocks (Reid, 1974). Reid (1974) stated that sediment of the Hazel Formation was deposited within an alluvial fan system, the sediment for which was derived from a granitic highland source area to the south.

Although the unit was apparently deposited directly upon units of the Allamore Formation, structural and stratigraphic relations between the Allamore and Hazel Formations are complex and subject to differing interpretations. King (1965) states that the contact represents a tectonic discontinuity, whereas Reid (1974) argues that it reflects a facies change as well as tectonic activity.

After deposition of the Hazel Formation, both it and the Allamore were deformed by orogenesis probably related to the structural emplacement of the Carrizo Mountain Formations and associated intrusive rocks along the Streeruwitz overthrust. For a few miles north of the trace of this thrust, the Allamore and Hazel Formations have been complexly folded. Deformation, as measured by fold intensity, appears to decrease northward with the northernmost exposures being relatively undisturbed. Thrust movement was apparently from south to north.

Van Horn Sandstone

The deformed and locally metamorphosed Allamore and Hazel Formations together with the Carrizo Mountains Formations were deeply eroded before being overlain by the Van Horn Sandstone. The sandstone has a maximum exposed thickness of about 100 m and characteristically consists of coarse-grained, red, arkosic sandstone. The unit forms massive beds, and is friable, poorly consolidated, crossbedded and contains significant amounts of pebbles and cobbles. Underlying and interbedded with the sandstone are thin to thick beds of conglomerate consisting of rounded pebbles, cobbles, and boulders made up of the older rocks of the area, as well as granite and rhyolite porphyry unlike any exposed in the vicinity. McGowen and Groat (1971) have stated that highlands to the north which are composed of granite and rhyolite porphyry were the exclusive source for the continentally derived Van Horn sediments. They believe these rocks were deposited as alluvial fans and fan deltas within an east-west-trending trough bounded on the south by deformed Carrizo Mountain, Allamore, and Hazel rocks. Most workers consider the Van Horn to be of Precambrian age (King and Flawn, 1953) as it is unfossiliferous and unlike any Cambrian rocks of the region; however, McGowen and Groat (1971) stated that it could also be as young as Ordovician.

Paleozoic and Younger Systems

The Van Horn Sandstone as well as older units were tilted and faulted prior to deposition of younger sediments. The Bliss Sandstone of Ordovician age unconformably overlies the Van Horn with a very low-angle of truncation separating the two. The Ordovician and other older Paleozoic systems have been extensively eroded from the Precambrian area as a result of deformation in late Pennsylvanian time so that in many places the formation immediately above the Precambrian is the Hueco limestone, of early Permian age (Wolfcamp). Locally within the Sierra Diablo foothills the Permian was also removed by erosion so that Cretaceous rocks lie directly on the Precambrian. Aside from unconsolidated bolson deposits of late Tertiary and Quaternary age, the only other rocks associated with the Precambrian are lavas and small intrusives, probably of early Tertiary age.

The Precambrian as well as younger associated units are broken by normal faults of Tertiary or later age. In the southern outcrops areas these faults show no systematic trend, but in the Sierra Diablo foothills most of them trend west-northwest, as do the major joints. Geologic evidence suggests that the west-northwest faults and joints of the Sierra Diablo foothills originated early in geologic time (King and Flawn, 1953). In one area in the Sierra Diablo foothills the west-northwest structures are crossed by the Hazel fracture zone, a set of en echelon, mineralized fractures with an east-west trend whose age relation to other structures is uncertain but appears younger (King and Flawn, 1953).

ANALYTICAL GEOCHEMISTRY STUDIES

Introduction

Geochemical and geological data were obtained at 340 locations and 30 element determinations were carried out on each sample using standardized NURE techniques at the Oak Ridge National Laboratory. Three elements (U, K, Th) were also determined utilizing standard techniques on 500 gram sample splits for all 340 locations at the Gamma Ray Spectroscopy Laboratory, University of Texas, El Paso. Thirty of the samples were also analyzed for organic carbon at the Oak Ridge facility.

The sample population was grouped into seven types based on factors related to their geologic occurrance. These groupings included samples from:

1. The Carrizo Mountain Group (PCCM)
2. The Allamore Formation (PCAl, PCAP, PCAV)
3. The Hazel Formation (PCNC, PCMs)
4. The Van Horn Sandstone (PCVS)
5. Along the unconformity beneath the Hazel Formation (AAAA, BBBB, CCCC)
6. Along unconformities beneath the Van Horn Sandstone with other Precambrian units (VVVV, WWWW, XXXX, YYYY)
7. Along fault contacts between the Van Horn and other Precambrian units (FVAL, FVHS)

The analytical data for 33 chemical element determinations on these 340 samples are given in microformat in Appendix A. Values for organic carbon analyses are to be found in Table A-1, while standard statistical parameters together with detection limits for the chemical determinations are given in Table A-2.

These data have been subjected to various statistical techniques. The range of variation in and frequency behavior of values for some of the elements analyzed are shown by the histograms and lognormal probability diagrams given in Figures B-1 through B-7. Significant variation between 27 elements was computed by means of correlation coefficients as shown in Appendix A. Cluster analysis was applied to these 27 elemental values and with the results are shown on the dendogram in Figure C-1. Median values maximum-minimum values, and selected percentile increments for selected elements are plotted by geologic sample type in Figures D-1 to D-9.

Discussion of Histograms, Percentile Plots and Statistical Summary Data for Elemental Analysis

The behavior of uranium is of primary interest to this study. Ninety-seven percent of the uranium values as determined by the various techniques fall below 10 ppm, however anomalous values do exist and will be discussed in more detail below. Total uranium as determined by neutron activation has a mean value of 2.95 ppm, which is slightly depleted with respect to values from granitic rocks, although typical of those from a shale-limestone mixture. The mean Th value is 6 ppm, which is lower than commonly expected, as is the average Th/U ratio of 2. Equivalent uranium has a mean value of 2.89 (Oak Ridge) and 2.90 (UTEP). These values are quite close to the mean value for total uranium (2.95), indicating that the uranium present is for the most part in secular equilibrium. The close similarity between the histogram and percentile plots for uranium utilizing these two analytical techniques is noteworthy.

The mean value of thorium at 6 ppm is lower than that commonly expected for either granites and continental sediments; similarly, the Th/U ratio of 2 is also low.

Based on results listed in Appendix A it may be observed that values for selected lithophile elements (B, Be, Li, and P) and chalcophile elements (Ag, Cu, Zn) are anomalously high while Mo is low. As discussed below, such distributions are a function of host rock lithology or geologic environment.

Discussion of Correlation Coefficients between Elemental Analyses

The correlation coefficients given in Appendix A are based on chemical variation of 27 elements analyzed. Correlation coefficients of the various elements with respect to uranium are summarized in Table B-1.

Although uranium does not correlate strongly with any element, coefficients with P, As, Y, and Zr render the highest values, ranging between 0.35 and 0.45. Ranges of values for correlation coefficients of these "uranium-sensitive" elements with others analyzed are also summarized in Table B-1, along with values for Ni.

While P, As, Y and Zr show the highest correlation coefficients with uranium, the summary provided in Table B-1 of the coefficients of P, As, Y, and Zr indicate that the geochemical environment responsible for this relationship is largely that of association with lithophile elements, particularly rare earth elements, which possibly occur in minerals such as monazite (a phosphate) and zircon. The overall high correlation values for Y, Zr, and P values with other lithophile elements in Table B-1 reinforce this interpretation. To a lesser extent uranium appears to be associated with siderophile elements, such as arsenic, which commonly occurs in a base-metal sulfide environment.

Discussion of the Dendogram (Figure C-1)

As noted from Figure C-1, uranium does not show a direct positive affiliation with any other elements. It appears remotely affiliated with phosphorous, and even less so with lithium; a general association with Ce, Sr, Ca, Mg, and Se is suggested.

General Statements Relating Element Distribution with Geologic Environment

Positve elemental affiliations with uranium include: 1) Ag, Zn, Cu; 2) Sc, V, Cr, Ni, Co, Fe; and 3) Al, Ti, K, Y, Zr. These three groupings may be geochemically classified as 1) a base-metal, chalcophile element suite; 2) a mafic, lithophile element suite, and 3) a lithophile, rare earth element suite, respectively. These geochemical affinities are characterized by various geologic environments or units which have been identified in the Van Horn area. The base-metal suite (Ag, Zn, Cu) is related to widespread polymetallic sulfide mineralization as evidenced by numerous such occurrences throughout the region, particularly in the Hazel Sandstone. Several abandoned mines are present involving small base metal sulfide deposits.

The lithophile-mafic element suite (Sc, V, Cr, Ni, Co, Fe) is apparently generated by the occurrence of numerous mafic volcanic rocks in the region particularly in the Carrizo Mountain Group. Members of this suite, such as Ni and Co, are traditional uranium pathfinders in unconformity-related geologic environments. However, as evidenced from the dendogram, Ni and Co are not closely related to uranium in this project area. The rare earth suite appears to be generated from the presence of the metamorphosed rhyolitic tuff of the Carrizo Mountain Group.

The Carrizo Mountain Group contains a metamorphosed rhyolitic, ash flow tuff which is late Precambrian in age. This unit is anomolously enriched in uranium, rare earth (Ce, Y, Nb), and lithophile elements (Be, Th, Zr) compared to other rock types of the region. Although comparisons have not been made with other Precambrian ash-flow tuffs, the values of 3.4 ppm for total uranium and 3.0 ppm for thorium appear unusually high for a tuff which has been subjected to devitrification, diagenesis, and low-grade metamorphism. It is suggested that the Carrizo Mountain Group is a possible uranium exploration source for deposits either of the Proterozoic unconformity type or of the volcanogenic-leaching model in volcanic and volcaniclastic rocks. Uranium occurrences of possible economic significance have recently been discovered in rhyolitic ash flow tuffs of Precambrian age in Labrador and in Sweden, making this suggested target quite explicit.

The total ground gamma response (Fig. D-9) was significantly higher over the Carrizo Mountain Group as expressed by a median value of 955 cps in contast to an overall average of 630 cps for all units. Ground gamma, laboratory gamma, and total uranium, responses differ between the Carrizo Mountain Group and geologic units by the same proportions, hence the CMG units are identifiable in ground surveys.

The Allamore Formation is characterized by high values of Li and P and by low values of Ce, Zr, Y, Th, Nb and Be which is directly attributable to its predominantly carbonate character.

The Hazel Sandstone, as noted above, is characterized by the presence of high values of base metal-chalcophile elements not uncommonly associated with elevated uranium values. Interestingly, Mo is low in this unit as in all others in the region.

High boron values are peculiar to the Van Horn Sandstone, although the unit does not contain noteably high uranium values.

GEOPHYSICAL STUDIES

A Bouguer gravity map was constructed for the study area based on a station spacing of approximately one mile apart utilizing data previously available in the University of Texas, El Paso gravity data bank for the Trans Pecos area together with over 100 readings carried out as part of this study. The integrated results were then compiled and are presented in Plate 2.

The Bouguer anomaly configuration in the area consists essentially of a northwest-southeast trending high ridge flanked to the northeast and southwest by basinal lows exhibiting shallow gradients (2 mgal/mi). The locus of the axis of this ridge-like high is coincident with a relatively narrow (2 mi) but steep (75 gammas/mi), magnetic gradient (Plate 3). This geophysical boundary corresponds reasonably well with the geological boundary between the Carrizo Mountain Group to the southwest and the younger Precambrian units to the northeast. The general gravity signature of the study area is typical of that for the Trans Pecos region with the basins representing accumulation of sediment and the high perhaps a fundamental structural boundary in the crust.

Although more complex in character, the magnetic signature directly reflects the nature of crustal rock types. Magnetic values were drawn on results from 3 mile-spacing flight lines obtained under the NURE program (Geometrics, 1978).

Volcanic units of the Carrizo Mountain Group form a north-south trending high (260 gammas). It is noteworthy that the magnetic trend is approximately alligned with the structural trend of these units. The remainder of the magnetic signature is more diffuse and consist of broad domes (140 gammas) and basins (120 gammas which trend roughly east-west and which represent the signature of the Late Precambrian and younger sediments comprising the area. Again the overall magnetic pattern is similar to that for much of West Texas, save for the steeper gradients coincident with the gravity ridge and the Carrizo Mountain Group.

EXAMINATION OF NURE ANOMALY SITES

Three areas previously identified as anomalous during the NURE program (Geometrics, 1978) were examined on the ground and sampled in hopes of better explaining the anomalous conditions. Unfortunately, results of these investigations proved negative with respect to offering a reasonable explanation for the NURE results. Anomaly U8 is a uranium anomaly which occurred in an area consisting of predominantely Van Horn Sandstone (Fig. 4). The area was sampled on a grid with points approximately 300 m apart. Results of this survey are shown in Table 1 and they proved negative with regard to adequate explanation for the high uranium values noted by NURE. Thorium/potassium anomalies 48 and 39 were similarly sampled (Figs. 5 and 6). These anomalies occurred in units of the Hazel and Van Horn, respectively; again results proved negative (Tables 2 and 3).

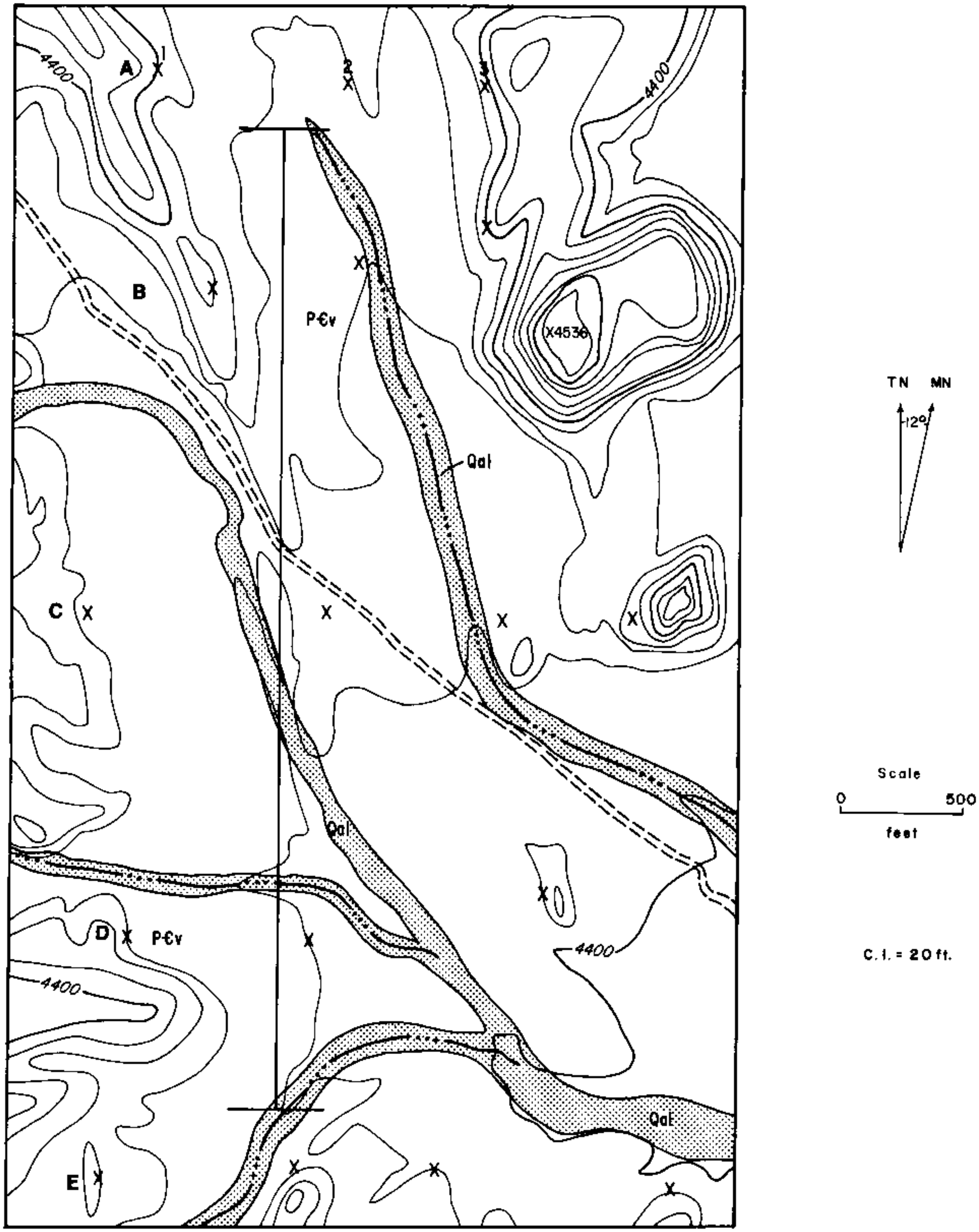
Samples were not collected for chemical analyses as anomalous values were not recorded at any of the three sites. However, comparative average values for chemically determined U, Th, K by geological formation may be found in Figures D-1 through D-9 (Appendix D).

TABLE I

Values for U, Th, K at NURE Anomaly (U8), Van Horn Area,
Measured on Gamma Spectrometer, U. T. El Paso
(see Figure 4 for sample locations)

Sample Number	Th ppm	U ppm	K %	Th/U	Th/K
A1	1.1058246	.715639536	.327606048	1.55	3.38
A2	1.0241616	.540757908	.336327648	1.89	3.05
A3	2.3073465	.815899886	.32523984	2.52	7.09
B1	1.3519383	.691863606	.323806464	.195	4.18
B2	2.0999616	.514155816	.229127808	4.08	9.17
B3	1.3358013	.918726048	.551248096	1.45	2.42
C1	1.8296424	.663250932	.344124	2.76	5.32
C2	1.3664616	.527293606	.323074608	2.59	4.23
C3	1.5507657	.651566862	.455411616	2.38	3.41
C4	.9542835	.772457094	.38860416	1.24	2.46
D1	1.5964383	.685817676	.310818864	2.33	5.14
D2	1.1284164	.467419536	.287494272	2.41	3.93
D3	1.6485657	.64914849	.305362176	2.54	5.40
E1	1.2444561	.800661978	.354263808	1.55	3.51
E2	1.6388835	.75552849	.37916208	2.17	4.32
E3	1.614189	.490787676	.30002304	3.29	5.38
E4	1.2412287	.836121978	.33019976	1.48	3.76

Figure 4. Reported uranium anomaly (U8) and survey sites for this study.



EXPLANATION

Formations:

Qal Quaternary alluvium

P€v Precambrian Van Horn Sandstone

Reported anomaly

Unimproved dirt road

Arroyo

Qal/P€v Lithologic contact

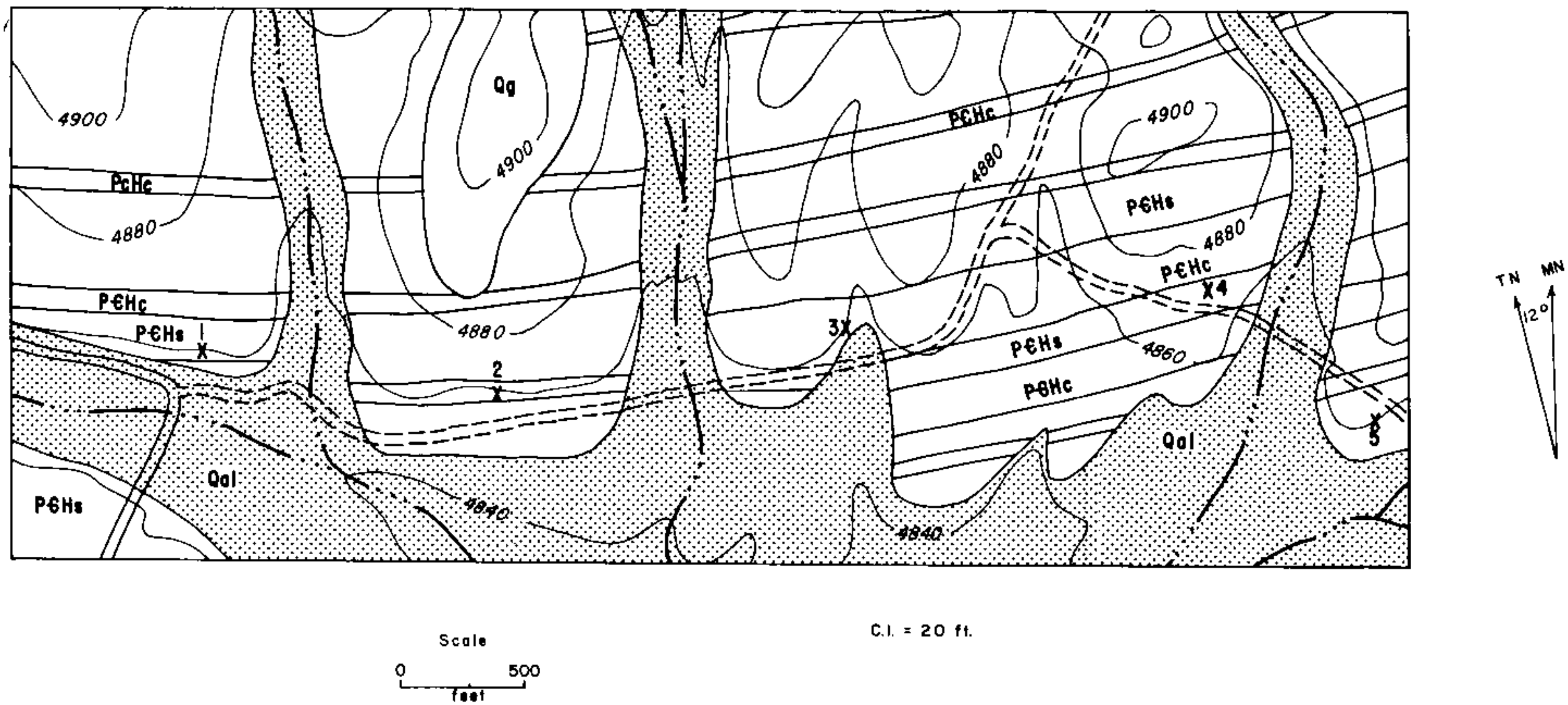
-4400- Contour line

B x3 Survey site

TABLE II

Values for U, K, Th at NURE Anomaly 48, Van Horn Area,
Measured on Gamma Spectrometer, U. T. El Paso
(See Figure 5 for sample locations)

Sample Number	Th ppm	U ppm	K %	Th/U	Th/K
1	.12375123	.340891164	.142984944	3.63	8.655
2	.8758479	.562115466	.100965792	1.56	8.675
3	.13224027	.480312792	.148847376	2.75	8.884
4	.6963849	.38965221	.161144832	1.79	4.322
5	1.3648479	.550023606	.147038592	2.48	9.282



EXPLANATION

Formations:

Qal Qg	Quaternary alluvium and older gravels
P€Hs P€Hc	Precambrian Hazel Formation; sandstone and conglomerate

= = = = =	Unimproved dirt road
—··—	Arroyo
Qal / P€Hc	Lithologic contact
—4900—	Contour line
3 x	Survey site

Figure 5. Reported thorium / potassium anomaly (Th/K 48) and survey sites for this study.

TABLE III

Values for U, K, Th at NURE Anomaly 39, Van Horn Area,
Measured on Gamma Spectrometer, U. T. El Paso
(See Figure 6 for sample locations).

Sample Number	Th ppm	U ppm	K %	Th/U	Th/K
A1	1.4529657	.653985234	.421549056	2.27	3.45
A2	.6281205	.603621396	.20364936	1.04	3.08
A3	2.0951205	.567345816	.123287568	3.69	16.99
A4	1.0472424	.823228722	.461262672	1.27	2.27
B1	1.125189	.502879536	.13450224	2.24	8.37
B2	2.2858794	.615699072	.344108832	3.71	6.64
B3	.8350164	.474674652	.371714592	1.76	2.21
B4	1.2492972	.74741978	.410267856	1.67	3.05
C2	.929589	.50771628	.13882512	1.83	6.70
C2	1.5572205	.580646862	.41632368	2.68	3.74
C3	.978489	.506507094	.3387204	1.93	2.89
C4	1.4581931	.618525234	360293088	2.35	4.04
D1	1.244263	.145861164	.12850112	8.61	9.92
D2	1.2638205	.587901978	.371616	2.15	3.40
D3	1.0031835	.771247908	.48421944	1.30	2.07
D4	1.4050794	.63746442	.520929792	2.21	2.70
E1	1.0843575	.415438	.26873904	2.61	4.03
E2	.8366301	.458817912	.396070608	1.82	2.11
E3	1.0306164	.469837908	.446873712	2.19	2.31
E4	1.0572205	.580646862	.43149168	1.82	2.45
F1	.5416164	.481929768	.116550912	1.12	4.65
F2	0193205	.593947908	.0390296	1.72	2.62
F3	2.1424068	.58386662	.416919024	3.67	5.14
F4	1.0080246	.718057908	.278575488	1.40	3.62
G2	1.0632327	2.255731164	.244917216	0.47	4.34
G3	1.17773164	.46621035	.517725552	2.53	2.27
G4	1.7902746	.698710932	.532411968	2.56	3.36

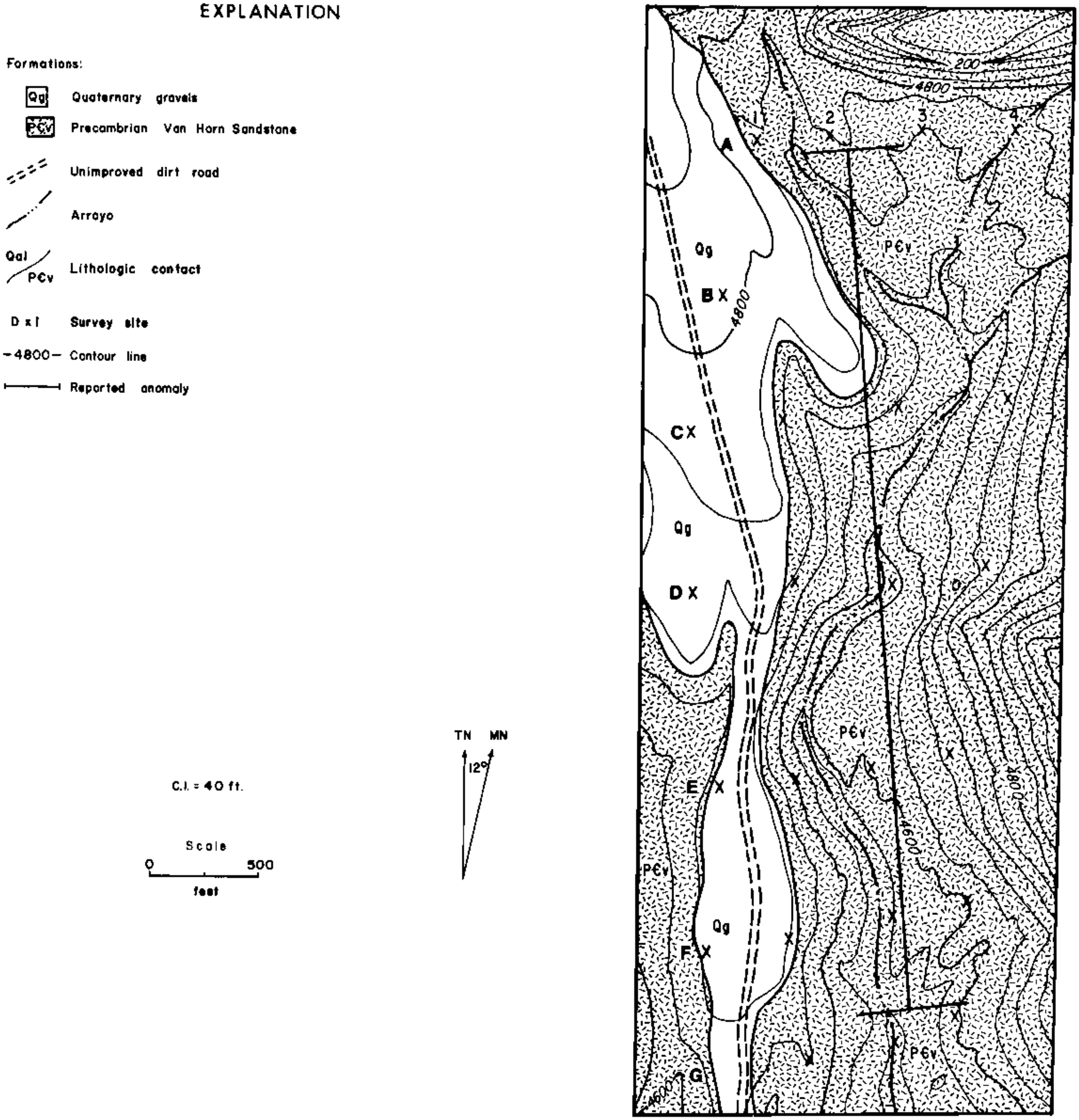


Figure 6. Reported thorium/potassium anomaly (Th/K 49) and survey sites for this study.

EXAMINATION OF ANOMALOUS SITES NOTED IN PRESENT STUDY

Three areas were observed to give anomalous gamma-spectrometer readings well above background during the course of conducting the present survey. These areas were then sampled and gamma spectrometer readings taken over a systematic grid. The first such area identified is referred to as the Garon Ranch site (Fig. 7). The anomaly occurs primarily in units of the Allamore limestone where they are adjacent to units of the Hazel Formation in an area of moderately complex folding. Uranium values up to 6 ppm were recorded at this site (Table 4). As yet there is no clear-cut geological explanation for this anomaly, however, it is believed that limestone units such as the Allamore might possibly concentrate uranium carried in ground water by menas of reduction involving organic carbon.

The second anomalous area occurs along the Dallas Fault east of Tumbledown Mountain (Fig. 8). Here, a near-vertical fault displays normal dip separation and causes juxtaposition of Van Horn and Allamore units. The area was prospected and developed to a limited extent as vein-type sulfide deposits, but without success (King and Flawn, 1953). Results of the sampling program for this project indicate uranium values of up to 80 ppm (Table 5) occur in spatial association with visible sulfide mineralization.

The third anomalous area noted in the present project is within felsic volcanic units of the Carrizo Mountain Group (Fig. 9). Uranium values of up to 70 ppm were noted (Table 6) for selected samples within rhyolite units presumably the result of element concentrations under normal conditions attendant with volcanogenic uranium deposits. This target type warrants further investigation at both local and regional scale.

TABLE IV

Values for U, Th, K at the (U8), Garren Ranch Anomaly, Van Horn Project, as Measured on Gamma Spectrometer, U. T. El Paso (see Figure 7 for sample locations)

Sample Number	Th ppm	U ppm	K %	Th/U	Th/K
A1	.391689	.521017326	.39150504	0.75	1.00
A2	.6394164	.479511396	.123869472	1.34	5.16
A3	1.84497	3.315495816	.04774128	0.56	38.6
A4	6.4262913	6.050357244	.167879424	3.15	38.3
B1	.5690493	.180519768	.009203184	3.15	61.8
B2	3.0797709	4.222537794	.039724992	0.73	77.5
B3	1.2380012	.871581978	.300447744	1.42	4.12
B4	.8253342	.581054652	.212306496	1.42	3.89
C1	.4712493	.18293814	.045492624	2.58	10.36
C2	2.2738011	3.428723142	.216698688	0.66	10.79
C3	1.0832328	.947359536	.521288824	1.14	2.08
C4	.6232794	.656811596	.238650896	0.95	2.61
D1	.6705657	.67333221	.336450576	0.99	1.99
D2	.9849438	.435587094	.322364736	2.26	3.06
D3	1.0290027	.487567908	.138267696	2.11	7.44
D4	.7388301	.459363024	.235176048	1.61	3.14
E1	.5953575	.427530582	.14303424	1.39	4.16
E2	.587289	.516180582	.24498216	1.14	2.40
E3	1.2525246	.712011978	.114429138	1.76	10.95

Values of chemical Analyses on Selected Samples Associated with the Garren Ranch Anomaly, Van Horn Project. Analyses carried out by Oak Ridge National Laboratories. (see Figure 7 for sample locations)

Sample Numbers	Th ppm	U ppm	K %	Th/U	Th/K
583	5.0	1.14	0.43	4.38	11.63
584	4.0	0.98	0.13	4.08	30.77
585	3.0	1.69	0.01	1.78	30.0
586	3.0	15.45	3.83	0.19	0.78
587	5.0	1.94	0.70	2.58	7.14
588	0	14.42	3.45	0.42	1.74
590	3.0	1.60	0.67	1.88	4.48
591	13.0	1.78	1.79	7.3	7.3
592	6.0	2.10	2.17	2.85	2.76
593	3.0	2.75	0.16	1.09	18.75
594	60.0	10.34	4.23	5.80	14.18
679	44.0	74.65	1.07	0.59	41.12
680	5.0	2.90	0.18	1.72	27.78
681	42.0	4.90	2.56	8.57	16.40

EXPLANATION

Formations:

Qal Quaternary alluvium

P€Hc
P€Hs Precambrian Hazel Formation; conglomerate and sandstone

P€Als
P€Ap Precambrian Allamoore Formation; limestone, phyllite, and
P€Av volcanic rocks

Unimproved dirt road

Arroyo

P€Av / Qal Lithologic contact

-4900- Contour line

B x 3 Survey site

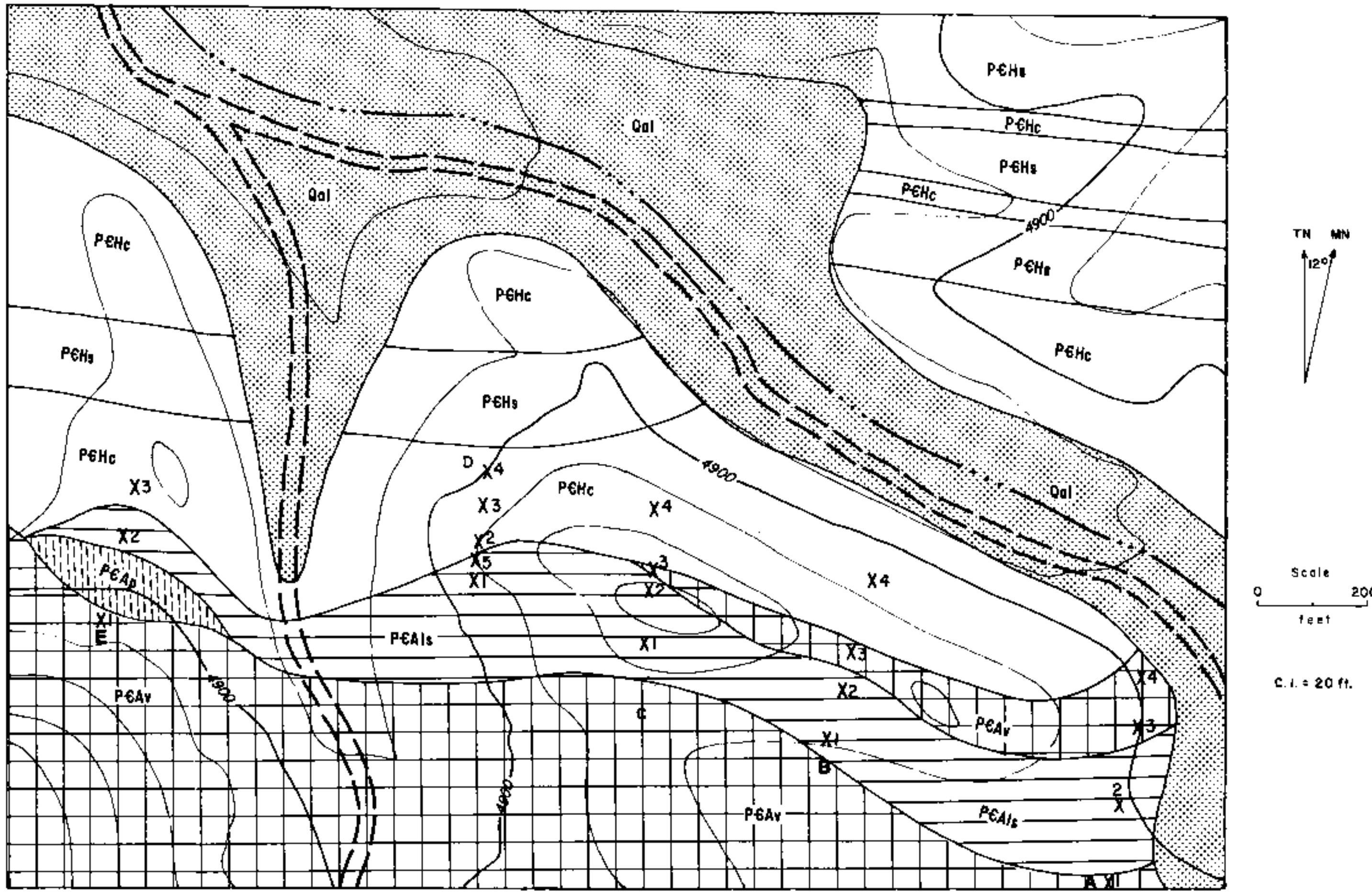


Figure 7. Garren Ranch uranium anomaly associated with the Allamoore Formation.

TABLE V

Values for U, Th, K at Anomaly area along Dallas Fault, Van Horn Project, as Measured on Gamma Spetrometer, U. T. El Paso (see Figure 8 for sample locations)

Sample Number	Th ppm	U ppm	K %	Th/U	Th/K
A1	2.6824095	1.083526398	0526592	25.48	2.48
A2	.3949164	.485557326	.404193072	0.81	0.98
A3	.3556986	80386512	.473673888	0.94	0.75
B1a	2.0091054	.976345002	.158168112	2.06	12.70
B1b	1.3487109	.727323606	.371790432	1.85	3.63
B2	.763526	.724103838	.3370533072	1.05	2.27
B3	.3573123	.725313024	.096076554	0.49	7.44
B4	.2202945	.24990407	.06912816	0.85	3.19
C1	1.58323525	4.04726256	.509595504	0.39	3.11
C2	1.9842642	2.32140978	.168717456	0.85	11.76
C3	.4647945	.23385814	.09785256	.99	4.75
C4	.636189	.415971396	.16806144	1.24	3.79
D1	.8892465	.95096628	.43621272	0.94	2.04
D2	.8022534	.298583838	.074099472	2.69	10.83
D3	2.3125299	3.0032003142	-0.006764928	0.77	-341.84
D4	.8790753	6655466	.3771992	1.67	2.33

Values Measured at Oak Ridge National Laboratories for Sample Sites in the Same Locality (See Fig. 8 for Sample Locations)

Sample Number	Th ppm	U ppm	K %	Th/U	Th/K
2729 (508)	4.0	5.8	5.8	0.69	0.69
(509)	9.0	1.3	3.9	6.92	2.31
(510)	1.8	1.0	0.15	1.8	12.0
2721 (403)	7.0	60.0	3.9	0.12	1.79
2722 (404	7.0	1.3	4.5	5.38	1.56
(405)	1.8	2.9	1.9	0.62	0.95
2866 (599)	.0	81.42	2.26	0.05	1.77
2867 (606)	10.0	22.32	3.63	0.45	2.75
2868 (600)	3.0	1.42	0.12	2.11	25.0
2869 (607)	10.0	11.05	0.23	0.90	43.48

EXPLANATION

Formations

Ob	Ordovician Bliss Sandstone
PЄv	Precambrian Van Horn Sandstone
PЄHs	Precambrian Hazel Sandstone
PЄAls PЄAv	Precambrian Allamoore Limestone and Volcanic rocks

Trail

Arroyo

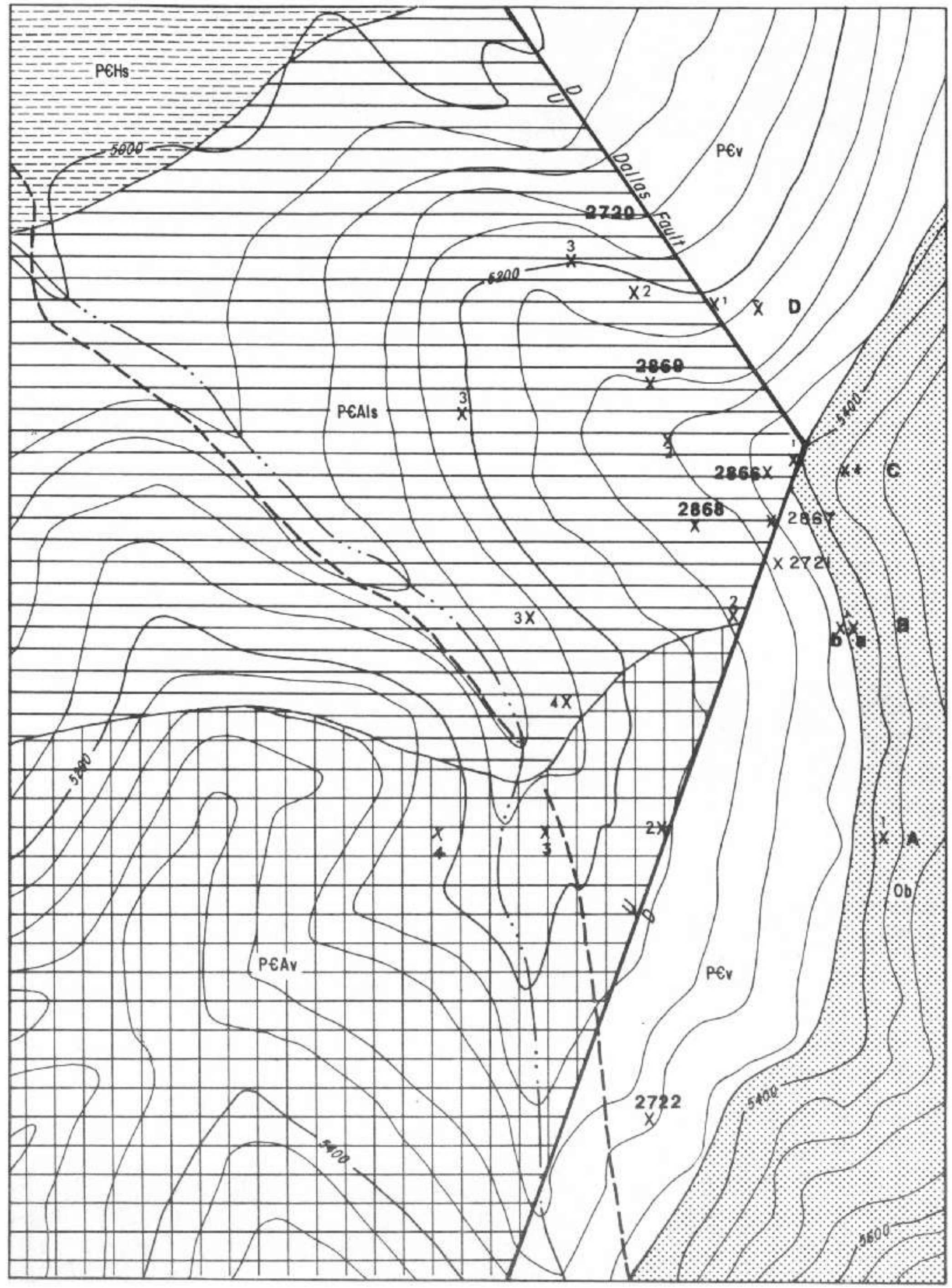
Ob / PЄv Lithologic contact

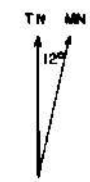
U / D High-angle fault; D on downthrown side

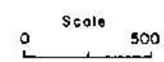
-5200- Contour line

x 2866 Sample site

2 x C Survey site







C.I. = 40 ft.

Figure 8 Dallas Fault uranium anomaly.

TABLE VI

Values for U, Th, K at the Carrizo Mountain Group Anomalous Area, Van Horn Project, as Measured on Gamma Spectrometer, U. T. El Paso, and Chemically Determined U ppm at Oak Ridge National Laboratories [U ppm (OR)]

Sample Number	Th ppm	U ppm	U ppm (OR)	K %	Th/U	Th/K
608	13.67	3.71	4.1	3.80	3.68	3.60
598	14.04	2.91	2.1	3.89	4.82	3.61
603	9.91	2.44	2.4	4.65	4.06	2.15
597	11.84	3.01	2.4	3.91	3.93	3.03
604	4.88	2.94	2.7	3.32	1.66	1.47
611	5.93	4.11	3.2	5.81	3.89	2.75
605	5.01	1.91	2.1	4.72	2.62	1.06
722	13.86	3.53	2.4	6.50	3.93	2.17
595	12.25	3.40	3.8	4.67	3.60	2.62
596	19.85	2.89	1.7	4.92	6.87	4.03

EXPLANATION

SYMBOLS

GEOLOGIC

Mes/Pal Lithologic contact

D Normal fault: D on downthrown side; dashed where hypothetical or concealed

• 569 Sample locality

CULTURAL

Roads: 54 Texas state highway

80 U. S. highway

10 Interstate highway

Railroad

City

STRATIGRAPHY

(see Plate I for a complete description)

Qal Undifferentiated Quaternary alluvium

Ti Tertiary intrusive rocks

Mes Mesozoic rocks

Pal Paleozoic rocks

PCv Precambrian (?) Van Horn Sandstone

PCha Precambrian Hazel and Allamoore Formations

PCc Precambrian Carrizo Mountain Formation

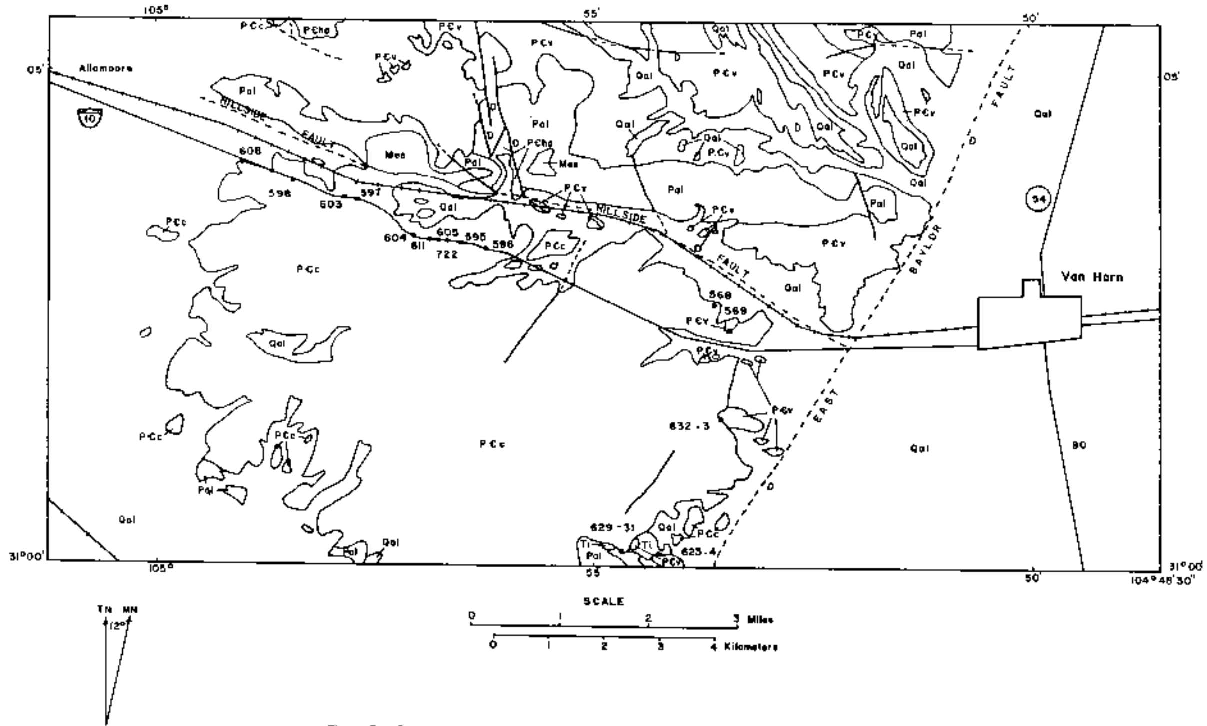


Figure 9. Sample locations in the northern Carrizo Mountains, Van Horn area, Texas.

SUMMARY AND CONCLUSIONS

The results of this present survey indicate that:

1) The anomalous results of the NURE program reported for this study area appear spurious.

2) Three areas containing anomalous uranium values were identified. Careful control of geological sampling permits reasonable interpretation of each occurrence.

3) The anomalous areas identified may be explained as a function of uranium enrichment a) associated with ground water movement and concentration in areas high in organic carbon (Garren ranch), b) associated with vein-type base metal sulfide occurrences along faults (Dallas Fault), or c) associated with felsic volcanic activity (Carrizo Mountain Group).

4) Further detailed study possibly including geophysical surveys and drilling appears warranted for areas (b) and (c) above. Although the anomalies are not large they are at least 10 times background and the geologic environments are typical for model deposits of a similar nature.

5) Geophysical data confirm the general geologic framework for the area and particularly of the Carrizo Mountain Group rocks relative to the Precambrian sediments.

APPENDIX A

Analytical Data for 33 chemical element determinations on 340 samples together with correlation coefficient matrix; on microfische -- see back pocket.

TABLE A-1

Values for Organic Carbon Analyses, Van Horn Project

Sample No.	% of Organic Carbon
151458	0.039
151474	0.045
151475	0.033
151482	0.095
151483	0.029
151384	0.025
151594	0.128
151599	0.045
151600	0.033
151606	0.048
151607	0.091
151679	0.087
151680	0.052
151681	0.145
151686	0.162
151687	0.507
151688	0.285
151689	0.345
151690	0.026
151691	0.016
151692	0.247
151693	0.138
151694	0.067
151695	0.060
151696	0.208
151697	0.109
151698	0.052
151699	0.030
151700	0.030

Detection Limits for Chemical Determinations, Van Horn Project

VAN HORN UNCONFORMITY ROCK — TODAY'S DATE IS 02-07-80

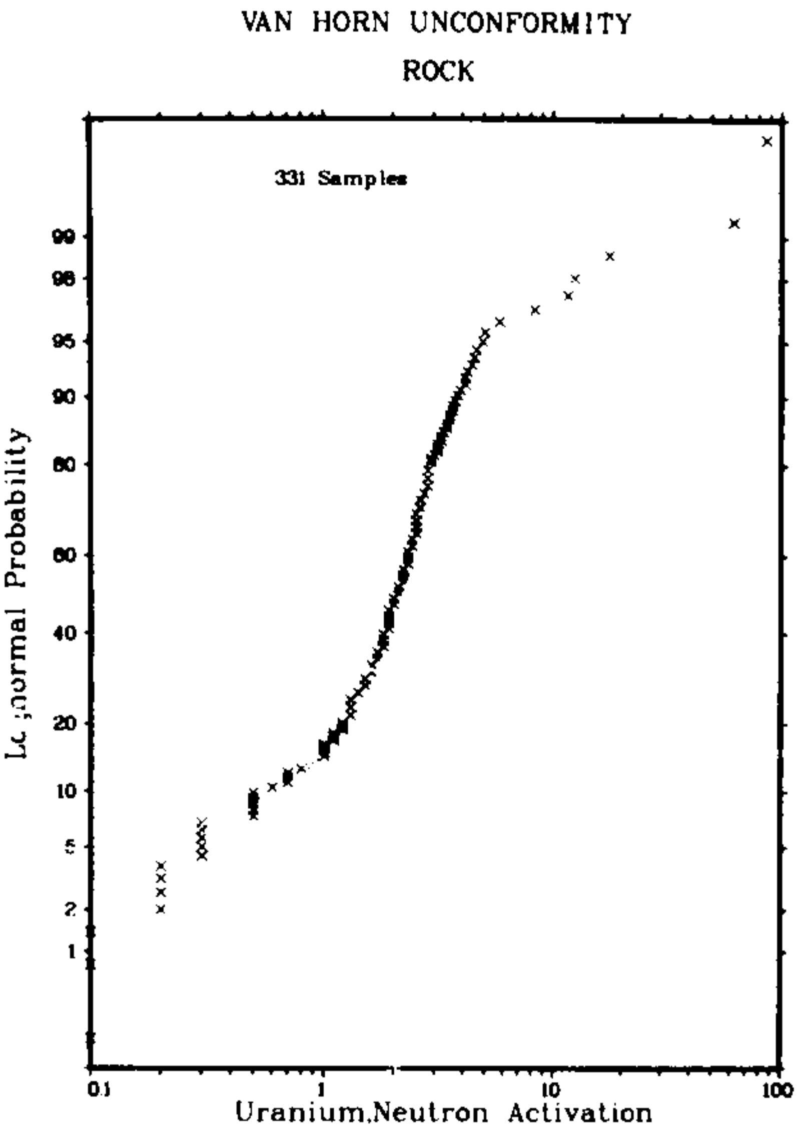
ELEMENT	NO. SAMPLES ANALYZED: MEASURABLE VALUES	NO. SAMPLES ANALYZED: BELOW DETECTION LIMIT	DETECTION LIMIT	MINIMUM VALUE	MAXIMUM VALUE	MEAN	MEDIAN	MODE	STANDARD DEVIATION	COEFFICIENT OF VARIATION	LN TRANSFORMATION: MEAN	LN TRANSFORMATION: S. D.	LN TRANSFORMATION: ROBUST MEAN	LN TRANSFORMATION: ROBUST S. D.
U	329	5	<0.25	<0.25	81.42	2.88	1.81	1.63	7.060	2.454	0.62	0.71	0.57	0.67
U-NT	331			0.10	86.20	2.94	2.00	1.91	6.845	2.327	0.60	0.69	0.62	0.86
U/TU	330			0.25	13.20	1.16	0.93	0.92	1.240	1.071	-0.02	0.46	-0.06	0.41
AG	22	312	<2	<2	62	12	<2	<2	15.2	1.2	2.00	0.96		
AL	331	3	<0.05	<0.05	7.93	3.74	4.19	5.17	1.731	0.463	1.03	1.06	1.13	1.16
B	214	120	<10	<10	1691	59	18	<10	149.0	2.5	3.50	0.83	2.88	1.11
BA	334			3	29330	859	416	421	2480.2	2.9	5.91	1.25	5.94	1.32
BE	275	59	<1	<1	109	2	<1	<1	6.8	3.3	0.46	0.60		
CA	329	5	<0.05	<0.05	25.88	3.63	1.59	0.14	4.581	1.263	0.44	1.44	0.42	1.46
CO	298	36	<4	<4	79	15	12	14	11.6	0.7	2.55	0.61	2.43	0.61
CR	332	2	<1	<1	120	27	24	5	19.4	0.7	2.96	0.97	3.01	0.93
CU	327	7	<2	<2	21634	606	19	17	2764.7	4.5	3.49	1.70	3.26	1.74
FE	333	1	<0.05	<0.05	14.29	2.39	2.19	2.06	1.741	0.729	0.59	0.89	0.66	0.96
LI	334			1	254	26	22	3	27.9	1.0	2.80	0.99	2.87	1.00
MG	330	4	<0.05	<0.05	9.68	2.03	1.26	0.24	2.031	1.002	0.18	1.11	0.17	1.13
MN	334			11	6226	587	383	156	772.9	1.3	5.84	1.08	5.86	1.02
MO	47	287	<4	<4	51	9	<4	<4	9.9	1.1	1.94	0.67		
NA	293	41	<0.05	<0.05	3.13	0.86	0.26	<0.05	0.866	1.006	-0.95	1.44	-1.25	1.49
NB	291	43	<4	<4	189	13	8	6	18.7	1.4	2.28	0.71	2.04	0.66
NI	300	34	<2	<2	105	14	11	<2	12.6	0.9	2.38	0.74	2.27	0.85
P	318	16	<5	<5	19457	560	316	9	1465.6	2.5	5.69	1.00	5.57	1.55
SC	328	6	<1	<1	36	6	6	7	5.3	0.3	1.67	0.77	1.69	0.77
TH	264	70	<2	<2	60	6	4	<2	5.4	0.9	1.65	0.56	1.46	0.61
TI	334			29	22232	2324	1981	83	2174.5	0.9	7.29	1.19	7.38	1.36
V	330	4	<2	<2	333	58	51	60	48.2	0.8	3.79	0.83	3.80	0.91
Y	334			1	136	16	15	12	13.6	0.8	2.60	0.72	2.63	0.66
ZN	328	6	<2	<2	13567	141	42	27	877.7	6.2	3.88	0.98	3.81	1.00
ZR	333	1	<2	<2	564	92	83	84	71.1	0.8	4.25	0.83	4.29	0.94
K	328	6	<0.02	<0.02	6.44	2.31	2.30	0.07	1.426	0.616	0.42	1.22	0.48	1.37
SR	334			4	1270	158	96	73	170.1	1.1	4.68	0.85	4.67	0.87
CE	316	18	<10	<10	231	53	45	25	35.4	0.7	3.79	0.63	3.73	0.76
TGAM	214			162	2040	657	630	631	268.5	0.4	6.41	0.38	6.42	0.38
TOT	1			576	576	576	*****	576	0.0	0.0	6.36	0.0		
EK	327			0.0	9.4	2.7	2.6	2.6	1.64	0.62				
CPK	1			564	564	564	*****	564	0.0	0.0	6.34	0.0		
EU	327			0.1	68.2	2.9	2.1	2.4	6.12	2.13	0.66	0.76	0.66	0.66
CPU	1			162	162	162	*****	162	0.0	0.0	5.09	0.0		
ETH	327			0.0	75.4	6.3	6.3	7.8	5.86	0.93				
CPTH	1			66	66	66	*****	66	0.0	0.0	4.19	0.0		
AS	322	11	<0.1	<0.1	474.2	7.6	1.8	1.1	41.32	5.47	0.72	1.09	0.60	1.16
SE	191	142	<0.1	<0.1	8.1	0.7	0.2	<0.1	0.79	1.20	-0.75	0.76		

IHC0021 STOP 0

APPENDIX B

Figures B-1 through B-7. Plot of elemental abundance ____________ against log normal probability and frequency, Van Horn Project.

1. Uranium, Neutron Activation
2. Uranium
3. U/U-Nt
4. Equivalent uranium
5. Thorium
6. Vanadium
7. Total Gamma


VAN HORN UNCONFORMITY
ROCK
331 Samples
Lognormal Probability
99
98
95
90
80
60
40
20
10
5
2
1
0.1
1
10
100
Uranium,Neutron Activation

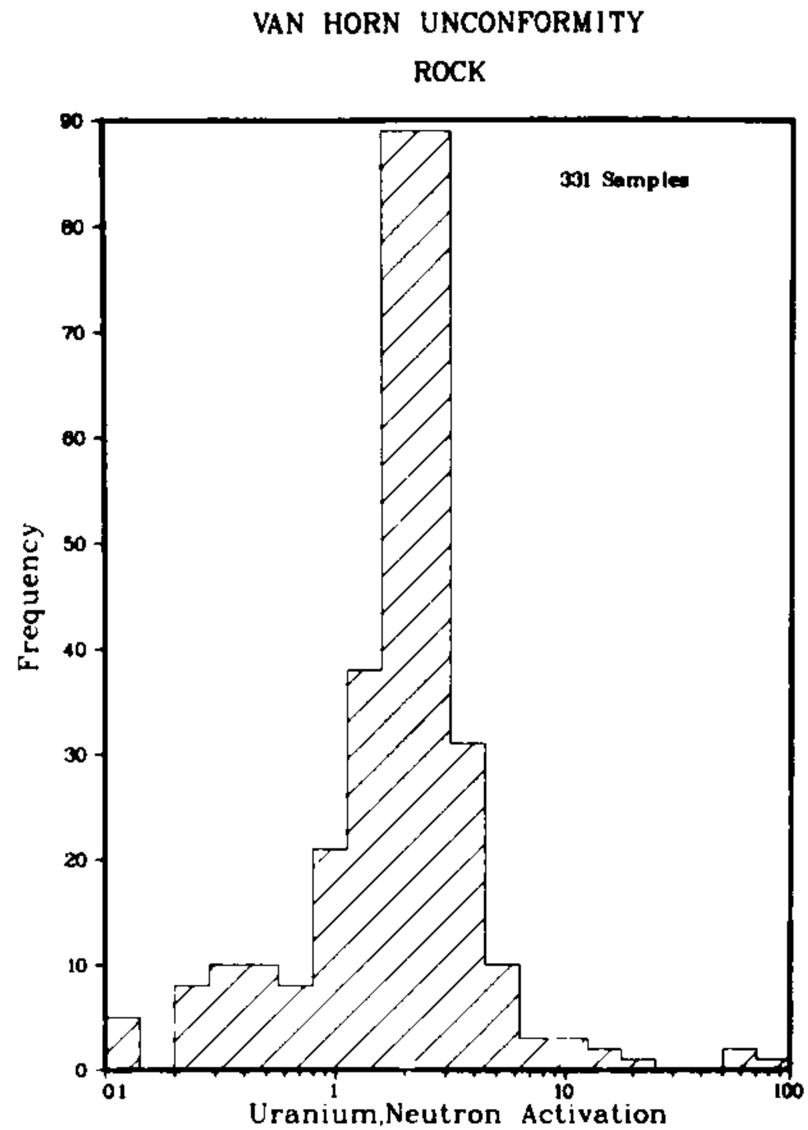
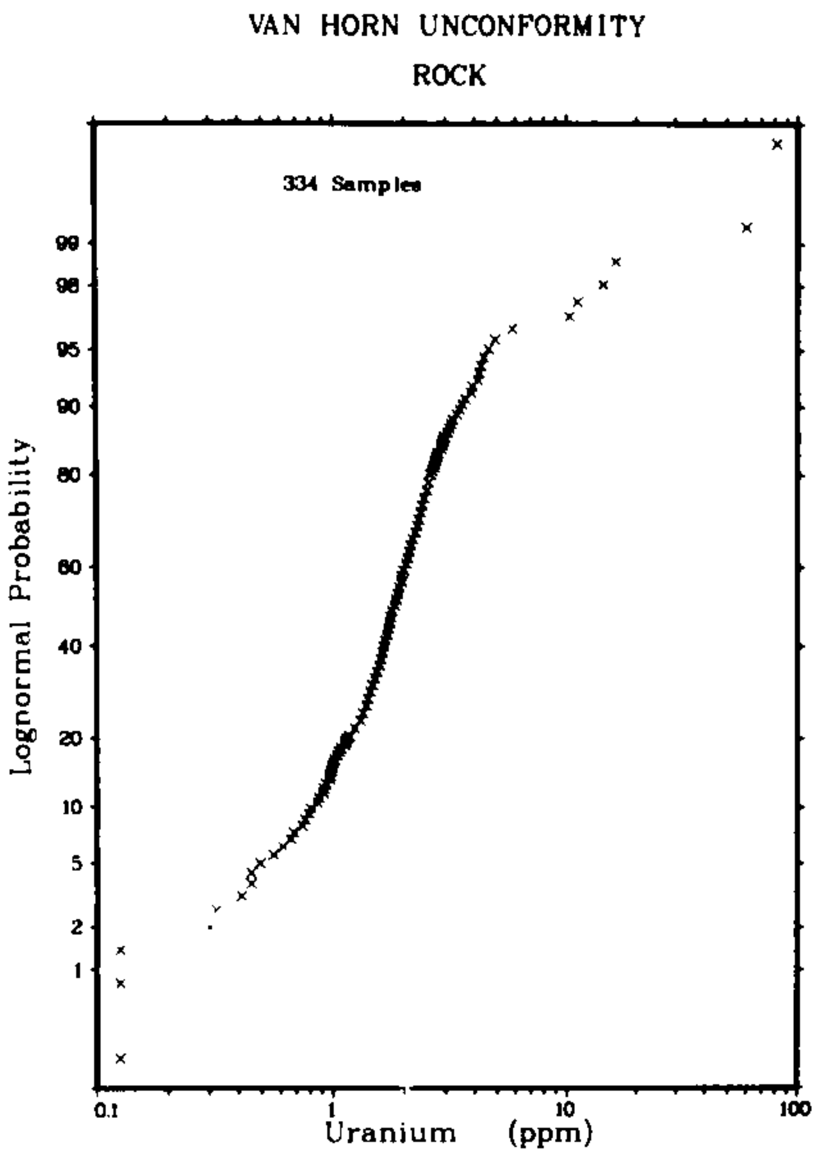

VAN HORN UNCONFORMITY
ROCK
331 Samples
Frequency
90
80
70
60
50
40
30
20
10
0
0.1
1
10
100
Uranium,Neutron Activation

Figure B-1.


VAN HORN UNCONFORMITY
ROCK
334 Samples
Lognormal Probability
99
98
95
90
80
60
40
20
10
5
2
1
0.1
1
10
100
Uranium (ppm)

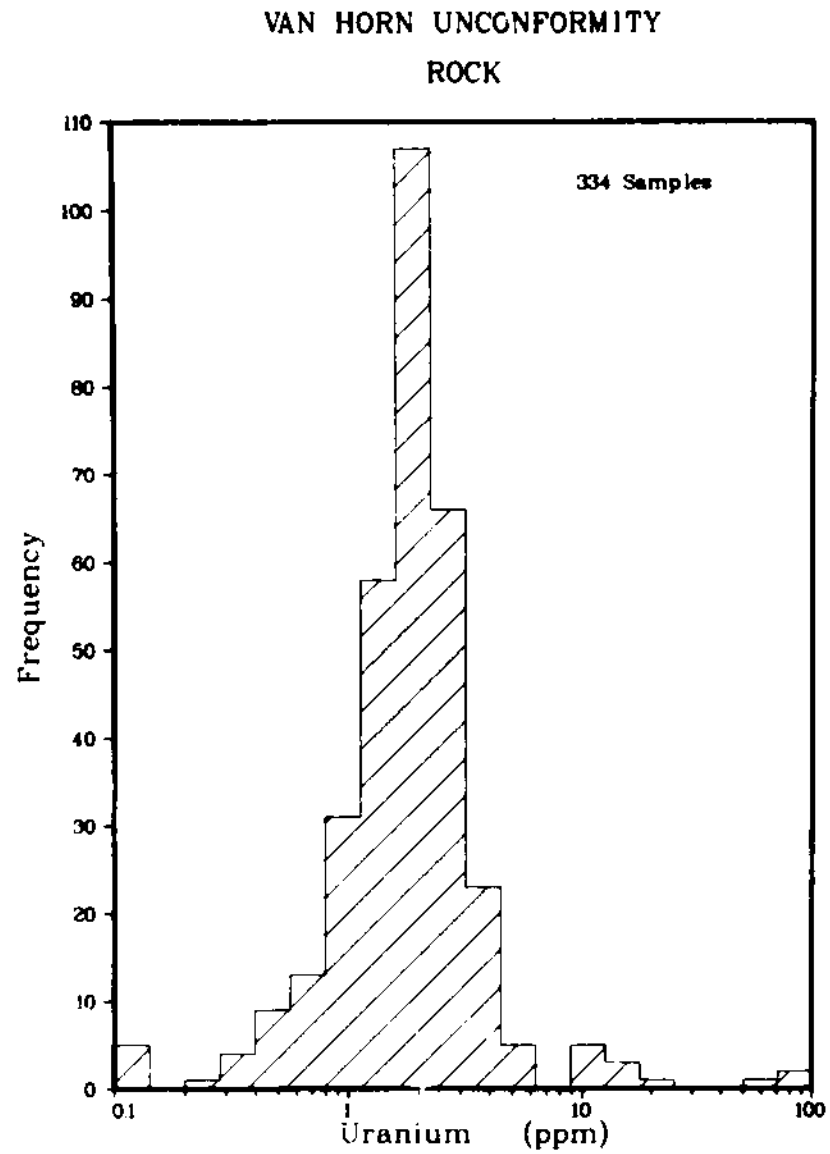
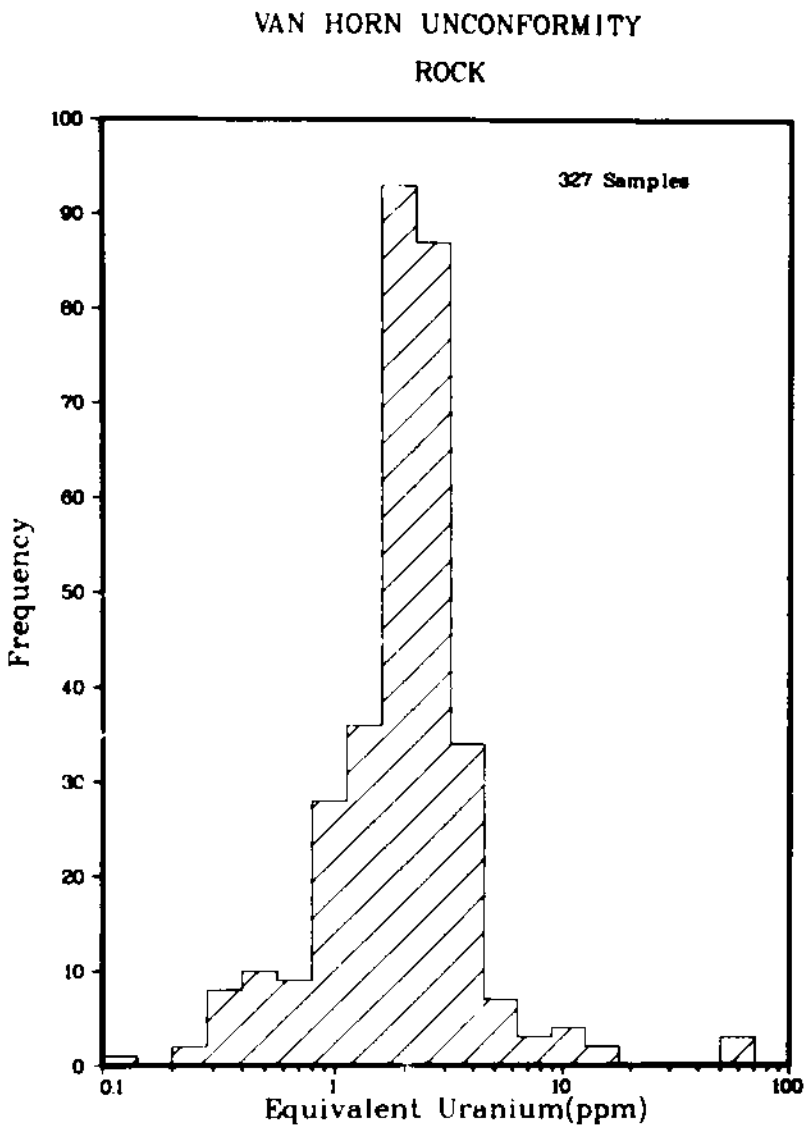
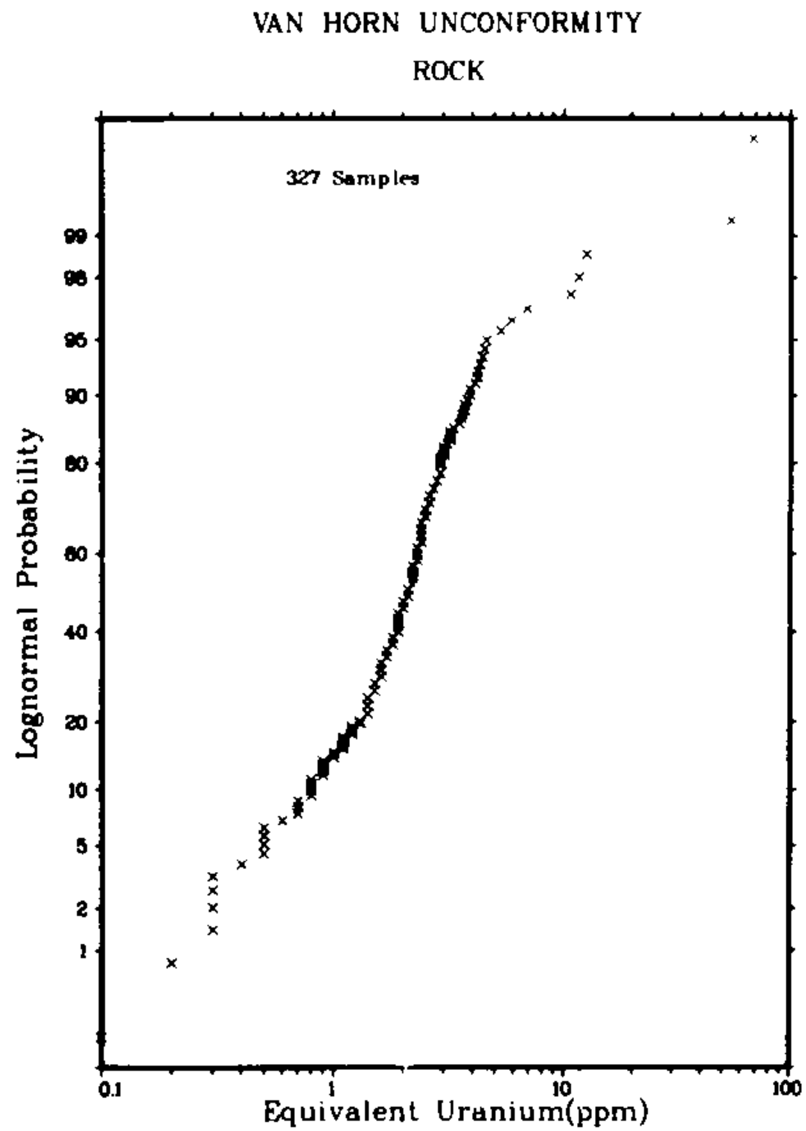

VAN HORN UNCONFORMITY
ROCK
334 Samples
Frequency
110
100
90
80
70
60
50
40
30
20
10
0
0.1
1
10
100
Uranium (ppm)

Figure B-2

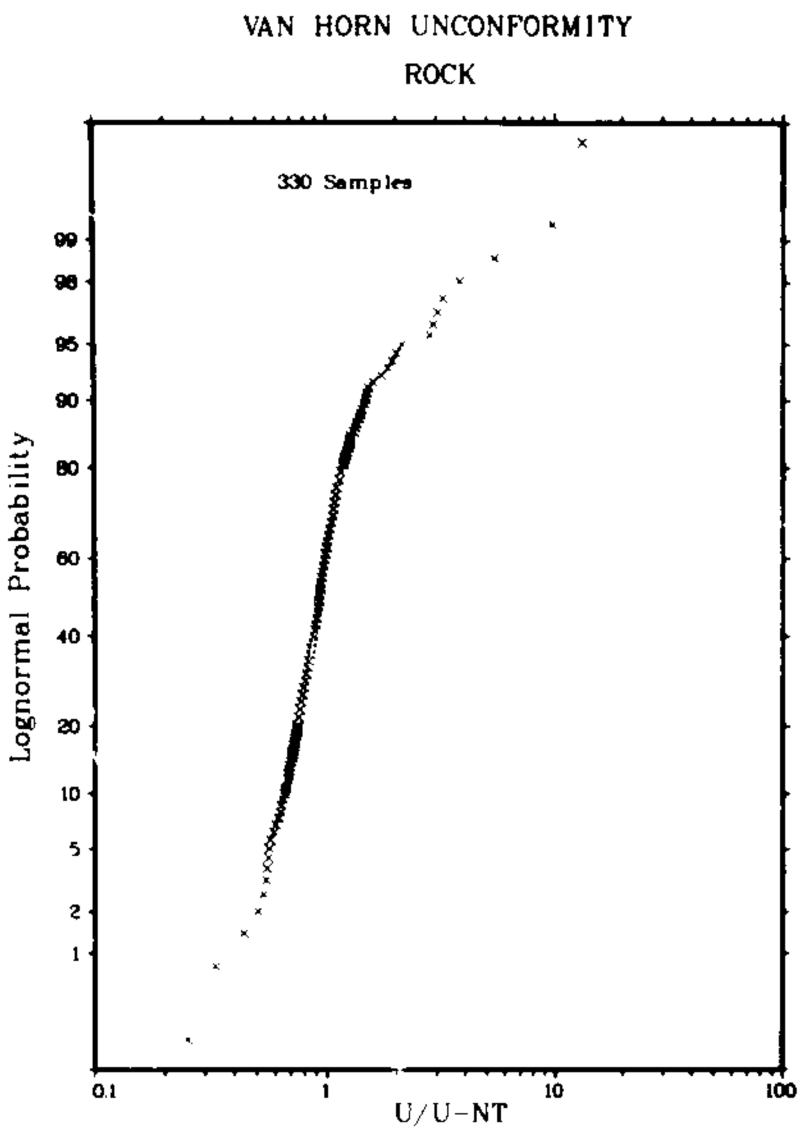


VAN HORN UNCONFORMITY
ROCK
327 Samples
Frequency
Equivalent Uranium(ppm)

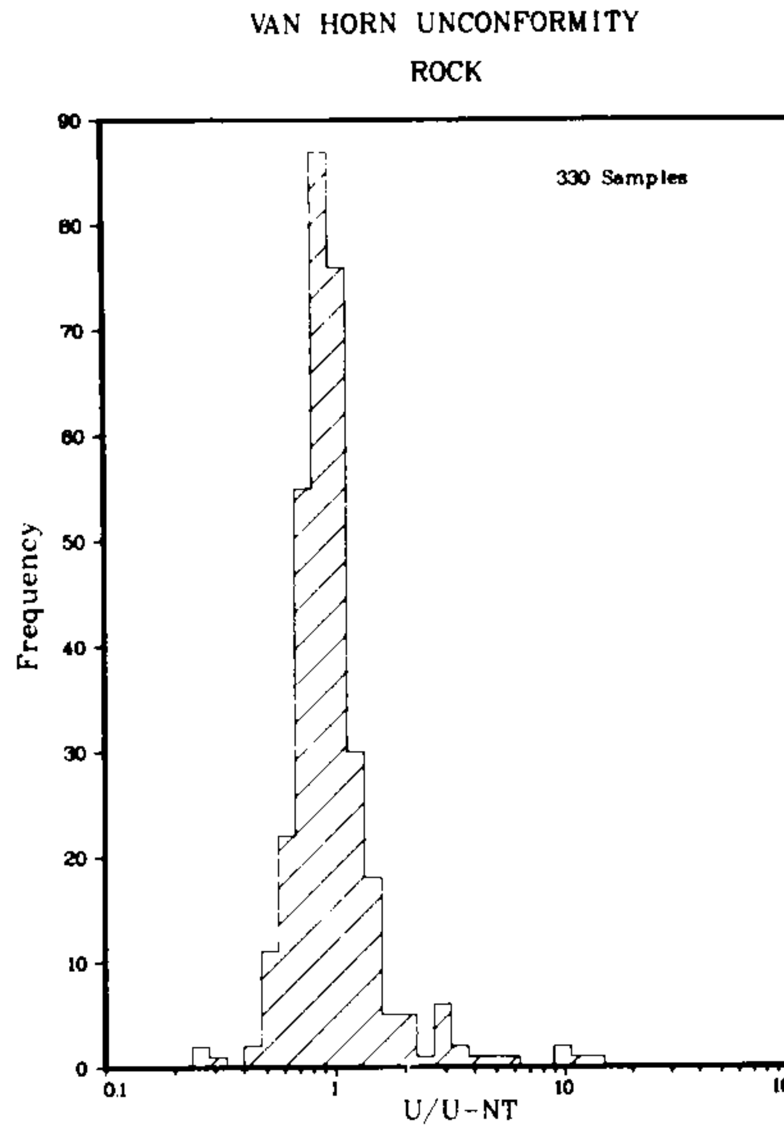


VAN HORN UNCONFORMITY
ROCK
327 Samples
Lognormal Probability
Equivalent Uranium(ppm)

Figure B-3

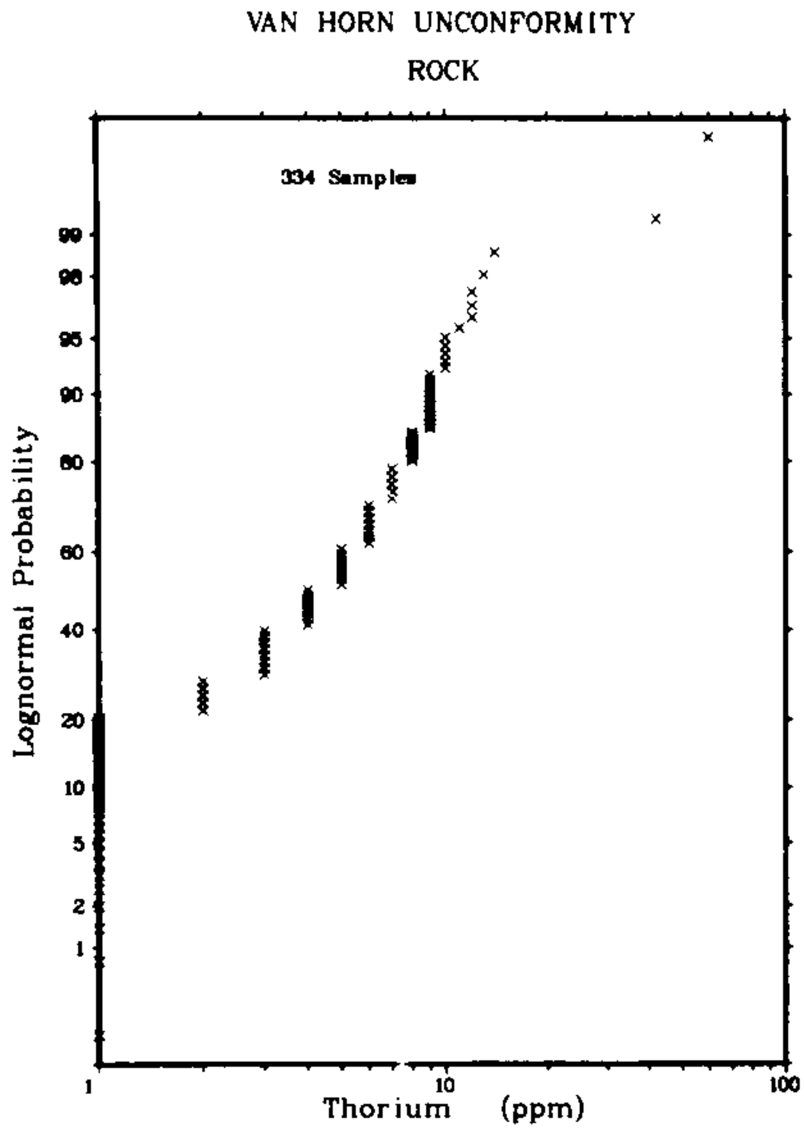


VAN HORN UNCONFORMITY
ROCK
330 Samples
Lognormal Probability
99
98
95
90
80
60
40
20
10
5
2
1
0.1
1
10
100
U/U-NT



VAN HORN UNCONFORMITY
ROCK
330 Samples
Frequency
90
80
70
60
50
40
30
20
10
0
0.1
1
10
100
U/U-NT

Figure B-4


VAN HORN UNCONFORMITY
ROCK
334 Samples
Lognormal Probability
99
98
95
90
80
60
40
20
10
5
2
1
1
10
100
Thorium (ppm)

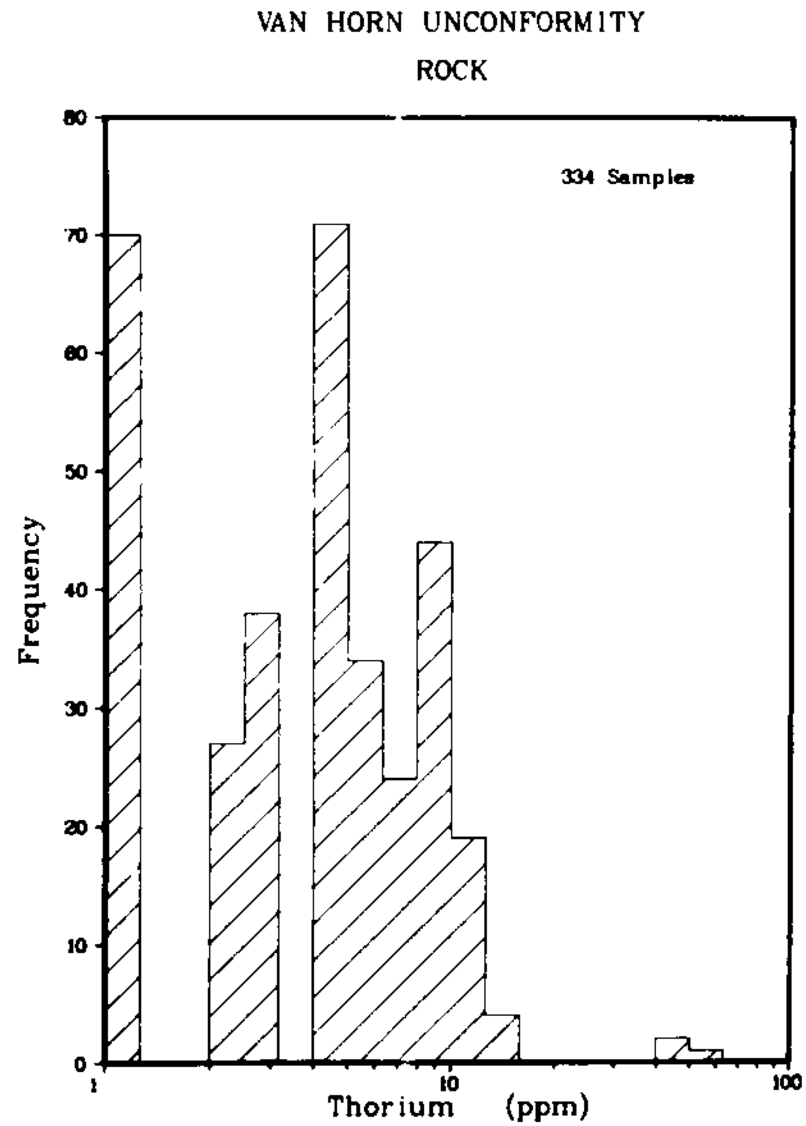
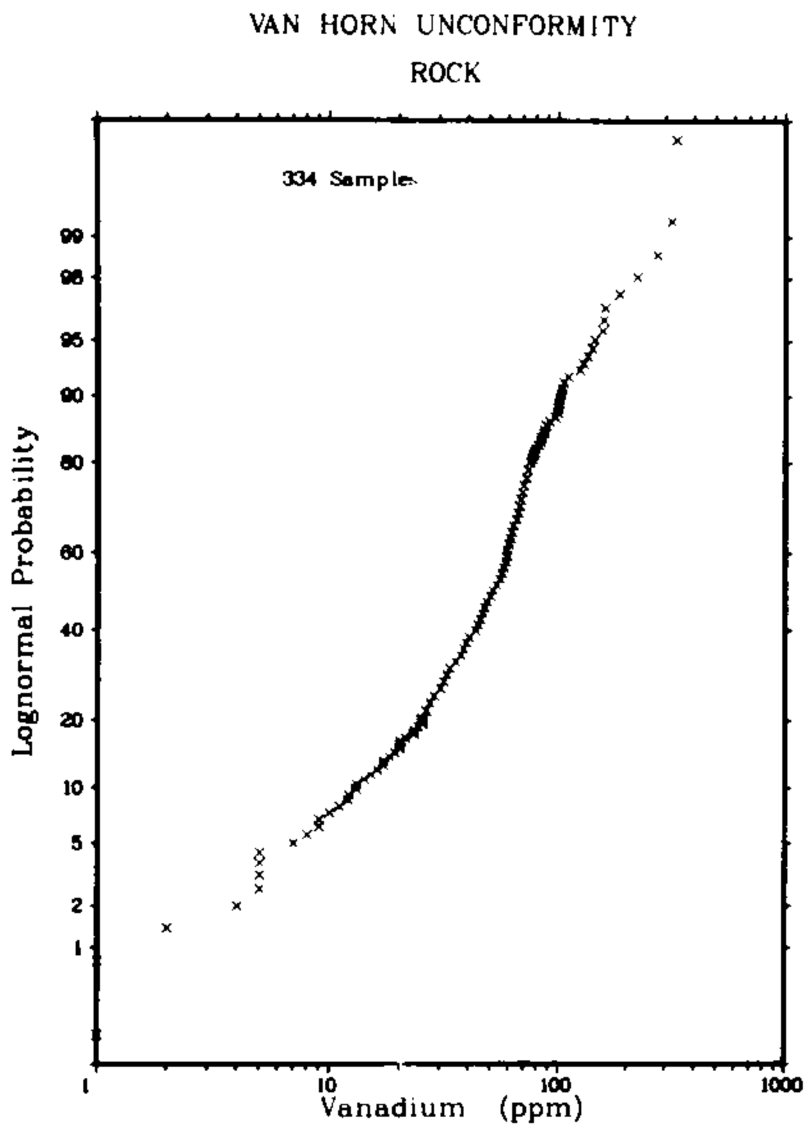
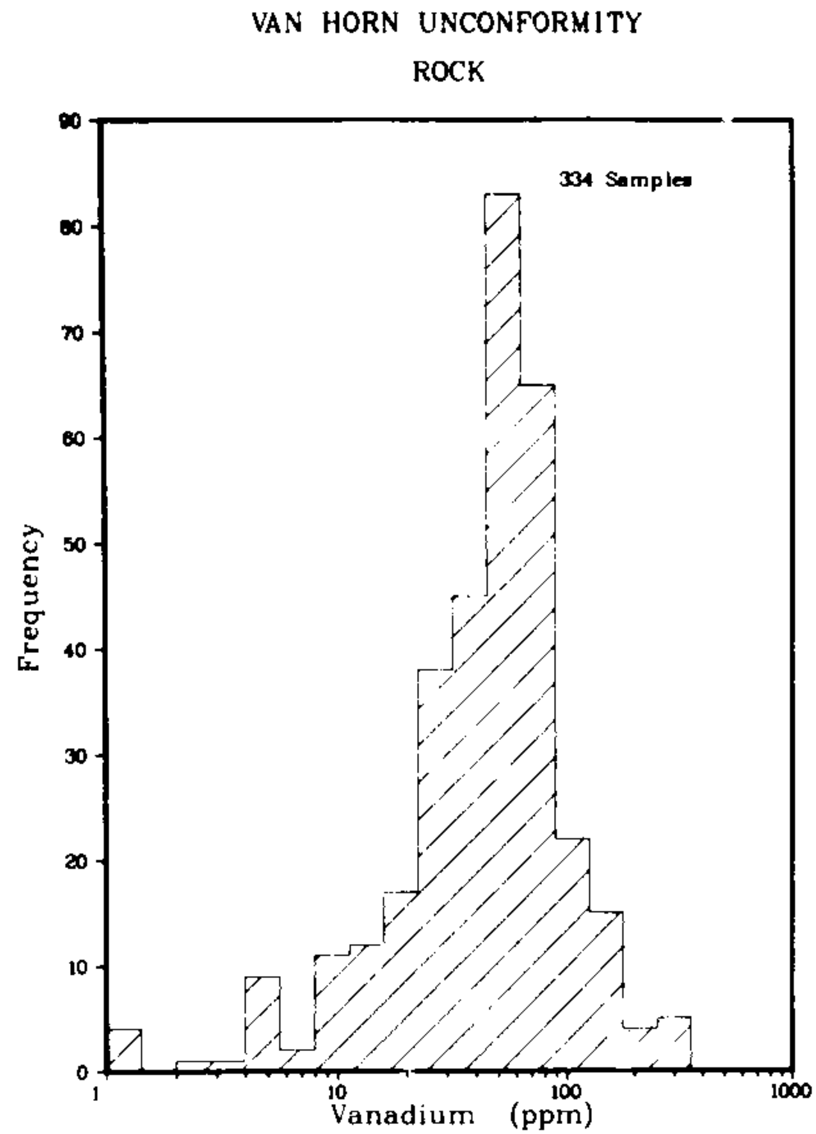

VAN HORN UNCONFORMITY
ROCK
334 Samples
Frequency
80
70
60
50
40
30
20
10
0
1
10
100
Thorium (ppm)

Figure B-5

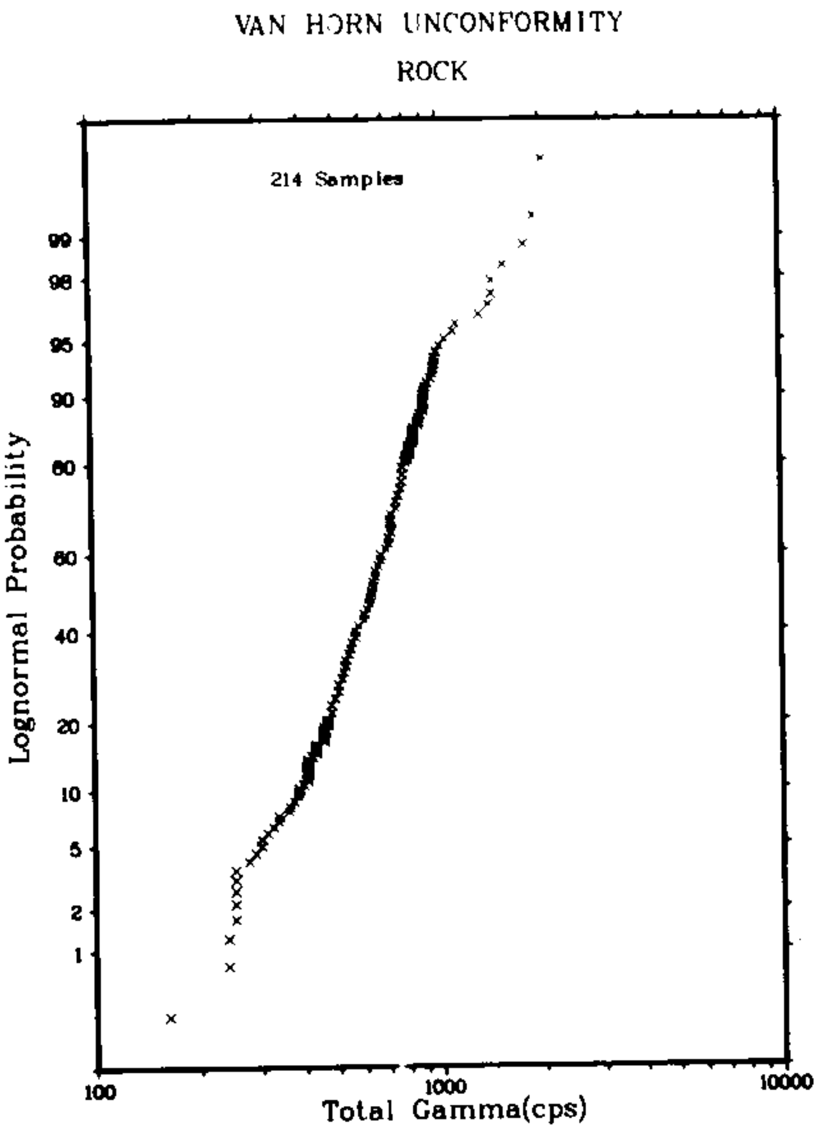


VAN HORN UNCONFORMITY
ROCK
334 Samples
Lognormal Probability
Vanadium (ppm)



VAN HORN UNCONFORMITY
ROCK
334 Samples
Frequency
Vanadium (ppm)

Figure B-6


VAN HORN UNCONFORMITY
ROCK
214 Samples
Lognormal Probability
99
98
95
90
80
60
40
20
10
5
2
1
100
1000
10000
Total Gamma(cps)

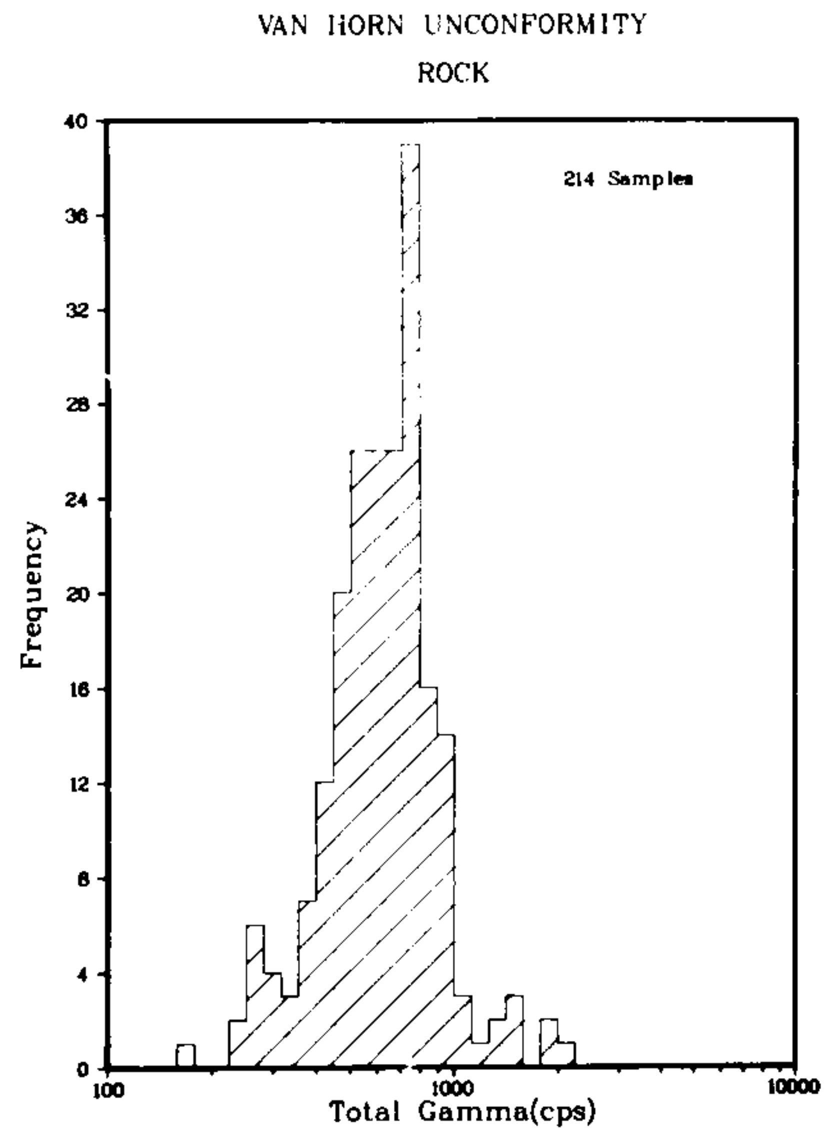

VAN HORN UNCONFORMITY
ROCK
214 Samples
Frequency
40
36
32
28
24
20
16
12
8
4
0
100
1000
10000
Total Gamma(cps)

Figure B-7

TABLE B-1

Ranges of Values of Correlation Coefficients of Uranium, and Selected Elements with Each Other. Summary of Pertient Data from Correlation Coefficient Matrix, Appendix A

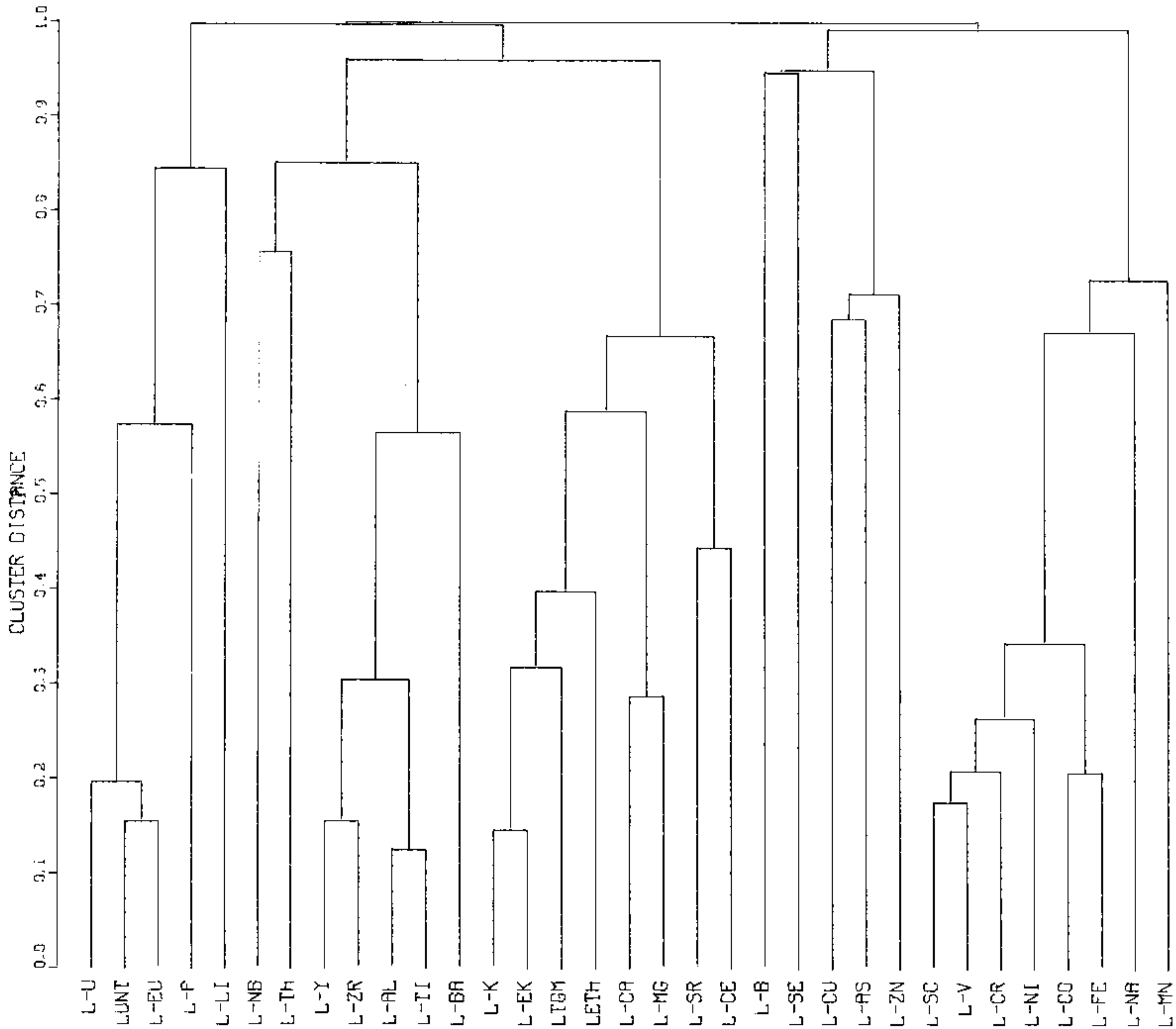
Ranges of Values of Correlation Coefficients	U with	P with	As with	Y with	Zr with	Ni with
Greater than 0.45	none	Sc,V,Cr, Co,Fe,Y		P,Ce,Sc, Cr,Fe,Th, Al,Ti,K,	Ce,Sc,Fe, Al,Ti,K, Y	Sc,V,Cr, Li,Co,Fe, Al,Ti
$0.35<x\leq 0.45$	P,As,Y, Zr	Al,Ti,U	U	V,Ni,Mn, Nb,U,Ba	U,V,Cr, Th,Nb,Ba	Zn,Na,Mn, Y
$0.25<x\leq 0.35$	Th,K	Cu,Ni,Na Zr	Zn,Cu		P,Ni	P,K,Zr
$0.15<x\leq 0.25$	Ce,Cu,Sc, V,Fe,Nb, Al,Ti,Ba	Li,Se,As Zn,Mn,Th, K	P,Sr,Se V,Cr,Co Ba	Zn,Co.Na	Se,Co,Na	Ce,Ba,

APPENDIX C

Dendogram of Cluster Analysis

33 VARIABLES CLUSTERED USING 344 SAMPLES.
DATE PLOTTED IS 02-12-80
CLUSTERING CRITERION -- COMPLETE LINKAGE
NORMALIZATION -- RAW DATA IS USED
METRIC -- (1.-ABS(PEARSON CORRELATION))

Dendogram Illustrating Cluster Analysis on Chemical Determinations, 27 Elements, Van Horn Project

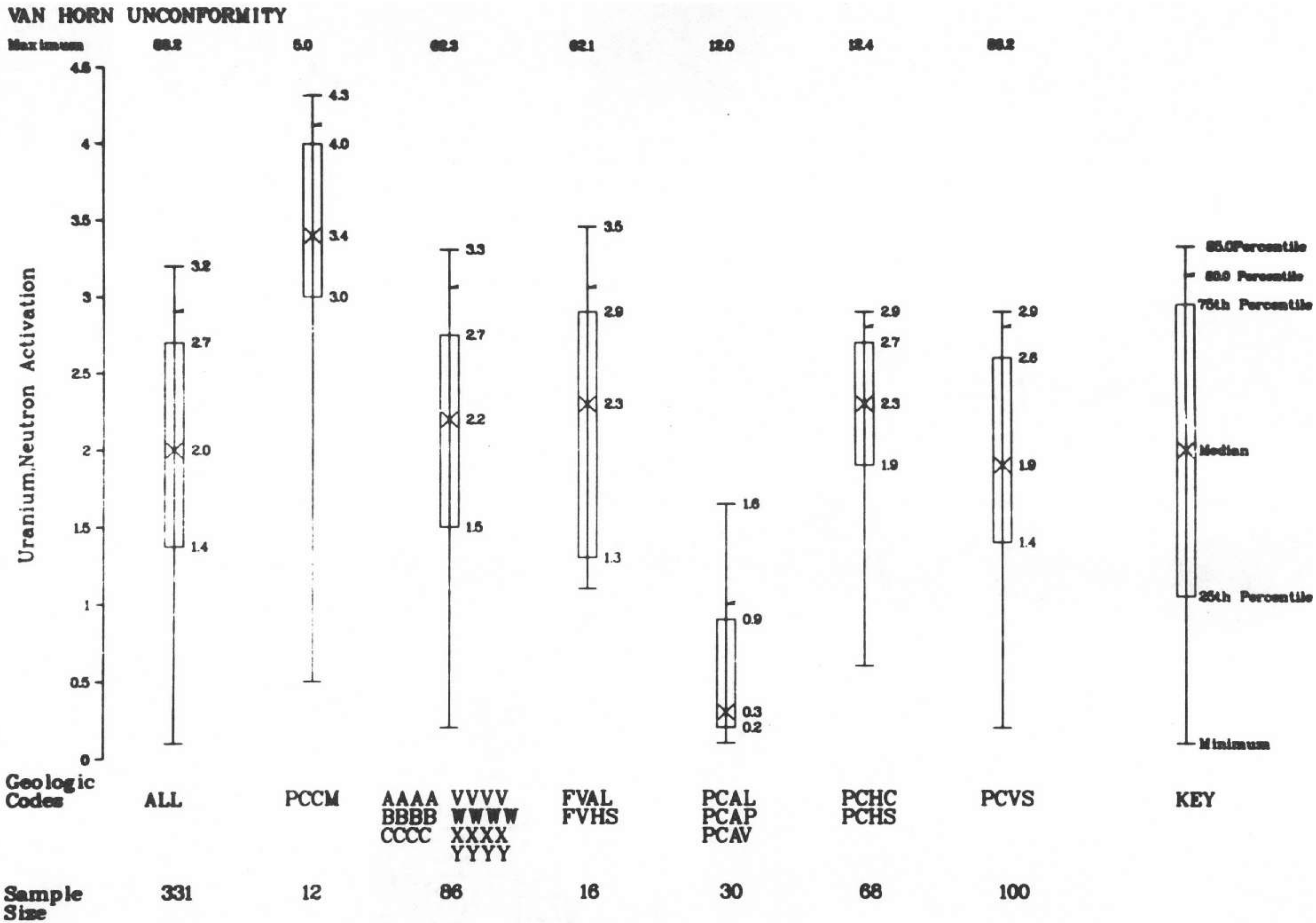


VARIABLE NAMES

APPENDIX D

Figures D-1 through D-9. Median values, maximum minimum values and selected percentile increments for _________ versus geological sample type, Van Horn Project. See text for explanation of geological sample type.

1. Uranium, neutron Activation
2. U/U-Nt
3. Uranium
4. Equivalent uranium
5. Thorium
6. Equivalent thorium
7. Potassium
8. Equivalent potassium
9. Total gamma



VAN HORN UNCONFORMITY
Maximum
5.0
12.0
12.4
Uranium,Neutron Activation
Geologic Codes
ALL
PCCM
AAAA BBBB CCCC
VVVV WWWW XXXX YYYY
FVAL FVHS
PCAL PCAP PCAV
PCHC PCHS
PCVS
KEY
Sample Size
331
12
86
16
30
68
100
75th Percentile
Median
25th Percentile
Minimum

Figure D-1

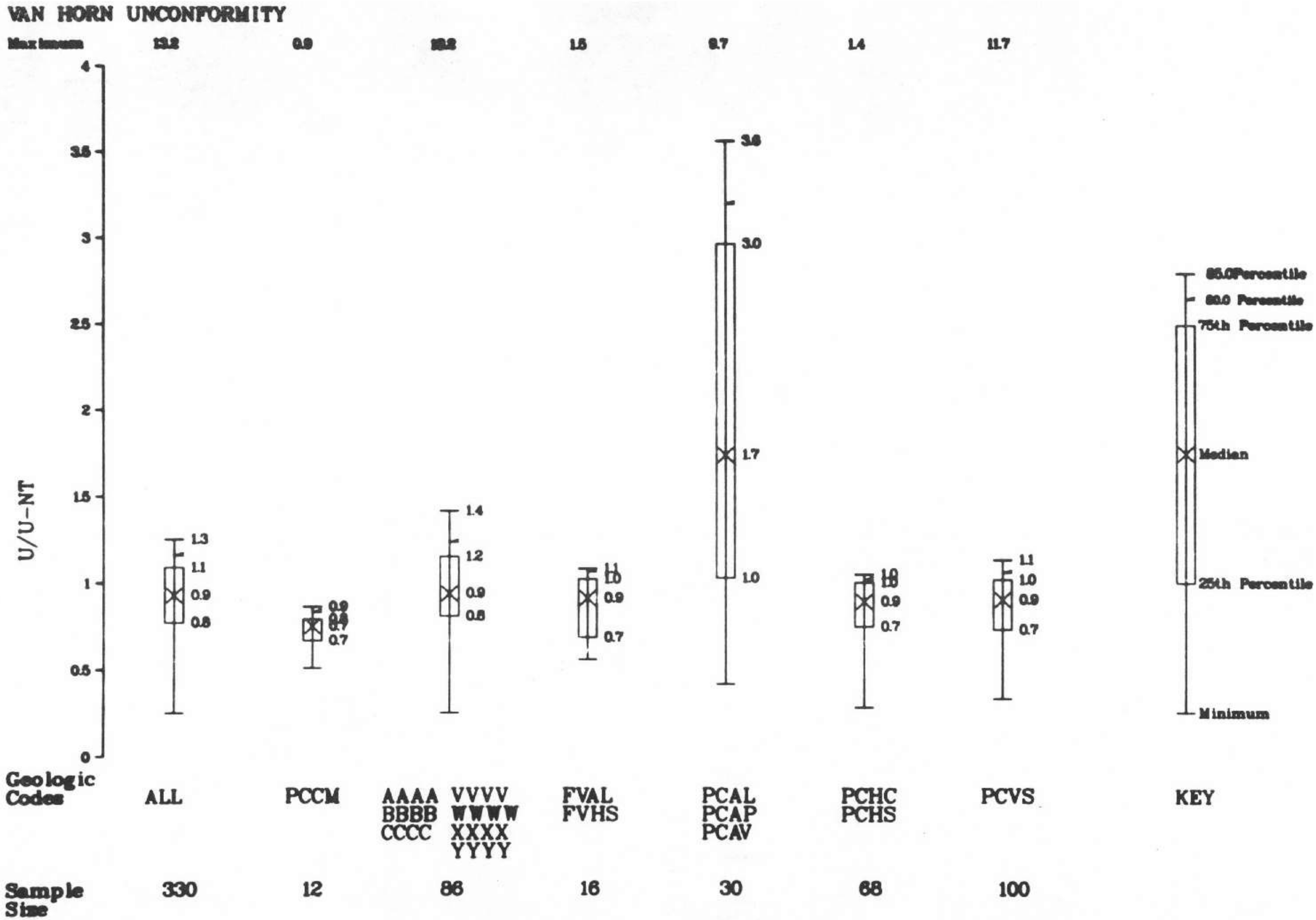

VAN HORN UNCONFORMITY
Maximum
U/U-NT
Geologic Codes
ALL
PCCM
AAAA BBBB CCCC
VVVV WWWW XXXX YYYY
FVAL FVHS
PCAL PCAP PCAV
PCHC PCHS
PCVS
KEY
75th Percentile
Median
25th Percentile
Minimum
Sample Size
330
12
86
16
30
68
100

Figure D-2

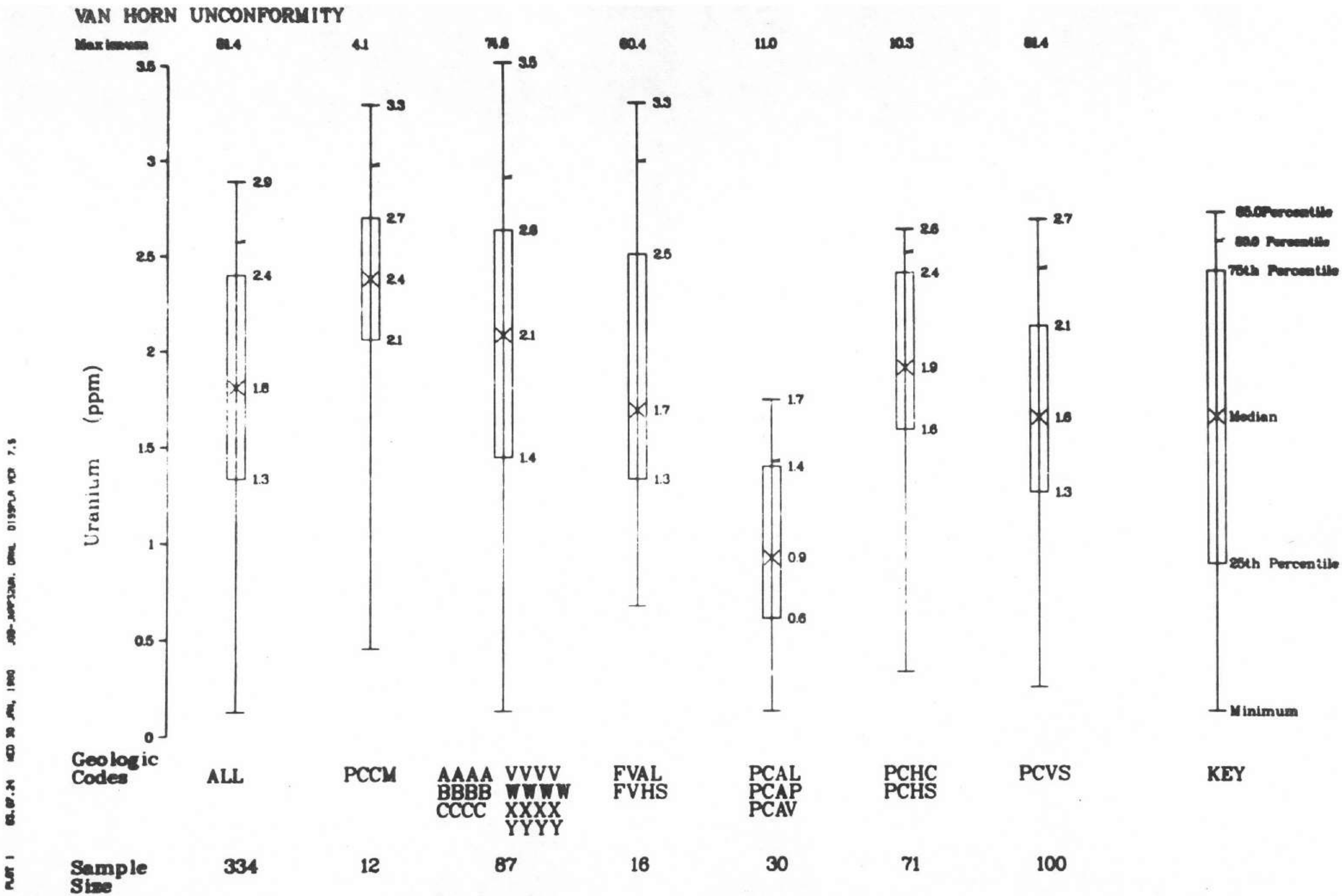

VAN HORN UNCONFORMITY
Maximum
Uranium (ppm)
Geologic Codes
ALL
PCCM
AAAA BBBB CCCC
VVVV WWWW XXXX YYYY
FVAL FVHS
PCAL PCAP PCAV
PCHC PCHS
PCVS
KEY
95.0 Percentile
90.0 Percentile
75th Percentile
Median
25th Percentile
Minimum
Sample Size
334
12
87
16
30
71
100

Figure D-3

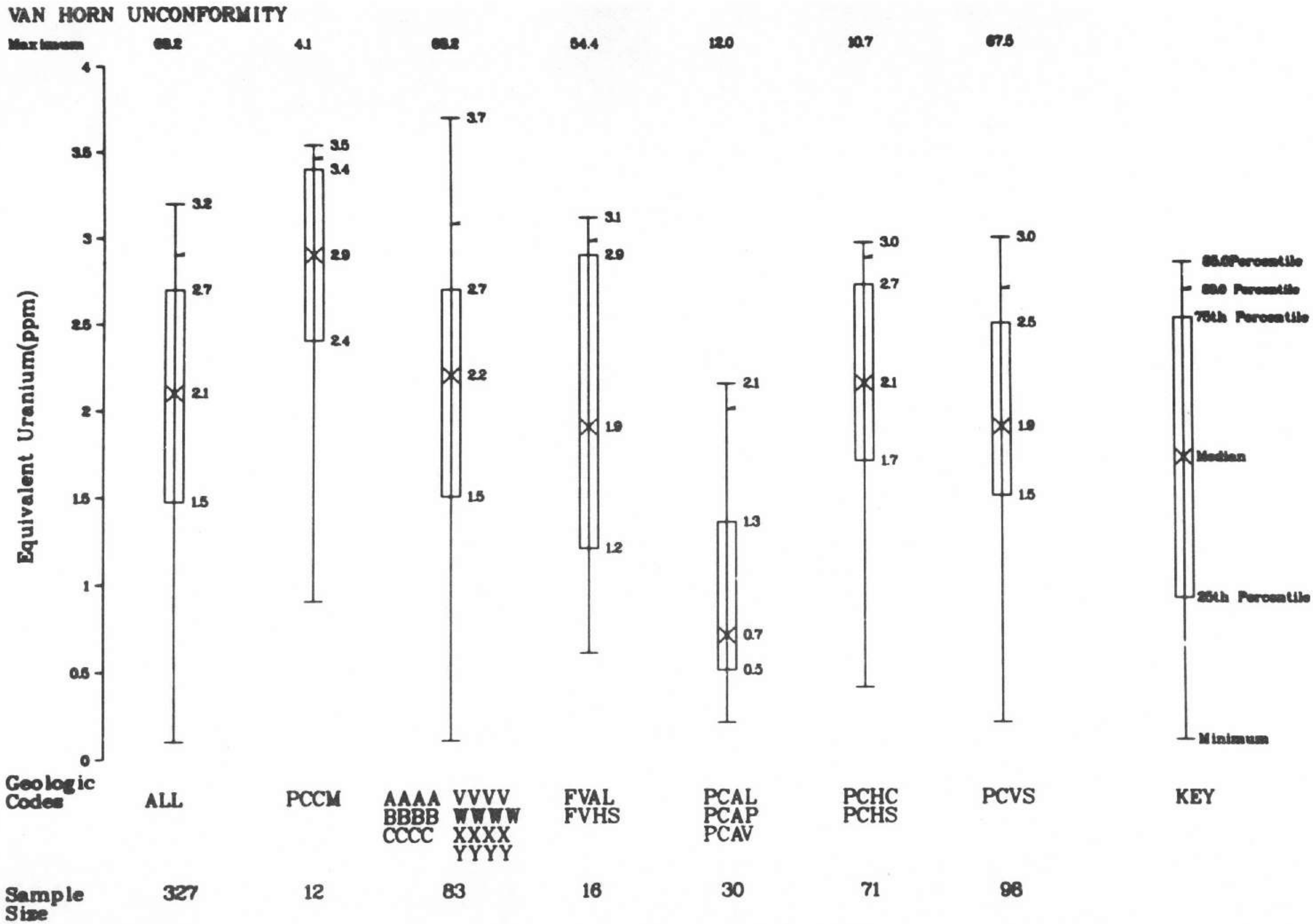

VAN HORN UNCONFORMITY
Maximum 68.2 4.1 68.2 54.4 12.0 10.7 67.5
Equivalent Uranium(ppm)
0 0.5 1 1.5 2 2.5 3 3.5 4
3.2 2.7 2.1 1.5
3.5 3.4 2.9 2.4
3.7 2.7 2.2 1.5
3.1 2.9 1.9 1.2
2.1 1.3 0.7 0.5
3.0 2.7 2.1 1.7
3.0 2.5 1.9 1.5
95.0Percentile
90.0 Percentile
75th Percentile
Median
25th Percentile
Minimum
Geologic Codes
ALL
PCCM
AAAA BBBB CCCC
VVVV WWWW XXXX YYYY
FVAL FVHS
PCAL PCAP PCAV
PCHC PCHS
PCVS
KEY
Sample Size
327 12 83 16 30 71 98

Figure D-4

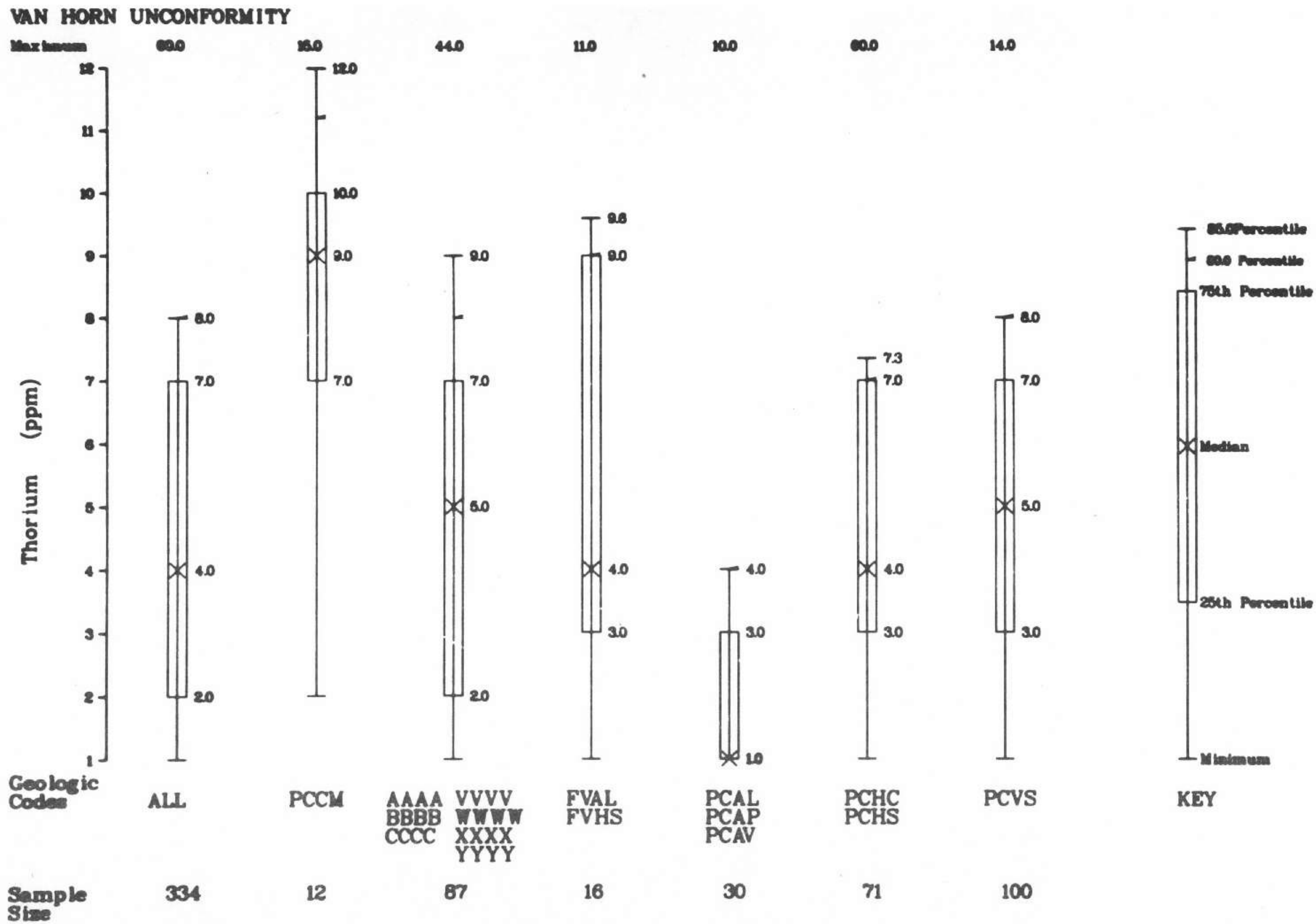

VAN HORN UNCONFORMITY
Maximum
60.0
16.0
44.0
11.0
10.0
60.0
14.0
Thorium (ppm)
95.0 Percentile
90.0 Percentile
75th Percentile
Median
25th Percentile
Minimum
Geologic Codes
ALL
PCCM
AAAA BBBB CCCC
VVVV WWWW XXXX YYYY
FVAL FVHS
PCAL PCAP PCAV
PCHC PCHS
PCVS
KEY
Sample Size
334
12
87
16
30
71
100

Figure D-5

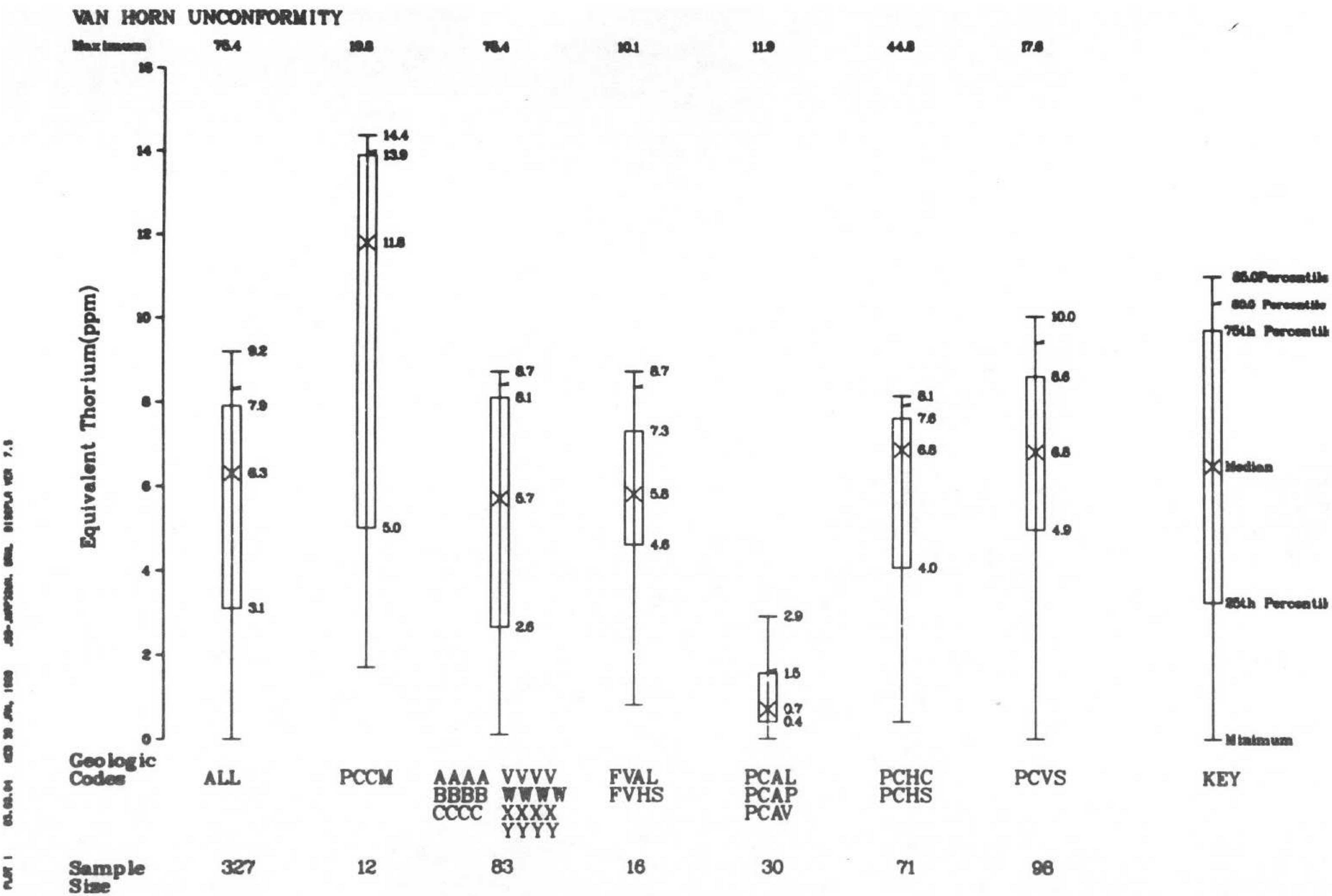

VAN HORN UNCONFORMITY
Maximum
78.4
19.8
78.4
10.1
11.9
44.8
17.8
Equivalent Thorium(ppm)
14.4
13.9
11.8
5.0
9.2
7.9
6.3
3.1
8.7
8.1
5.7
2.6
8.7
7.3
5.8
4.6
2.9
1.6
0.7
0.4
8.1
7.6
6.8
4.0
10.0
8.6
6.8
4.9
Median
Minimum
Geologic Codes
ALL
PCCM
AAAA VVVV
BBBB WWWW
CCCC XXXX
YYYY
FVAL
FVHS
PCAL
PCAP
PCAV
PCHC
PCHS
PCVS
KEY
Sample Size
327
12
83
16
30
71
98

Figure D-6

VAN HORN UNCONFORMITY

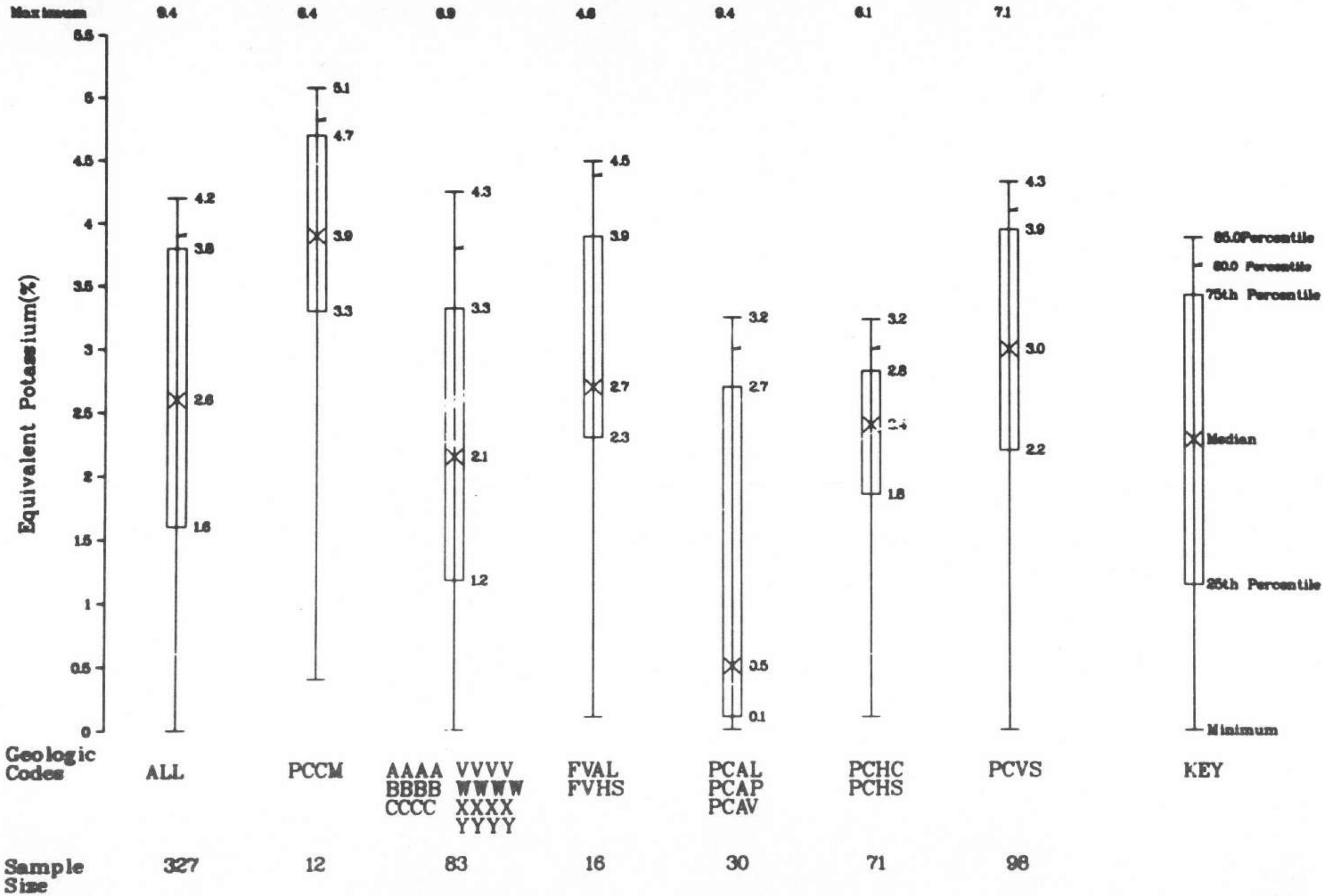
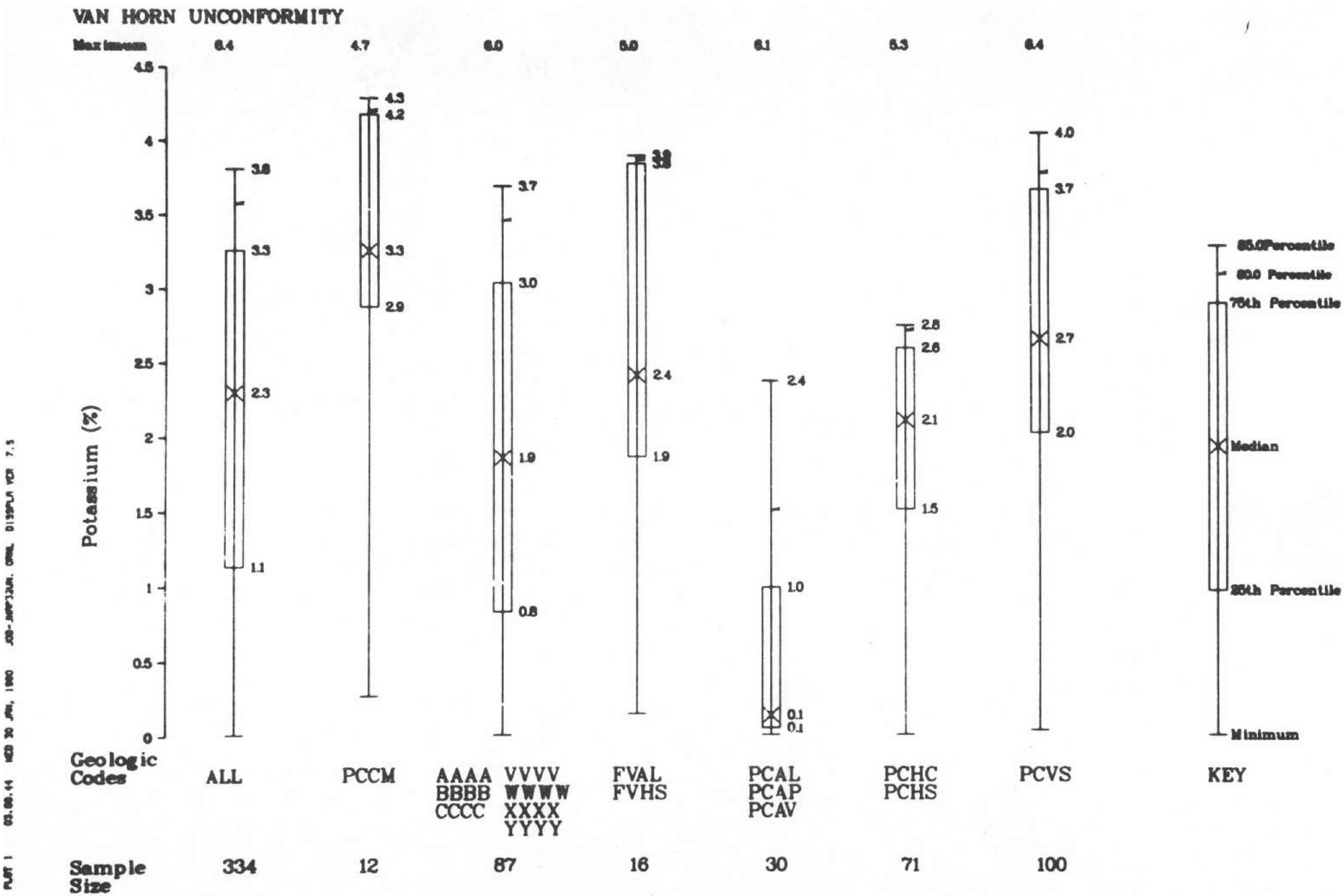
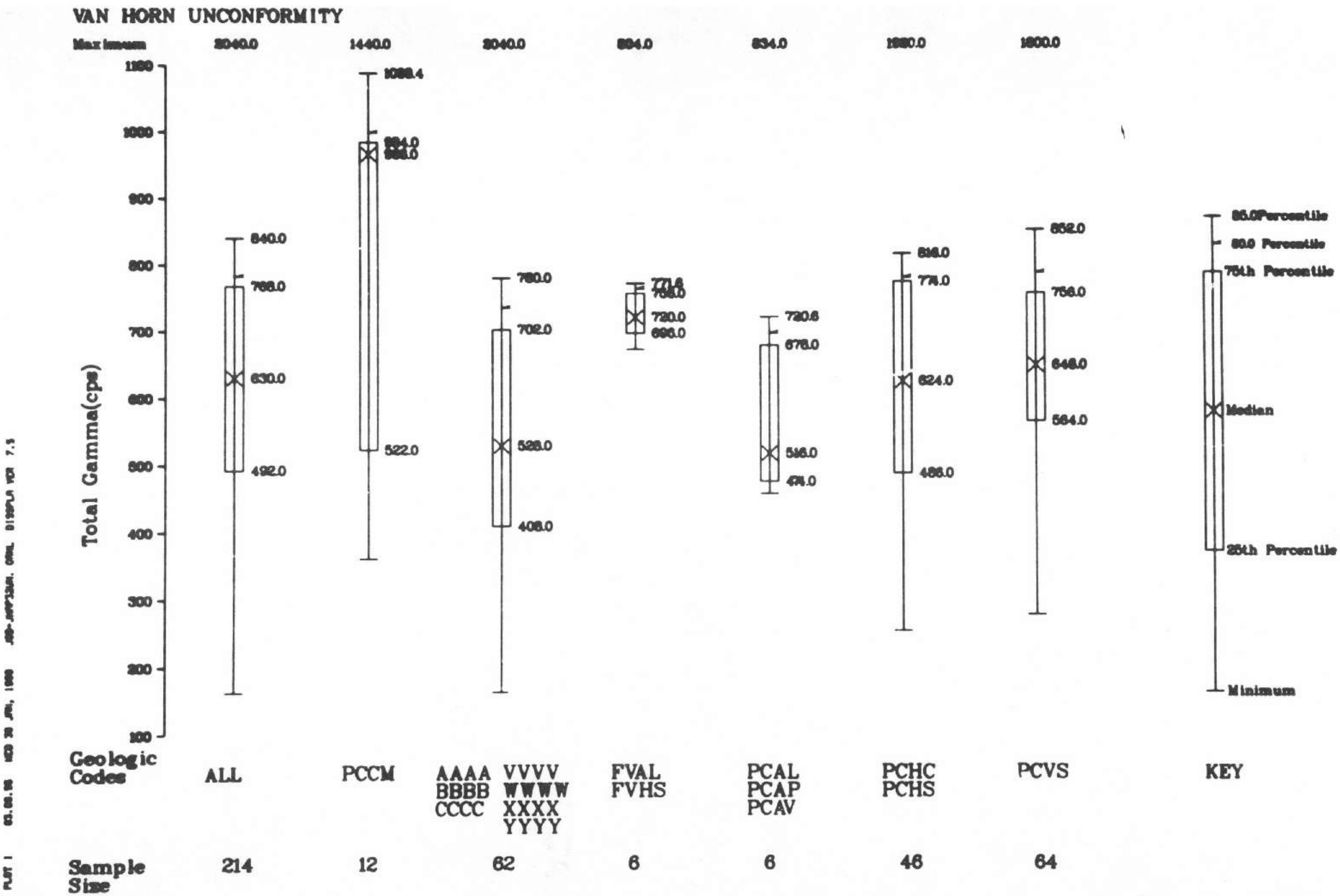


Figure D-7



VAN HORN UNCONFORMITY
Maximum
6.4
4.7
6.0
5.0
6.1
5.3
6.4
Potassium (%)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
85.0Percentile
80.0 Percentile
75th Percentile
Median
25th Percentile
Minimum
Geologic Codes
ALL
PCCM
AAAA VVVV
BBBB WWWW
CCCC XXXX
YYYY
FVAL
FVHS
PCAL
PCAP
PCAV
PCHC
PCHS
PCVS
KEY
Sample Size
334
12
87
16
30
71
100

Figure D-8



VAN HORN UNCONFORMITY
Total Gamma(cps)
Geologic Codes
ALL
PCCM
AAAA BBBB CCCC VVVV WWWW XXXX YYYY
FVAL FVHS
PCAL PCAP PCAV
PCHC PCHS
PCVS
KEY
Sample Size
214
12
62
6
6
46
64
Median
75th Percentile
25th Percentile
Minimum

Figure D-9

BIBLIOGRAPHY

Cunningham, C.G., Steven, T.A., Rasmussen, J.T., Romberger, S.B., 1979, The genesis of the Marysvale, Utah, hydrothermal uranium deposits (abs.): Geol. Soc. Amer. Abs. with Programs, v. 11, n. 7, p. 408

Dahlkamp, F.J., 1978, Geological appraisal of the Key Lake U-Ni deposits, northern Saskatchewan: Econ. Geol., v. 73, n. 8, p. 1430-1449.

Derry, D.R., 1973, Ore deposition and contemporaneous surfaces: Econ. Geol., v. 68, p. 1374-1380.

Dennison, R.E. and Heatherington, Jr., E.A., 1969, Basement rocks in far West Texas and southcentral New Mexico: in Border Stratigraphy Symposium, New Mexico Bureau of Mines and Mineral Resources Circ. 104, p. 1-16.

Gandhi, S.S., 1978, Geological setting and genetic aspects of uranium occurrences in the Kaipokok Bay -- Big River area, Labrador: Econ. Geol., v. 73, n. 8, p. 1492-1522.

Geometrics, 1978, Aerial gamma ray and magnetic survey, Van Horn and Pecos quadrangles, Texas: U.S. Dept. of Energy, Open-File Report, GJBX-2 (78).

Goodell, P.C., Trentham, R.C., and Carraway, K.E., 1979, Geologic setting of the Pena Blanca uranium deposits, Chihuahua, Mexico: U.S. Dept. of Energy, Open-File Report, GJBX-11-179, Chpt. 9, p. 1-38.

Hegge, M.R., and Rowntree, J.C., 1978, Geologic setting and concepts on the origin of uranium deposits in the east Alligator River region, N.T., Australia: Econ. Geol., v. 73, n. 8, p. 1420-1429.

Hove, J. and Sibbald, T.I.I., 1978, On the genesis of Rabbitt Lake and other unconformity-type uranium deposits in northern Saskatchewan, Canada: Econ. Geol., v. 73, n. 8, p. 1450-1743.

Kalliokoski, J., Langford, F.F., and Ojakangas, R.W., 1978, Criteria for uranium occurrences in Saskatchewan and Australia as guides to favorability for similar deposits in the United States: U.S. Dept. of Energy Open-File Report, GJBX-114(78), p.

King, P.B., and Flawn, P.T., 1953, Geology and mineral deposits of Precambrian rocks of the Van Horn area, Texas: Univ. Texas Pub. 5301, 218 p.

King, P.B., 1965, Geology of the Sierra Diablo region, Texas: U.S. Geol. Sur., Prof. Paper 480, p. 1-179.

McGowen, J.H., and Groat, C.G., 1971, Van Horn sandstone, West Texas: An alluvial fan model for mineral exploration: Bur. Econ. Geol., Univ. Texas, Austin, Rept. of Invest., n. 72, p. 1-57.

Reid, J.C., 1974, Hazel Formation, Culberson and Hudspeth Counties, Texas: M.S. Thesis, Univ. Texas, Austin, 88 p.

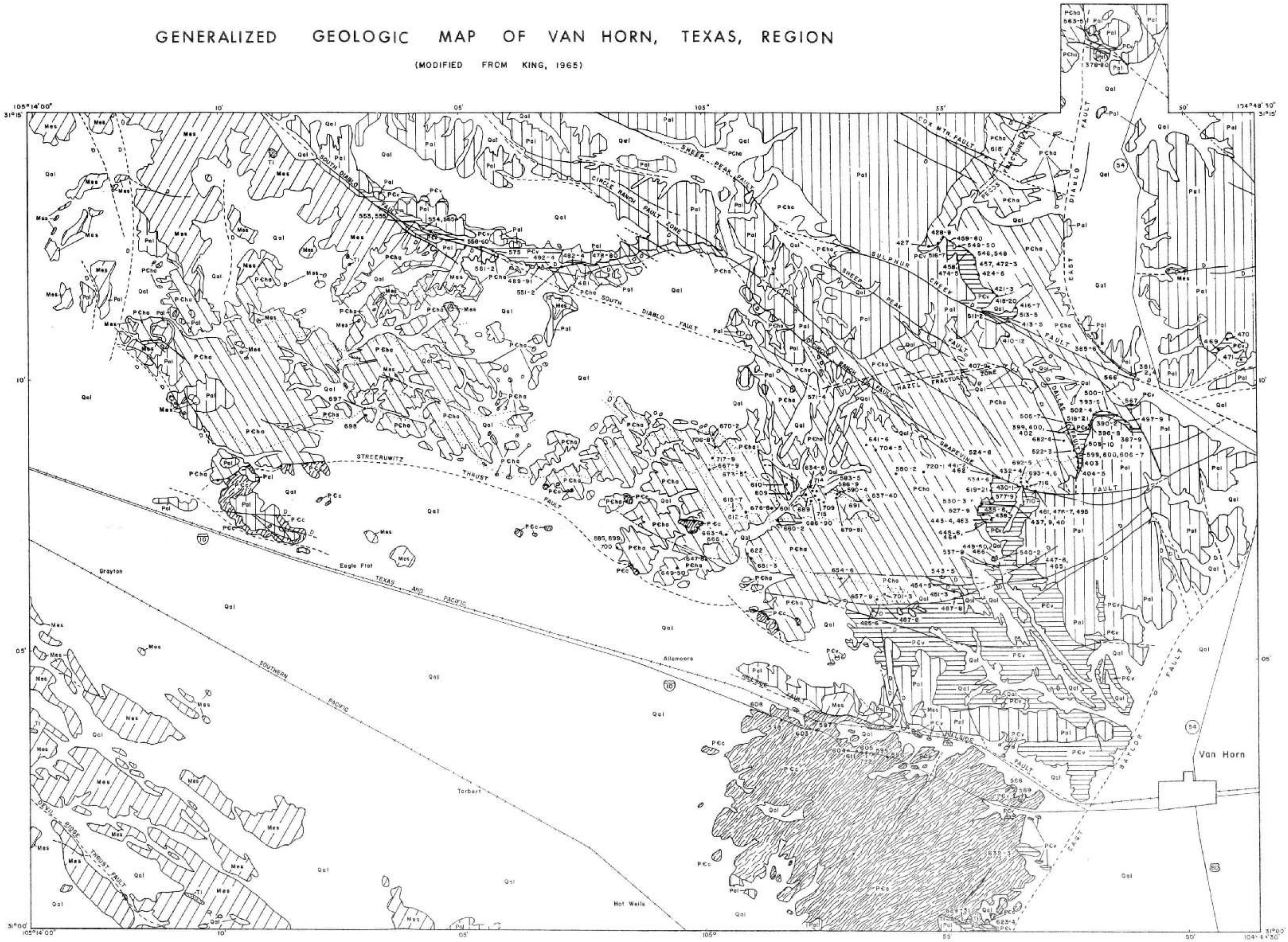
Rytuba, J.J., and Conrad, W.K., 1979, Structural and petrologic association of uranium deposits within the McDermitt Caldera complex, Nevada-Oregon: Geol. Soc. Amer., Abs. with Programs, v. 11, n. 7, p. 508-509.

Wasserburg, G.J., Wetherill, G.W., Silver, L.T., and Flawn, P.T., 1962, A study of the ages of the Precambrian of Texas: Jour. Geophys. Res., v. 67, p. 4021-4047.

Wylie, A.M., 1970, Correlation of geology with gravity and magnetic anomalies Van Horn-Sierra Blanca region, Trans Pecos, Texas: Unpublished Ph.D. Dissertation, Univ. Texas, Austin, 351 p.

GENERALIZED GEOLOGIC MAP OF VAN HORN, TEXAS, REGION

(MODIFIED FROM KING, 1965)



EXPLANATION

STRATIGRAPHY

Cenozoic

Qal — Undifferentiated alluvial, lacustrine, fluviatile, fanglomerate, and landslide deposits

Ti — Intrusive and extrusive rocks: remnants of basalt flows and diabase

Mesozoic

Mes — Undifferentiated shale, sandstone, and limestone

Major Unconformity

Paleozoic

Pal — Undifferentiated shale, sandstone, limestone, dolomite, and chert

Major Unconformity

Precambrian (?)

P€v — Van Horn Sandstone: red arkosic sandstone and conglomerate; crossbedded and unfossiliferous

Major Unconformity

Late Precambrian

P€ha — Hazel and Allamoore Formations
Hazel Fm.: red, fine-grained sandstone overlying and interbedded with conglomerate principally formed of fragments derived from Allamoore Fm.

Unconformity

Allamoore Fm.: thin- to thick-bedded cherty limestone, talcose phyllite, basaltic lava, tuff, breccia, and shallow intrusive rocks

Major Unconformity

P€c — Carrizo Mountain Formation: quartzite and arkosic quartzite, slate, schist, limestone, metarhyolite: cataclastically altered and in part mylonized, and greenstone: largely altered to amphibolite

Base Concealed

SYMBOLS

GEOLOGIC

Mes/Pal — Lithologic contact

Transcurrent fault: arrows show relative strike-slip movement; dashed where hypothetical or concealed

Normal fault: D indicates downthrown side; dashed where hypothetical or concealed

Low-angle thrust faults: barbs on upper plate; widely-spaced barbs, fault of Precambrian age; closely-spaced barbs, fault of Tertiary age; dashed where concealed

Lineament: well-marked linear features which are either faults with slight displacement or strong joints; includes mineralized fissures of Hazel Pecos fracture zones

Surface of movement: contact between Hazel and Allamoore Formations, which is variously a zone of small to large slippage or a low-angle fault with much displacement

717-9 — Sample locality (Ex. 717 thru 719)

CULTURAL

Roads: (54) Texas state highway

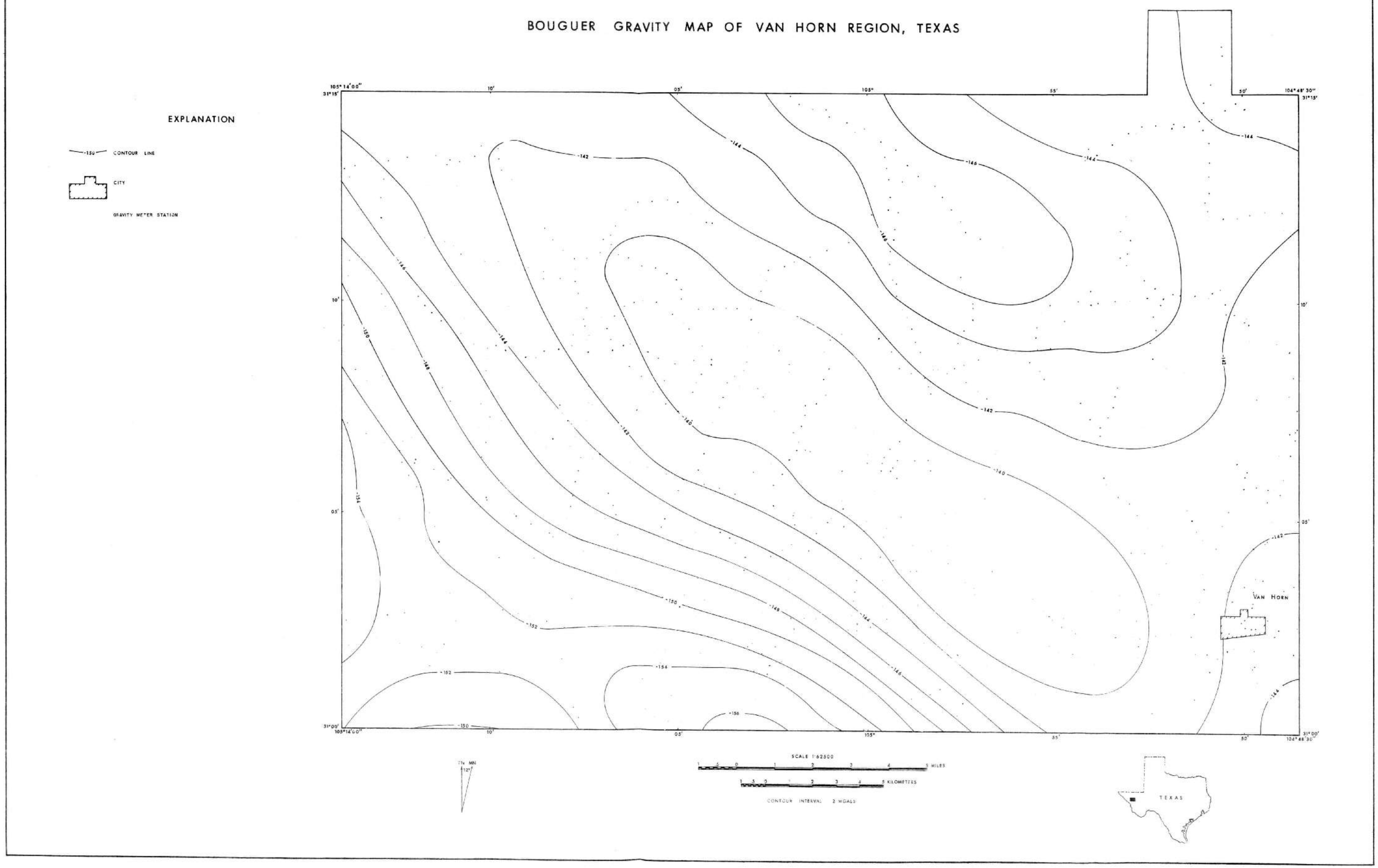
(80) U.S. highway

(10) Interstate highway

Railroad

City

BOUGUER GRAVITY MAP OF VAN HORN REGION, TEXAS



AEREOMAGNETIC MAP OF VAN HORN REGION, TEXAS