UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Geochemical maps and evaluation of stream-sediment geochemical data of the Wiseman 1° x 3° quadrangle, Brooks Range, Alaska

by

John B. Cathrall,[1] John T. Dillon,[2]
James D. Hoffman,[1] William P. Brosge[1]
and James D. Bliss[1]

Open-File Report 87-12

[1]U.S. Geological Survey

[2]Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys

1987

CONTENTS

TABLES

ILLUSTRATIONS

PLATES

INTRODUCTION

Geochemical studies were conducted in the 1° x 3° Wiseman quadrangle in the central Brooks Range, Alaska in 1977-1982 by the United States Geological Survey (USGS) under the Alaska Mineral Resource Assessment Program (AMRAP) and in cooperation with the State of Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys (DGGS). Additional investigations by other USGS and DGGS personnel consisted of mapping bedrock and surficial deposits, and collection of gravity, aeromagnetic, and other geophysical data. The geochemical investigation included the collection of samples of: stream sediment, panned concentrates from stream sediments, rocks, and pebbles from stream bedload.

GEOLOGY

The bedrock geology of the Wiseman quadrangle has been mapped by Dillon and others (1986); their generalized map is the geologic base for plates 1 and 2 of this report. The surficial geology has been separately mapped by Hamilton (1979). The unconsolidated deposits he mapped are shown as a single generalized unit on plates 1 and 2. They consist mainly of glacial drift and lake beds that fill the larger valleys and cover most of the lowlands south of the Brooks Range. Depth to bedrock beneath some of the valley deposits is as much as 250 ft on Glacier Creek, more than 365 ft on Wiseman Creek, and 100 to 275 ft on Rosie Creek (Reed, 1938).

Bedrock in the Wiseman quadrangle ranges in age from Proterozoic to Cretaceous, and in degree of metamorphism from polymetamorphic gneiss of the amphibolite facies to completely unmetamorphosed rocks (Dillon and others, 1986). However, most of the rocks in the quadrangle are Devonian or older, and most are in the greenschist facies of metamorphism. In this report the bedrock units are grouped into six areal subdivisions: I, Angayucham; II, Schist belt; III, Skajit; IV, Beaucoup-Whiteface; V, Doonerak, and VI, Endicott. The age and lithology of the rocks in each subdivision is described in the section on Geochemical Lithologic Subdivisions. The structural setting for these subdivisions is described below and illustrated by the cross section (plates 1 and 2).

The youngest and least metamorphosed rocks are those along the southern margin of the quadrangle. In that area, volcanic rocks, graywacke, and chert of Mississippian to Triassic age form the outlying mountains at the south edge of the Brooks Range and are overlain in the foothills to the south by Cretaceous sandstone, conglomerate, and shale that are partly nonmarine. The volcanic rocks and graywacke have been thrust northward over the schists of the southern Brooks Range along a thrust fault system of regional extent--The Angayucham Thrust System (Jones and others, 1984)--and have been slightly metamorphosed to prehnite-pumpellyite and greenschist facies (Dusel-Bacon and others, in press). According to Jones and others (1984), this thrust system is a major lithotectonic terrane boundary between the Angayucham terrane on the south and the Arctic Alaska terrane, which comprises all of the rocks to the north. The folded but unmetamorphosed mid-Cretaceous sediments of the Koyukuk basin that overlie the volcanic rocks of the Angayucham terrane evidently are younger than the thrusting and metamorphism, because they contain abundant clasts of the Brooks Range metamorphic rocks as well as clasts of the nearby volcanic rocks (Dillon and Smiley, 1984). Thus, the age of thrusting and of the latest metamorphism is probably Jurassic to Early Cretaceous, and the regional metamorphism in the Brooks Range is probably the result of tectonic burial beneath the volcanic rocks thrust over them from the south.

North of the Angayucham Thrust Zone, the Arctic Alaska terrane (Brooks Range) consists of a series of imbricated and folded thrust plates of Paleozoic and Proterozoic rocks in which the intensity of folding and metamorphism, as well as the age of the exposed rocks, decreases northward, but the horizontal displacement remains great. Any contact may be a bedding plane fault. Thrusting and overturning seems generally to have been directed northward, but the structural trends are not continuous from south to north. At the southern edge of the range, an east-west trending belt of schist 10 to 15 mi wide is roughly parallel to the adjacent Angayucham Thrust System. This southern belt is composed of schist, marble, and metavolcanic rocks of the greenschist facies and some rocks of the amphibolite facies that have been retrograded to greenschist. Another east-west striking belt that crosses the northern quarter of the quadrangle is composed of slightly metamorphosed Upper Devonian to Triassic sedimentary rocks. This northern belt is part of the folded thrust system that forms the north front of the Brooks Range. In each of these two belts, a few key rock units can be traced completely across the quadrangle. Between the northern and southern belts, the continuity of rock units and thrust plates in the middle half of the quadrangle is disrupted by a broad arch that trends diagonally across the quadrangle from SW to NE, and by two large synforms on the flanks of the arch. Erosion of folded thrust plates has exposed a large window on the arch near Mt. Doonerak and has preserved probable klippen in the synforms near Crag Peak and Jesse Mountain.

The two linear belts are bounded almost continuously by faults. The schist belt just north of the Angayucham thrust system has been thrust over the rocks to the north. The belt of Upper Devonian to Triassic rocks has been overthrust on the southwest by older Devonian rocks of the Crag Peak synform, and on the southeast has been thrust over the Upper and Lower Paleozoic rocks in the Mt. Doonerak window.

In order to interpret the geochemical data, the rocks of the quadrangle are described in the next section of this report under six areal subdivisions that correspond closely to these main structural elements. The Angayucham subdivision includes all the rocks south of the Angayucham Thrust System, the Schist Belt subdivision includes all the rocks of the southern belt except some carbonate rocks of the Skajit Limestone along its northern edge, and the Endicott subdivision includes all the rocks in the northen linear belt of Upper Devonian to Triassic rock. The three remaining subdivisions are in the central part of the quadrangle. The Doonerak subdivision includes all the Lower Paleozoic rocks within the Doonerak window at the NE end of the arch that trends across the quadrangle. The Skajit subdivision includes the Proterozoic basement gneiss and overlying Skajit Limestone above the Doonerak window at the SW end of this arch, as well as the minor amount of Skajit Limestone involved in the linear schist belt. The Beaucoup-Whiteface subdivision includes all of the Devonian or older metaclastic rocks in the two broad synforms flanking the arch, as well as those in a narrow anticline along Wiseman Creek that separates the Jesse Mountain synform from the north edge of the schist belt. The number of thrust plates within these two synforms may be greater than is shown on the geologic map. Devonian fossils have been found at several horizons, but the recent discovery of Cambrian and Ordovician fossils not far below Devonian fossils in similar rocks in the Chandalar quadrangle (Dillon, unpublished data) suggests that lower Paleozoic rocks may lie along faults between some of the Devonian rocks in the synforms.

The thrust system that dips northward and southward from the Doonerak window probably underlies all of the other subdivisions north of the schist belt (see plate 1 X section). It is most evident at the east end of the window where the Upper Devonian Hunt Fork Shale and Beaucoup Formation in the upper plate are thrust over Mississippian rocks on both flanks of the window. The thick, northerly derived Upper Devonian clastic sequence in the northern Brooks Range, of which the Hunt Fork is the lower and finer grained part, is missing between the Mississippian rocks and the Cambrian to Silurian rocks of the lower plate within the window, just as it is missing beneath the Mississippian rocks in the subsurface of the North Slope subsurface. According to Mull and others (1976) and Jones and others (1984), the Lower Paleozoic basement rocks of the North Slope, unconformably overlain by Mississippian rocks, lie at depth beneath the northern Brooks Range and rise to the surface in the window at Mt. Doonerak. The fault between these rocks and the overlying Hunt Fork Shale continues northward from Mt. Doonerak beneath all the exposed Upper Devonian to Triassic rocks in the northern Brooks Range. They have moved northward along this fault from somewhere south of Mt. Doonerak. Thus, the rocks of the Endicott subdivision, which lies on the north flank of the window, are an allochthon above this fault that has moved northward at least 60 mi.

The same fault must underlie the rocks of the Beaucoup-Whiteface subdivision south of the window. Mississippian rocks have not been found along most of the south flank of the window, so the location of the fault between Silurian or older rocks in the lower plate and Devonian or older rocks in the upper plate must be inferred. However, the Hunt Fork Shale crops out continuously in the upper plate about 2 mi south of the inferred fault. Inasmuch as the Hunt Fork Shale is the southern, distal part of the Upper Devonian clastic sequence (Brosge and Tailleur, 1970), these rocks probably originated farther south than some of the coarser grained rocks in the Endicott subdivision and thus have also been transported northward. The Hunt Fork Shale is present in both the Beaucoup-Whiteface subdivision and the Skajit subdivision. In the latter, it overlies the Skajit Limestone, so the Skajit must also be part of the upper plate of the Doonerak window.

GEOCHEMICAL LITHOLOGIC SUBDIVISIONS

The geochemical results were found to be so variable that a better interpretation could be made if the quadrangle was subdivided into six areas, each with significantly different geochemical populations and bedrock lithologies. We have designated these areas as "geochemical lithologic subdivisions." The boundaries of these subdivisions are located at major changes in the geochemistry, and are drawn to follow important geologic contacts that coincide with those changes. The boundaries of these subdivisions are shown on plates 1 and 2 and on figures 1 and 2. The geology of each subdivision is summarized below.

Subdivision I--ANGAYUCHAM

Lithology: Bedrock is mostly covered by glacial and alluvial deposits. In and adjacent to the Brooks Range, bedrock is dark gray phyllite and graywacke, mafic volcanic rocks, and minor radiolarian chert, all of Late Paleozoic to Triassic age. In the Koyukuk basin, bedrock is Cretaceous marine and non-marine sandstone, shale, and conglomerate. The northern boundary of the subdivision is the Angayucham Thrust Zone in the east and the younger Malamute right-lateral fault in the west.

Metamorphic facies: The Cretaceous clastic rocks are unmetamorphosed; the volcanic rocks are partly in the prehnite-pumpellyite metamorphic facies; and the graywacke and phyllite are in the lower greenschist facies (Dusel-Bacon and others, in press).

Subdivision II--SCHIST BELT

Lithology: This subdivision contains most of the coarse-grained quartz schist in the quadrangle. Coarse-grained mica-quartz schist of possible Early Paleozoic to Proterozoic age is exposed in about half of the area, mainly in the eastern and southern parts. This schist is underlain in the east by interlayered mica-quartz schist, calcareous schist, and marble also of uncertain age. These schists plunge generally westward. In the western half of the subdivision, the coarse-grained schist is overlain by the Devonian Ambler metavolcanic rocks consisting of interlayered black schist and quartzite, marble, and abundant mafic and felsic volcanic rocks. The northernmost rocks of the subdivision for most of its extent are black fine-grained schists, quartzite, and some metaconglomerate in two overturned synclines that appear to be the stratigraphically highest rocks in the subdivision, although many of the contacts are faults.

In addition to the abundant volcanic rocks in the Ambler metavolcanic rocks, mafic and felsic dikes and sills are common in the coarse-grained schist, and two small granitic bodies of Devonian age intrude the calcareous schist at the Wild River and the Middle Fork of the Koyukuk.

Metamorphic facies: All of the rocks have greenschist facies mineral assemblages. About half of the rocks, mainly in the eastern and southern parts of the subdivision, also contain relict amphibolite facies mineral assemblages (Dusel-Bacon and others, in press) including biotite, garnet, hornblende, and plagioclase.

Subdivision III--SKAJIT

Lithology: The rocks are mostly marble and dolomite of the Skajit Limestone of Devonian and older (?) age. West of Sixty Mile Creek, there also are extensive exposures of interlayered schist, calcareous schist, quartzite, phyllite, marble, and metabasite of probable Proterozoic age that underlie the Skajit. These older rocks are intruded by several small plutons of granite gneiss of probable Proterozoic age. The Ernie Lake pluton at the west edge of the quadrangle is the largest. North of this pluton, at the head of Mettenpherg Creek, is one small exposure of the Ambler metavolcanic rocks. East of the John River, black phyllite of the Devonian Hunt Fork Shale along with interlayered chloritic phyllite, carbonate rocks, and chloritic calcareous metasandstone of probable Devonian age, overlie the Skajit Limestone. In this area, large metabasite sills are common in the Skajit Limestone.

Metamorphic facies: Rocks in this subdivision are in the greenschist facies. The Proterozoic (?) rocks surrounding the granite-gneiss plutons are retrograded from the epidote-amphibolite facies and contain relict garnet, biotite, hornblende, and locally, kyanite. Similar facies occur along the southeast boundary of the subdivision.

Subdivision IV--BEAUCOUP-WHITEFACE

Lithology: The rocks are almost entirely clastic metasediments of several different stratigraphic units shuffled together in broad thrust sheets. These units include the Hunt Fork Shale and the Beaucoup Formation, both of Devonian age, and the rocks of Whiteface Mountain and of several other unnamed units, of Devonian or older age. Black phyllite, slate, and black metasiltstone underlie about one third of the area, and chloritic phyllite, chloritic metasiltstone, sandstone, graywacke, and conglomerate underlie most of the rest. Volcanic clasts are common in the graywackes along the northwestern and northeastern boundaries of the subdivision. Thin beds of limestone occur in the phyllites, and most phyllites are partly calcareous. The only large outcrops of dolomite, limestone, and marble are in the Skajit Limestone along the North Fork Koyukuk and Glacier Rivers and east of Mashooshalluk Creek. Mafic volcanic rocks and mixed mafic and felsic intrusive rocks are common in and around the Skajit outcrops. Felsic volcanic rocks that are probably equivalent to those in the Ambler metavolcanic rocks occur along the northern boundary of the subdivision from Redstar Mountain northeastward through Whiteface Mountain to the quadrangle boundary.

Metamorphic facies: All of the rocks contain greenschist facies mineral assemblages. The only coarsely crystalline schists are in the southern part of the subdivision, where locally they contain biotite. Chloritoid is common in quartzose rocks throughout the subdivision, but the degree of metamorphic recrystallization and foliation decreases northward, so that in the northern half of the area phyllites with relict sedimentary texture, bedding, and shelly megafossils predominate.

Subdivision V--DOONERAK

Lithology: The rocks are in the core of a doubly plunging anticline which is also a structural window. They consist mostly of black phyllite and siltstone of Cambrian through Silurian age. At the southwest end of the anticline, red and green phyllite and argillite, meta-tuff, and metawacke of possible Cambrian to Devonian age are interlayered with and partly overlie the black phyllites. Meta-basite sills of probable Devonian age are common in all of these rocks. The northeastern quarter of the subdivision, around Mt. Doonerak, is underlain mainly by andesitic to basaltic volcaniclastic rocks of Ordovician and Cambrian (?) age interlayered with graywacke, tuffaceous phyllite, and black phyllite, and intruded by basalt and diabase.

The boundary of the subdivision follows the faults that bound the window, except in the northeast, where Mississippian carbonate rocks within the window are excluded from this lithologic subdivision.

Metamorphic facies: The metasedimentary rocks and metabasite sills are in the lower greenschist facies, and volcanic rocks in the northeast are in the prehnite-pumpellyite facies. The metasediments contain white mica and locally contain identifiable shelly fossils and graptolites. The Devonian (?) metabasite sills within the metasediments contain stilpnomelane and actinolite.

Subdivision VI--ENDICOTT

Lithology: Fine- and coarse-clastic sedimentary rocks of the Endicott Group of Late Devonian and Mississippian age underlie almost all of this subdivision. Black slate and phyllite of the Hunt Fork Shale underlie about half of the area, and lies along most of the southern boundary of the subdivision. Marine shale and sandstone of the Noatak Sandstone, and non-marine sandstone, conglomerate, and shale of the Kanayut Conglomerate underlie most of the remaining area. A syncline at the head of the Tinayguk River contains some black Kayak shale of the uppermost Endicott Group, but is mostly Lisburne Group limestone, dolomite, and chert of Mississippian age overlain by varicolored, slightly baritic shale and siltstone of Permian age.

Carbonate rocks of the Lisburne Group and minor amounts of clastic rocks of Mississippian to Triassic age also occur east of the North Fork of the Koyukuk River in a narrow band within the Doonerak window. These rocks lie between the stratigraphically underlying Lower Paleozoic rocks of the Doonerak subdivision to the south and the structurally overlying Hunt Fork Shale to the north. Conglomerate of the Beaucoup Formation occurs locally along the fault beneath the Hunt Fork in this area, and a narrow band of Beaucoup Formation conglomerate and limestone lies directly along the subdivision boundary between the North Fork and the Tinayguk Rivers.

A few small mafic sills intrude the Hunt Fork Shale, and minor amounts of felsic tuff occur in both the Mississippian clastic rocks and the Beaucoup Formation east of the North Fork.

The southern boundary of the subdivision follows a series of faults. The boundary is a major south-dipping fault west of the Allen River, where rocks of the Beaucoup-Whiteface subdivision have been thrust northward over the Hunt Fork Shale. Between the Tinayguk and North Fork Koyukuk Rivers, the boundary coincides with the inferred major north-dipping fault that separates the Hunt Fork Shale and Beaucoup Formation from the underlying Lower Paleozoic rocks of the Doonerak window. East of the North Fork, the boundary lies slightly south of this fault and follows the base of the Mississippian rocks within the window.

Metamorphic facies: The less competent rocks and those lowest in the stratigraphic and structural pile show evidence of lower greenschist facies metamorphism. The Hunt Fork Shale is actually phyllite and slate, and together with the enclosed greenstone sills, contains lower greenschist facies mineral assemblages. The younger rocks structurally below the Hunt Fork have polymetamorphic fabrics. The Kanayut Conglomerate and Lisburne Group carbonates stratigraphically above the Hunt Fork do not contain metamorphic minerals although regional vitrinite reflectance data indicate temperatures reached more than 300°C (Brosge and others, 1981).

ELEMENT SELECTION

The elements selected for discussion are divided into three groups. The first group contains those elements of potential economic significance that commonly occur well above the lower limit of analytical determination and whose elemental concentration varies markedly in different lithologies. These elements are Cu, Pb, Zn, and Ba.

The elements in the second group are commonly associated with mineral deposits, but the analytical level of determination by spectrographic methods is so high that nearly all detectable values are statistically significant. These elements are Ag, Au, As, Bi, Sb, Sn, W, and Mo.

The third group are elements of less likely economic significance, that have values above the level of determination. The elements show relatively little variation among different lithologies, and their distribution is not directly related to possible deposits in the quadrangle in any discernible way. Their values are not anomalous in terms of the average abundance that might be expected in the various lithologies within this quadrangle. These elements are Be, B, Co, Cr, La, Nb, Ni, Sc, Sr, V, Y, and Zr. From this group only Co, Ni, and Cr are discussed.

METHOD OF EVALUATION

Evaluation of the geochemical data of the Wiseman quadrangle is complicated by variation of the element concentrations reflecting the various lithologic units. The rocks contain a large percentage of black shales and fine-grained clastic rocks and the overall metamorphic grade decreases to the north. Some of these lithologic units contain unusual concentrations of elements of potential economic significance and other associated minor elements, but lack hydrothermally altered and mineralized rocks. They also lack the conspicuous sulfide minerals of Cu, Pb, and Zn, a characteristic of metal-rich black shales. Therefore, the geochemical reflections of lithology, geology, geological environments, and geophysical features require consideration of associations among the elements.

A total of 1,607 stream-sediment samples and 1,257 panned heavy-mineral-concentrate samples from stream sediments were collected and analyzed for this geochemical evaluation. Sample description, collection methods, media selection, sample preparation, analytical results, statistical data, and analytical techniques are given in Dillon and others (1981a, 1981b), O'Leary and others (1984), and Cathrall and others (1984).

Additional geochemical data was obtained from the National Uranium Resource Evaluation and nationwide Hydrogeochemical and Stream Sediment program of the U.S. Department of Energy. The report and a magnetic tape provided by the Los Alamos Scientific Laboratories, 1981, Los Alamos, N. Mex., and the Oak Ridge Gaseous Diffusion Plant, 1981, Oak Ridge, Tenn., allow a summary of the principal features of this geochemical data, and corroborates our geochemical data (Cathrall, J. B., Hoffman, J. D., Miesch, A. T., Wilch, L. O., and Lewis, J. S., 1983, Summary of selected geochemical data from U.S. Department of Energy. National Uranium Resource Evaluation on sediment samples from the Wiseman quadrangle, Alaska: U.S. Geological Survey Administrative Report, 55 p. On file at Technical Data Unit, Branch of Alaska Geology, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, California 94025).

The following system has been devised for figures 2 to 34, tables 1 and 2, and the related text.

Figure 2 is a master map, or template, for use in orienting figures 3 to 34. The figure shows latitude, longitude, scale, major drainages, outline of the 24 (scale 1:63,360) individual quadrangles that make up the Wiseman (1:250,000 scale, 1° x 3°) quadrangle, and the six selected geochemical lithologic subdivisions.

The six geochemical lithologic subdivisions described earlier are shown on figures 1 and 2, and plates 1 and 2, are referred to as: I - Angayucham, II - Schist Belt, III - Skajit, IV - Beaucoup-Whiteface, V - Doonerak, and VI - Endicott. Within these units, elemental concentrations from stream-sediment and the nonmagnetic fraction of heavy-mineral concentrations from stream sediments were statistically analyzed separately. The analyses show that geochemical signatures are different for each of the geochemical-lithologic subdivisions and indicate that the lower limit of anomalous concentrations of selected elements vary from subdivision to subdivision (tables 1 and 2). The threshold values for each of the subdivisions were determined by inspection of histograms and percentile tables and consideration of (1) the average crustal abundance of the determined elements in the different lithologic units (following Levinson, 1974; and Krausckopf, 1967), and (2) previously established threshold values in adjoining quadrangles having the same lithologies (from: Philip Smith Mountains, Reiser and others, 1983; Survey Pass, Cathrall and others, 1979 a,b; and Chandalar, Reiser and others, 1979). The histograms and percentile tables were created from analytical data retrieved from the U.S. Geological Survey computer-based file, RASS (Rock Analysis Storage System) (VanTrump and Miesch, 1977). The threshold values of the elements in the six subdivisions range from concentrations occurring at the 80th to the 99th percentile of the sample populations (tables 1 and 2). Some of the elements shown on tables 1 and 2 are not present in anomalous amounts in some subdivisions. They either show little variation within an area or their variance can be explained when compared to the average crustal abundance for the various rock units.

Figures 3A and 3B are locality maps showing the sites at which the stream-sediment samples and panned heavy-mineral-concentrate samples from stream sediments were collected.

Figures 4 to 34 are a series of computer-generated single-element geochemical maps that are the building blocks for the multi-element maps (plates 1 and 2). These single-element maps are the basis for interpreting the geochemistry of the Wiseman quadrangle. They show the observed element distribution in the entire quadrangle without correction for local geology or local geochemical background. The symbols represent the approximate percentile of the overall population of values or range of values for each element measured at the respective locality.

N, used in the concentration column on some figures, indicates the element was not detected at the value shown; L, indicates detected, but less than the value shown. Percentiles were not used on figures 11 (Bi), 13 (Au), 14 (Sn), and 28 (Au) since few detections were reported. Figures 13 (Au) and 28 (Au) show symbols only at sites where gold was detected. All other figures include symbols for all samples collected and analyzed. Figure 12 (Hg) shows symbols only in the two areas for which Hg analyses were made.

The method of analyses (S, semiquantitative direct-current arc emission spectroscopy; AA - atomic absorption spectrometry; CM - colorimetric; Inst - instrumental), element (by use of chemical symbols), and sample type (seds - stream sediment; C3 - nonmagnetic heavy-mineral concentrates from stream sediment) are listed at the bottom of each map.

Tables 3 through 8 summarize the geochemical anomalies within the Wiseman quadrangle based on the geochemical data and geology. Each table is for one of the geochemical-lithologic subdivisions shown on plates 1 and 2. The tables list the areas of geochemical anomalies; describe the geologic units associated with each anomalous area; list the anomalous elements; and summarize the suspected and (or) permissive types of deposits that may exist and the criteria for selection. Deposit types are consistent with those found in Cox (1983a, 1983b) and Singer and Mosier (1983a, 1983b). Figure 1 and plates 1 and 2 show the location of the areas of major geochemical anomalies in their respective geochemical lithologic subdivision as listed in tables 3-8. Geochemically anomalous areas are only one part of the criteria for areas permissible for specific deposit types. The comprehensive mineral-resource assessment for the quadrangle is being prepared.

REFERENCES CITED

Brosge, W. P., and Reiser, H. N., 1960, Progress map of the geology of the Wiseman quadrangle, Alaska: U.S. Geological Survey Open-File Report 60-19, 2 sheets, scale 1:250,000.

Brosge, W. P., Reiser, H. N., Dutro, J. T., Jr., and Detterman, R. L., 1981, Organic geochemical data for Mesozoic and Paleozoic shales, central and eastern Brooks Range, Alaska: U.S. Geological Survey Open-File Report 81-551, 18 p.

Brosge, W. P., and Tailleur, I. L., 1970, Depositional history of northern Alaska, in Adkison, W. L., and Brosge, M. M., eds., Geological seminar on the north slope of Alaska: American Association of Petroleum Geologists, Pacific Section, Menlo Park, Proceedings, p. D1-D17.

Cady, J. W., and Dillon, J. T., , Aeromagnetic map and interpretation of the Wiseman quadrangle, Brooks Range, Alaska: in preparation.

Cady, J. W., and Hackett, S. W., 1982, Maps showing aeromagnetic survey and interpretation of the Survey Pass quadrangle, Brooks Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map 1176-G, 3 sheets.

Cathrall, J. B., Cooley, E. F., O'Leary, R. M., Billings, T. M., and McDanal, S. K., 1979a, A listing and statistical summary of spectrographic and chemical analyses of stream-sediment samples from the Survey Pass quadrangle, Alaska: U.S. Geological Survey Open-File Report 79-837A, 55 p., 1 pl.

Cathrall, J. B., Cooley, E. F., McDanal, S. K., and Billings, T. M., 1979b, A listing and statistical summary of spectrographic analyses of heavy-mineral concentrates from stream-sediment samples for the Survey Pass quadrangle, Alaska: U.S. Geological Survey Open-File Report 79-837B, 52 p., 1 pl.

Cathrall, J. B., Billings, T. M., Cooley, E. F., and O'Leary, R. M., 1981, Map showing anomalous drainage areas of selected elements in the Survey Pass quadrangle, Brooks Range, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF 1176-D.

Cathrall, J. B., Dillon, J. T., and Chazin, Barbara, 1984, Maps of anomalous trace metals in rocks and stream-sediment pebbles of the Wiseman 1° x 3° quadrangle, Brooks Range, Alaska: U.S. Geological Survey Open-File Report 84-161-B, 1 sheet, scale 1:250,000, 44 p.

Cox, D. P., ed., 1983a, U.S. Geological Survey-INGEMINAS mineral-resource assessment of Colombia--ore deposit models: U.S. Geological Survey Open-File Report 83-423, 71 p.

______ 1983b, U.S. Geological Survey-INGEMINAS mineral-resource assessment of Colombia--additional ore deposit models: U.S. Geological Survey Open-File Report 83-901, 32 p.

Detra, D. E., 1977, Delineation of an anomalous lead-zinc area in the Philip Smith Mountains, A-2 quadrangle, Alaska: U.S. Geological Survey Open-File Report 77-223, 11 p.

Dillon, J. T., Brosge, W. P., and Dutro, J. T., Jr., 1986, Generalized geologic map of the Wiseman quadrangle, Alaska: U.S. Geological Survey Open-File Report 86-219, scale 1:250,000.

Dillon, J. T., Cathrall, J. B., and Moorman, M. A., 1981a, Geochemical reconnaissance of the southwest Wiseman quadrangle; summary of data on pan-concentrate and stream-sediment samples, Alaska Division of Geological and Geophysical Surveys: U.S. Geological Survey Open-File Report 133A, 176 p.

Dillon, J. T., Lamal, K. K., and Huber, J., , Source of gold deposits of the Upper Koyukuk and Chandalar districts, Alaska: in preparation.

Dillon, J. T., Moorman, M. A., and Lueck, L., 1981b, Geochemical reconnaissance of the southwest Wiseman quadrangle--summary of data on rock samples; Alaska Division of Geological and Geophysical Surveys: U.S. Geological Survey Open-File Report 133B, 164 p.

Dillon, J. T., and Smiley, C. J., 1984, Clasts from the Early Cretaceous Brooks Range orogen in Albian to Cenomanian molasse deposits of the northern Koyukuk basin, Alaska [abs.]: Geological Society of America Abstracts with Programs, Anchorage, p. 279.

Dusel-Bacon, Cynthia, Brosge, W. P., Till, A. B., Fitch, M. R., Mayfield, C. F., Reiser, H. N., and Miller, T. P., in press, Metamorphic facies map of northern Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map, I- , scale 1:1,000,000, 2 sheets, p.

Hamilton, T. D., 1979, Surficial geologic map of the Wiseman quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-1122, scale 1:250,000.

Jones, D. L., Siberling, N. J., Coney, P. J., and Plafker, George, 1984, Lithotectonic terrane maps of the North American Cordillera, in Silberling, N. J., and Jones, D. L., eds., Lithotectonic terrane maps of the North American Cordillera: Part A--Lithotectonic terrane map of Alaska, U.S. Geological Survey Open-File Report 84-523, sheet 1 of 4, scale 1:2,500,000, p. A3-A12.

Kraushopf, K. B., 1967, Introduction to geochemistry: McGraw-Hill Publishing Co., New York, New York.

Levinson, A. A., 1974, Introduction to exploration geochemistry: Applied Publ. Ltd., Calgary, Alberta, 612 p.

Los Alamos National Laboratory, 1983, The geochemical atlas of Alaska: U.S. Department of Energy, Los Alamos National Laboratory, Los Alamos, N.M. 87545, report GJBX-32 (83), 57 p.

Los Alamos National Laboratory, 1981, Uranium hydrogeochemical and stream-sediment reconnaissance of the Wiseman NTMS quadrangle, Alaska: U.S. Department of Energy, Grand Junction Office, report GJBX 257(81), 97 p.

Mull, C. G., Tailleur, I. L., Mayfield, C. F., and Pessel, G. H., 1976, New structural and stratigraphic interpretations, central and western Brooks Range and Arctic Slope: U.S. Geological Survey Circular 733, p. 24-26.

Oak Ridge Gaseous Diffusion Plant, 1981, Hydrogeochemical and stream-sediment reconnaissance basic data for Wiseman quadrangle, Alaska: U.S. Department of Energy, Oak Ridge Gaseous Diffusion Plant, report GJBX 171(81), 121 p.

O'Leary, Richard M., Hoffman, James D., Sutley, Stephen J., and Lewis, Judy S., 1984, Analytical results and sample locality maps of stream-sediment, heavy-mineral-concentrate, pebble, and rock samples from the Wiseman quadrangle, Alaska: U.S. Geological Survey Open-File Report 84-161-A, 3 sheets, scale 1:250,000, 400 p.

Reed, I., McK., 1938, Upper Koyukuk Region Alaska: Unpublished report to Territory of Alaska Department of Mines, 169 p. (mimeographed).

Reiser, H. N., Brosge, W. P., De Young, Jr., J. H., Marsh, S. P., Hamilton, T. D., Cady, J. W., and Albert, N. R. D., 1979, The Alaskan Mineral Resource Assessment Program--Guide to information contained in folio of geologic and mineral resource maps of the Chandalar quadrangle, Alaska: U.S. Geological Survey Circular 758, 23 p.

Reiser, H. N., Brosge, W. P., Hamilton, T. D., Singer, D. A., Menzie, II, W. D., Bird, K. J., Cady, J. W., Le Compte, J. R., and Cathrall, J. B., 1983, The Alaska Mineral Resource Assessment Program--Guide to information contained in folio of geologic and mineral resource maps of the Philip Smith Mountains quadrangle, Alaska: U.S. Geological Survey Circular 759, 22 p.

Singer, D. A., and Mosier, D. L., eds., 1983a, Mineral deposit grade-tonnage models: U.S. Geological Survey Open-File Report 83-623, 100 p.

_______1983b, Mineral deposit grade-tonnage models II: U.S. Geological Survey Open-File Report 83-902, 101 p.

Smith, P. S., and Mertie, J. B., Jr., 1930, Geology and mineral resources of northwestern Alaska: U.S. Geological Survey Bulletin 815, 351 p.

VanTrump, George, Jr., and Miesch, A. T., 1977, The U.S. Geological Survey RASS-STATPAC system for management and statistical reduction of geochemical data: Computers and Geosciences, v. 3, p. 475-488.

TABLE 1.--Lower limits of anomalous concentrations for selected elements from stream sediments for six (I-VI) geochemical lithologic subdivisions in the Wiseman 1° x 3° quadrangle, Brooks Range, Alaska

[Values are reported in ppm (parts per million); S, semiquantitative spectrographic analyses; AA, atomic absorption analyses; CM, colorimetric analyses; Inst, instrumental; NA, not applicable.; Angayucham-91, geochemical lithologic unit and number of samples analyzed from the unit; %, percentile of the sample population containing the threshold concentration]

Element and method of analyses	Geochemical Lithologic Units											
	I Angayucham-91		II Schist Belt-392		III Skajit-309		IV Beaucoup Whiteface-453		V Doonerak-158		VI Endicott-204	
	ppm	%	ppm	%	ppm	%	ppm	%	ppm	%	ppm	%
Copper - S	150	93	100	86	70	96	100	97	150	89	NA	
Lead - S	NA		70	97	70	96	50	94	50	99	50	98
Zinc - S	200	89	300	96	200	99	300	96	1,000	84	300	96
Barium - S	1,500	96	1,500	97	1,000	99	1,500	98	1,500	96	1,500	98
Silver - S	1	99	1	99	1	99	1	99	1	92	1	99
Arsenic - AA	NA		26	98	38	96	38	98	26	94	NA	
Antimony - AA	NA		3.8	98	3.8	97	5	98	12	92	12	99
Bismuth - S	NA		20	99	30	99	15	99	10	99	NA	
Gold - AA	NA		<0.05	98	<0.05	96	<0.05	97	<0.05	99	<0.05	99
Mercury - Inst	NA		NA		NA		NA				0.14	95
0.14 - 99												
Molybdenum - S	5	98	10	97	7	99	10	98	15	88	20	99
Tin - S	10	99	10	97	10	99	10	99	NA		10	99
Tungsten - CM	NA		2.5	97	2.5	95	3	98	3	92	4	97
Cobalt - S	NA		150	99	NA		70	99	70	96	NA	
Nickel - S	NA		200	99	NA		200	98	200	96	NA	
Chromium - S	NA		300	99	NA		300	99	NA		NA	

TABLE 2.--Lower limits of anomalous concentrations for selected elements from the nonmagnetic fraction of heavy-mineral concentrates from stream sediments for six (I-VI) geochemical lithologic subdivisions in the Wiseman 1° x 3° quadrangle, Brooks Range, Alaska

[Values are reported in ppm (parts per million); S, semiquantitative spectrographic analyses; NA, not applicable; Angayucham-84, number of samples analyzed from the Angayucham geochemical lithologic unit; %, percentile of the lower limit of anomalous concentration within the sample population]

Element and method of analyses	Geochemical Lithologic Units											
	I		II		III		IV		V		VI	
	Angayucham-84		Schist Belt-267		Skajit-186		Beaucoup Whiteface-377		Doonerak-149		Endicott-196	
	ppm	%	ppm	%	ppm	%	ppm	%	ppm	%	ppm	%
Copper - S	200	95	300	86	1,500	94	2,000	90	1,500	88	5,000	93
Lead - S	200	93	1,000	92	3,000	93	3,000	90	300	91	7,000	92
Zinc - S	<500	94	<500	86	1,500	93	2,000	92	1,500	93	10,000	93
Barium - S	>10,000	80	3,000	94	NA		NA		NA		NA	
Silver - S	5	94	5	94	10	91	10	88	5	89	10	88
Arsenic - S	1,000	99	700	92	1,000	89	700	88	1,000	92	1,000	96
Antimony - S	NA	99	200	98	200	94	200	99	200	97	200	99
Bismuth - S	20	99	20	97	20	94	20	90	NA		20	89
Gold - S	<20	94	<20	99	<20	99	<20	95	<20	98	<20	99
Molybdenum - S	NA		NA		70	99	15	98	15	93	20	97
Tin - S	100	90	70	94	70	94	50	96	20	97	100	98
Tungsten - S	100	92	100	93	<100	87	100	99	100	89	100	99
Cobalt - S	NA		500	99	500	97	500	97	NA		500	99
Nickel - S	NA		300	99	NA		500	95	NA		NA	
Chromium - S	700	98	700	99	NA		NA		700	99	1,000	96

TABLE 3.--Summary of the geochemical anomalous areas within the Angayucham geochemical lithologic subdivision (I), Wiseman 1° x 3° quadrangle, Brooks Range, Alaska

[Anomalous elements shown in parentheses occur less frequently than those not in parentheses; (IV) geochemical lithologic subdivision code; geochemical anomalous areas and geochemical lithologic subdivisions are shown on figure 1 and plates 1 and 2]

Area	Geologic map units	Description of geologic units	Anomalous elements	Permissive/suspected deposit type, criteria for selection, comments on deposit genetics
1	MzPzs MzPzv	METAGRAYWACKE AND PHYLLITE (Mississippian to Triassic)--Metagraywacke and phyllite with chert interlayers and metagabbro dikes. MAFIC VOLCANIC ROCKS (Devonian to Lower Jurassic)--Pillow basalt, diabase, radiolarian chert, and minor limestone of the Angayucham Terrane.	Cu, Pb, Zn, Ba, (Mo, W)	[Area 1] A. Cyprus massive sulfide 1. Favorable rocks: pillow basalt, diabase, fine-grained chert and phyllite. 2. Aeromagnetic highs indicate favorable rock type: MzPzv units both exposed and beneath Quaternary and Cretaceous cover often correlate with magnetic highs. 3. Favorable tectonic setting--Angayucham Thrust System--a major oceanic lithotectonic terrane may include oceanic plateau or island arc setting (Jones and others, 1984).
2	Ks	NONMARINE AND MARINE SANDSTONE AND CONGLOMERATE--(Cretaceous, Albian and (?) Cenomanian) Nonmarine conglomerate, marine sandstone, mudstone, carbonaceous shale and coal, sandstone, siltstone, shale, and conglomerate.	Au, Ag	[Area 2] A. Placer gold 1. Historical production and active placer operations. 2. Source appears to be from Quaternary surficial deposits and Cretaceous (Ks) rocks. 3. The gold is partly derived from reconstitution of detrital gold, reprecipitated gold from glacial meltwater, and from paleoplacers in the Cretaceous (Ks) rocks eroded from gold-rich Paleozoic rocks of the Schist Belt to the north.

Table 3.--Continued (Angayucham)

Area	Geologic map units	Description of geologic units	Anomalous elements	Permissive/suspected deposit type, criteria for selection, comments on deposit genetics
3	MzPzs MzPzv	See area 1.	Pb, Zn, Ag, (Au) (Sn, W)	[Area 3] A. Cyprus massive sulfide 1. See area 1 (A1-A3). B. Placer gold 1. Historical production and active placer operations on Twelve Mile Creek.
4	MzPzv Ks Kg	See area 1. See area 2. QUARTZ MONZONITE (Cretaceous and (?) Jurassic)--Coarse-grained, hornblende-biotite quartz monzonite.	Cu, Pb, Zn, Ba Au, Ag, (Bi) Sn, W	[Area 4] A. Cyprus massive sulfide 1. See Area 1 (A1 and A3). 2. An anomalous aeromagnetic low occurs over mafic volcanic rocks (MzPzv) rather than an aeromagnetic high as in areas 1, 3, and 5. Hydrothermal alteration from Quartz Monzonite (Kg) may have destroyed magnetite. B. Placer gold 1. Historical production and active placer operations on South Fork of Koyukuk River. 2. See area 2 (A2 and A3).
5	MzPzv	See area 1.	Cu, Zn, Ba, (Cr) Sn	[Area 5] A. Cyprus massive sulfide 1. See area 1 (A1-A3).
6.	Qs	SURFICIAL DEPOSITS (Quaternary)--Glacial deposits, alluvium, and colluvium.	Ag Mo, W	[Area 6] A. ? 1. The Ag, Mo, W anomaly north of area 5 may be related to Quaternary (Qs) glacial deposits derived from the granite gneiss (Pg) in the Ernie Lake area to the north.

TABLE 4. Summary of the geochemical anomalous areas within the Schist Belt geochemical lithologic subdivision (II), Wiseman 1° x 3° quadrangle, Brooks Range, Alaska

[Anomalous elements shown in parentheses occur less frequently than those not in parentheses; (IV) geochemical lithologic subdivision code; major geochemical anomalous areas and geochemical lithologic subdivisions are shown on figure 1 and plates 1 and 2]

Area	Geologic map units	Description of geologic units	Anomalous elements	Permissive/suspected deposit type, criteria for selection, comments on deposit genetics
1	PzPs PzPcs Dg Dt	SCHIST (Lower Paleozoic or Proterozoic--Coarse mica schist and paragneiss with lenses and bands of black, graphitic schist in muscovite quartzite and quarto feldspathic schist and a few layers of marble and calcareous schist. CALCAREOUS SCHIST (Paleozoic and Proterozoic)--Calcareous Calcareous schist with layers of marble and PzPs. GRANITE GNEISS (Devonian and Devonian?)--Coarse-grained, muscovite-biotite quartz monzonite gneiss. TACTITE (Devonian?)--Calc-silicate hornfels and skarn.	Cu, Pb, Zn, (Ba) Au, Ag, As, (Sb) (Mo, Sn, W)	[Area 1] <u>A. Copper and tungsten skarn</u> 1. Favorable host rocks. 2. Favorable environment and depositional setting. Miogeosynclinal sequence with mixed shale and carbonate protoliths intruded by quartz monzonite gneiss (Dg). 3. Magnetic low: the exposed quartz monzonite gneiss (Dg) may be part of a larger hidden pluton with buried cupolas. <u>B. Sediment-hosted, submarine exhalative Zn-Pb</u> 1. Favorable host rocks: black, graphic schist. <u>C. Placer gold</u> 1. Historical production and active placer operations.
2	PzPs PzPcs	See area 1.	Cu, Zn, Ba, (Ni) As, Sb, (Ag) Mo, W, (Sn)	[Area 2] <u>A. Sedimentary-hosted submarine exhalative Zn-Pb</u> 1. Favorable host rocks of the Hunt Fork Schist (Dhs): euxinic rocks, black, organic-rich shale, siltstone and sandstone. 2. Favorable geologic depositional environment. 3. Metamorphism adequate to increase grain size of metallic minerals.

TABLE 4.--Continued (Schist Belt)

Area	Geologic map units	Description of geologic units	Anomalous elements	Permissive/suspected deposit type, criteria for selection, comments on deposit genetics
2	Dhs	HUNT FORK SCHIST (Upper Devonian?)--Black quartz schist and biotite garnet quartz schist.		<u>B. Copper and tungsten skarn-?</u> 1. Geochemical signatures similar to area 1. 2. Favorable host rocks, environment and depositional setting similar to area 1. The eastern edge of this area abuts the northwest edge of area 1 where intrusions have been found. <u>C. Placer gold</u> 1. Historical production.
3	PzPs PzPcs	See area 1.	Cu, Zn, (Pb) Au, Ag, As	[Area 3] <u>A. Sediment hosted submarine exhalative Zn-Pb</u> 1. Favorable host rocks: black graphitic schist, calcareous schist, marble, limestone and shale. 2. Favorable environment and depositional setting. Miogeosynclinal sequence with mixed shale and carbonate protoliths which may have been deposited at shale carbonate facies transition. <u>B. Placer gold</u> 1. Historical production and active placer operations.
4	PzPs	See area 1.	Cu, Pb, Zn, Ba, (Co, Cr) Au, As, Sb, (Ag, Bi) (Mo, Sn, W)	[Area 4] <u>A. Massive sulfides in intermediate felsic rocks</u> 1. Favorable host-source rocks: Devonian bimodal intrusive and extrusive rocks with interlayers of metasedimentary phyllite and schist.

TABLE 4.--Continued (Schist belt)

Area	Geologic map units	Description of geologic units	Anomalous elements	Permissive/suspected deposit type, criteria for selection, comments on deposit genetics
4	PzPcs	See area 1.		2. Known deposits of this type occur in this subdivision in the Survey Pass and Ambler River quadrangles to the west where Devonian bimodal volcanics and intrusive rocks of the Ambler sequence contain economic base-metal massive sulfide deposits. The Devonian bimodal volcanics are surrounded by extensive terranes of quartz schist (PzPs) in all three quadrangles. 3. The aeromagnetic signature of this area is similar to that in the Ambler sequence west of the Reed River in the Survey Pass quadrangle (Cady and Hackett, 1982). The axes of aeromagnetic highs wrap around the massive sulfide deposits, which are within aeromagnetic lows (Cathrall and others, 1981).
	Dhs	See area 2.		
	Dc	CHLORITIC AND CARBONATE ROCKS (Middle or Upper Devonian?)--Green and gray phyllite and dolomite; chloritic, calcareous metasandstone and marble; and carbonate-clast conglomerate. dolomite; chloritic, calcareous metasandstone and marble; and carbonate-clast conglomerate.		
	Da	AMBLER METAVOLCANIC ROCKS--(Upper, Middle, and Lower? Devonian)--Interbedded black quartz schist and quartzite, marble, and calcareous schist. Abundant mafic and felsic volcanic rocks. Correlative with Ambler sequence of Hitzman and others (1982).		
	Df	FELSIC METAVOLCANIC ROCKS (Devonian)--Felsic flow, tuff, and blastoporphyritic intrusive rocks with interlayers of metasedimentary rocks.		B. <u>Copper skarn</u> 1. Favorable host rocks: marble limestone and calcareous phyllitic schist.
	Dm	METABASITE (Devonian and Devonian?, and Jurassic?)--Basic intrusive and extrusive rocks elsewhere in quadrangle.		2. Favorable environment and depositional setting. Miogeosynclinal sequence with mixed shale and carbonate protholiths intruded by quartz monzonite gneiss (Dg).
	Dfm	METAMORPHOSED BIMODAL IGNEOUS ROCKS (Devonian and Devonian?)--Complexly interlayered felsic and mafic extrusive and intrusive rocks undivided of Ambler volcanics in southern portion of quadrangle; mixed with clastic rocks at head of Michigan Creek.		3. Low amplitude magnetic high often associated with known hornfels and skarn in the Chandalar and Wiseman quadrangles are around the quartz monzonite gneiss (Dg) near the Wild River-Michigan Creek junctions.
	Dg	See area 1.		

TABLE 4.--Continued (Schist Belt)

Area	Geologic map units	Description of geologic units	Anomalous elements	Permissive/suspected deposit type, criteria for selection, comments on deposit genetics
4				C. Polymetallic vein 1. Observed quartz veins containing Pb, Au, and Ag; Smith and Mertie (1930, p. 343; Reed, 1938, p. 139-140; Brosge and Reiser, 1960). 2. Possible source rocks: felsic to intermediate extrusive and intrusive igneous rocks (Da, Df, Dfm). 3. Acceptable host in brittle-fracturing quartzose metasediments (PzPs, Dhs, Dc). 4. Metamorphic grade high enough to mobilize Au, As, Sb, and quartz into veins.
5	PzPs PzPcs Da Df	See area 1. See area 4.	Cu, Pb, Zn, Ag, As, (Sb, Bi) Mo, Sn, W	[Area 5] A. Massive sulfides in intermediate felsic rocks 1. See area 4 (A1-A3).
6	PzPs PzPcs Da Df Dm Dfm Dc Dbc	See area 1. See area 4.	Cu, (Zn, Pb, Ba, Co) Au, As, (Bi, Sb) Sn, (W)	[Area 6] A. Massive sulfides in intermediate felsic rocks 1. See area 4 (A1-A3). B. Contact metasomatic? 1. Acceptable host rocks and proper source rocks - felsic and intermediate extrusive and intrusive igneous rocks (Da, Df, and Dfm). C. Polymetallic veins 1. See area 4 (C1-C4).
7	Dhs Da Df Dc	See area 2. See area 4.	Cu, (Pb, Zn, Ba, Co, Ni) As, (Ag) Sn, W	A. Massive sulfides in intermediate felsic rocks 1. See area 4 (A1 and A2). B. Sedimentary-hosted submarine exhalative Zn-Pb 1. See area 2 (A1-A3).

TABLE 5.--Summary of the geochemical anomalous areas within the Skajit geochemical lithologic subdivision (III), Wiseman 1° x 3° quadrangle, Brooks Range, Alaska

[Anomalous elements shown in parentheses occur less frequently than those not in parentheses; (IV) geochemical lithologic subdivision code; geochemical anomalous areas and geochemical lithologic subdivisions are shown on figure 1 and plates 1 and 2]

Area	Geologic map units	Description of geologic units	Anomalous elements	Permissive/suspected deposit type, criteria for selection, comments on deposit genetics
1	Pg	GRANITE GNEISS (Proterozoic?)--Blastoporphyritic, foliated, coase-grained, biotite granite orthogneiss.	Pb, Zn, (Cu, Ba, Co) Ag. As. Bo. (Sb)	[Area 1] A. Copper/lead zinc skarn 1. Favorable host rocks crop out (calcareous schist and marble in unit Pb). 2. Exposed hornfels and skarn. 3. Low amplitude magnetic highs are associated with hornfels and skarn. 4. Pb-Cu-Ag occurrences have been found in several widely separated localities in the skarn. B. Polymetallic vein 1. Exposed occurrences of Pb, Ag, and Zn in veins. C. Stratabound carbonate-hosted Pb-Zn 1. Favorable host rocks (Skajit Limestone--marble, dolomite, carbonate conglomerate, and calcareous schist). 2. The Skajit Limestone contains known stratabound carbonate-hosted Pb-Zn deposits. Favorable regional setting - In the Philip Smith Mountains quadrangle (Detra, 1977) and the Survey Pass quadrangle (Cathrall and others, 1981).
	Pb	BANDED SCHIST (Proterozoic?)--Interlayered coase quartz-mica schist, quartzite, calcareous schist, graphitic marble phyllite, and metabasite. Locally gneissic.	Sn, W	
	Dsk	SKAJIT LIMESTONE (Devonian and older?)--Marble, dolomite, carbonate conglomerate, and calcareous schist. May include marble of undifferentiated older formations locally.		
	Dbc	CONGLOMERATE (Middle or Upper Devonian)--Quartz and chert-pebble conglomerate.		
	Da	AMBLER VOLCANICS (Upper, Middle, and Lower? Devonian)--Interbedded black quartz schist and quartzite, marble, and calcareous schist. Abundant mafic and felsic volcanic rocks. Correlative with Ambler sequence of Hitzman and others (1982).		
	Df	FELSIC METAVOLCANIC ROCKS (Devonian)--Felsic flow, tuff, and blastoporphyritic intrusive rocks with interlayers of metasedimentary rocks.		

TABLE 5.--Continued (Skajit)

Area	Geologic map units	Description of geologic units	Anomalous elements	Permissive/suspected deposit type, criteria for selection, comments on deposit genetics
1	Dbb	BLACK ROCKS (Upper Devonian and Middle or Upper Devonian)--Black calcareous phyllite and thin, dark limestone.		
2	Pg Pb Dsk Dbc	See area 1.	Pb, (Cu, Zn) Au, Ag, Sb, As, (Bi)	[Area 2] A. Copper skarn 1. See area 1 (A1-A4). B. Polymetallic vein 1. See area 1 (B1). C. Stratabound carbonate-hosted Pb-Zn 1. See area 1 (C1 and C2).
	Dc	CHLORITIC AND CARBONATE ROCKS (Middle or Upper Devonian?)--Green and gray phyllite and dolomite; chloritic, calcareous metasandstone and marble; and carbonate-clast conglomerate.	W, Sn	
3	Pg Pb Dsk Dbc	See area 1.	Cu, Pb, Zn, (Ba, Co) Au, Ag, Sb, As, (Sb)	[Area 3] A. Copper skarn 1. See area 1 (A1-A4). B. Polymetallic vein 1. See area 1 (B1). C. Stratabound carbonate-hosted Pb-Zn 1. See area 1 (C1 and C2).
	Dhf	HUNT FORK SHALE (Upper Devonian)--Black slate and phyllite, minor fossiliferous limestone; lithic wacke locally in upper part; basal quartz-chert clast conglomerate and sandstone.	W	

TABLE 5.--Continued (Skajit)

Area	Geologic map units	Description of geologic units	Anomalous elements	Permissive/suspected deposit type, criteria for selection, comments on deposit genetics
4	Dsk	See area 1.	Cu, Pb, Zn, (Ba, Co)	[Area 4] A. Polymetallic vein 1. Exposed quartz veins with Cu, Zn, and Ag. 2. Exposed malachite-stained gossan with pyrite veins. B. Placer gold 1. Historical production and active placer operations. C. Stratabound carbonate-hosted Pb-Zn 1. See area 1 (C1 and C2).
	Dhf	See area 3.		
	Dc	See area 2.	Ag, Sb, As, Bi (Au)	
	Dm	METABASITE (Devonian and Devonian?, and Jurassic?)--Metabasite of the bimodal Ambler volcanics in south-western portion of quadrangle. Basic intrusive and extrusive rocks elsewhere in quadrangle.	(Mo, Sn, W)	
	Dbcw	CALCAREOUS CHLORITIC WACKE (Middle or Upper Devonian?)--Upper part; calcareous wacke with common plagioclase clasts. Lower part; interbedded calcareous, limonitic quartz sandstone and conglomerate, limestone, and gray, red, and green phyllite. Local basal conglomerate. Correlates with Dw.		
	Dbb	BLACK ROCKS (Upper Devonian and Middle or Upper Devonian)--Black calcareous phyllite and thin, dark limestone.		
5	Dsk	See area 1.	Cu, Pb, (Co)	[Area 5] A. Copper skarn 1. Potential source rock in mafic intrusives of units Dm. 2. Permissive host rocks: pure and impure calcareous rocks of units Dsk and Dc. 3. A magnetic low, characteristic of buried and exposed plutons in the Survey Pass quadrangle, suggests a possible source for skarn mineralization.
	Dbb	See area 4.		
	Dc	See area 2.	As	
	Dm	See area 4.	W	

TABLE 5.--Continued (Skajit)

Area	Geologic map units	Description of geologic units	Anomalous elements	Permissive/suspected deposit type, criteria for selection, comments on deposit genetics
6	Dsk Dc	See area 1. See area 2.	(Pb) Au, Ag, Bi	[Area 6] A. <u>Placer gold</u> 1. Historical production and active placer operation.

TABLE 6.--Summary of the geochemical anomalous areas within the Whiteface-Beaucoup geochemical lithologic subdivision (IV), Wiseman 1° x 3° quadrangle, Brooks Range, Alaska

[Anomalous elements shown in parentheses occur less frequently than those not in parentheses; (IV) geochemical lithologic subdivision code; geochemical anomalous areas and geochemical lithologic subdivisions are shown on figure 1 and plates 1 and 2]

Area	Geologic map units	Description of geologic units	Anomalous elements	Permissive/suspected deposit type, criteria for selection, comments on deposit genetics
1	Dhf?	HUNT FORK SHALE (Upper Devonian)--Black slate and phyllite, minor fossiliferous limestone; lithic wacke locally in upper part; basal quartz-chert clast conglomerate and sandstone.	Pb, Zn, (Ba, Ni) Ag, As, Bi (Mo)	[Area 1] A. <u>Sedimentary-hosted submarine exhalative Zn-Pb</u> 1. Favorable host rocks - mainly organic-rich, black, rusty, fine-grained siliceous clastic rocks and local sandstone and conglomerate interbedded with black limonitic marine limestone. 2. Favorable depositional environment: shallow marine with euxinic sapropelic facies. 3. Favorable tectonic environment: rapid facies changes, syndepositional conglomerates, and distribution of basement rocks suggest extensional tectonics and basement-controlled high-angle faults.
	Dbcw	CALCAREOUS CHLORITIC WACKE (Middle or Upper Devonian?)--Upper part; calcareous wacke with common plagioclase clasts. Lower part; interbedded calcareous, limonitic quartz sandstone and conglomerate, limestone, and gray, red, and green phyllite. Local basal conglomerate. Correlates with Dw.		
	Dbs	BLACK SLATE, PHYLLITE, AND LIMESTONE (Middle or Upper Devonian or older?)--Black calcareous, phyllitic siltstone, slate, and quartzite with lenses of brown dolomite; black, calcareous phyllite and schist with thin limestone interbeds. No faunal control. In part resembles fossiliferous Ordovician rocks of Chandalar quadrangle (Dillon, pers. comm.).		

TABLE 6.--Continued (White-Beaucoup)

Area	Geologic map units	Description of geologic units	Anomalous elements	Permissive/suspected deposit type, criteria for selection, comments on deposit genetics
2	Dhf	See area 1.	Pb, Zn, Co, Ni, (Cu, Cr) Ag, As, Bi, (Sb) W	[Area 2] A. Sedimentary-hosted submarine 1. See area 1 (A1-A3).
	Dbs			
	Dsc	SILICEOUS CLASTIC ROCKS (Middle Devonian?)--Partly calcareous, chloritic siliceous metasiltstone, sandstone, phyllite, grit, and conglomerate felsic volcaniclastic rocks.		
3	Dsk	SKAJIT LIMESTONE (Devonian and older?)--Marble, dolomite, carbonate conglomerate, and calcareous schist. May include marble of undifferentiated older formations locally.	Cu, Zn, (Pb, Ni) Ag, As, Bi	[Area 3] A. Sedimentary-hosted submarine exhalative Zn-Pb 1. See area 1 (A1-A3).
	Dbs	See area 1.		
	Dsg	GRAYWACKE OF SILLYASHEEN MOUNTAIN (Middle Devonian)--Calcareous graywacke and conglomerate with shale chip, chert, and volcanic clasts; green and purple phyllite and siltstone; lenses of fossiliferous, tuffaceous limestone.		
	Dc	CHLORITIC AND CARBONATE ROCKS (Middle or Upper Devonian?)--Green and gray phyllite and dolomite; chloritic, calcareous metasandstone and marble; and carbonate-clast conglomerate.		
	Dbb	BLACK ROCKS (Upper Devonian and Middle or Upper Devonian)--Black calcareous phyllite and thin, dark limestone.		

TABLE 6. Continued (White-Beaucoup)

Area	Geologic map units	Description of geologic units	Anomalous elements	Permissive/suspected deposit type, criteria for selection, comments on deposit genetics
4	Dsc	See area 2.	Cu, (Zn, Ba, Pb) Au, Ag, As, Sb, Bi	[Area 4] A. <u>Placer gold</u> 1. Historical production and active placer operations. B. <u>Veins - precious metals</u> 1. Axis of aeromagnetic high sugggests buried pluton. 2. Proper geochemical signatures.
	Dt	TACTITE (Devonian?)--Calc-silicate hornfels and skarn.		
5	Dhf Dbcw	See area 1.	Pb, (Zn)	[Area 5] A. <u>Sedimentary-hosted submarine exhalative Zn-Pb</u> 1. See area 1 (A1-A3). B. <u>Placer gold</u> 1. See area 4 (A1).
	Dbc	CONGLOMERATE (Middle or Upper Devonian)--Quartz and chert-pebble conglomerate.	Au, Ag Bi, (As)	
	Dbs	See area 1.		
	Dc	CHLORITIC AND CARBONATE ROCKS (Middle or Upper Devonian?)--Green and gray phyllite and dolomite; chloritic, calcareous metasandstone and marble; and carbonate-clast conglomerate.		
6	Dbcw Dbs	See area 1.	Cu, Pb, (Co, Ni) Au, Ag, As, Sb, Bi, (Hg) Sn, W	[Area 6] A. <u>Placer gold</u> 1. Historical production and several active placer operations. B. <u>Simple stibnite vein</u> 1. Stibnite veins exposed at several localities. C. <u>Copper skarn</u> 1. Favorable host rocks: Dbcw and Dbs contain carbonates. 2. Dillon and others (1985) infer that the magnetic high over calc-silicate hornfelses and skarns and

TABLE 6.--Continued (White-Beaucoup)

Area	Geologic map units	Description of geologic units	Anomalous elements	Permissive/suspected deposit type, criteria for selection, comments on deposit genetics
6				surrounding lows over the nonmagnetic granite plutons in the Chandalar quadrangle could be followed down plunge beneath the placer deposits in this area. If so, then there is permissive evidence for skarn mineralization at depth. The regional metamorphic grade increases southward to upper greenschist facies in this area. Crystallization of magnetite during metamorphism could account for the highs. Metamorphic dewatering, remobilization and concentration of labile elements such as Au, Sb, As, Bi, and Hg during this prograde event may account for the abundance of veins. D. Sedimentary-hosted submarine exhalative Cu-Pb 1. See area 1 (A1-A3).
7	Dbcw Dbs	See area 1.	Cu, Pb, (Co) Au, Ag, As, Bi Sn, W	[Area 7] A. Placer Gold 1. Historical production and active placer operations. B. Copper skarn 1. See area 6 (C1-C2). C. Sedimentary-hosted submarine exhalative Cu-Pb 1. See area 1 (A1-A3).

TABLE 7.--Summary of the geochemical anomalous areas within the Doonerak geochemical lithologic subdivision (V), Wiseman 1° x 3° quadrangle, Brooks Range, Alaska

[Anomalous elements shown in parentheses occur less frequently than those in parentheses; (IV) geochemical lithologic subdivision code; geochemical anomalous areas and geochemical lithologic subdivisions are shown on figure 1 and plates 1 and 2]

Area	Geologic map units	Description of geologic units	Anomalous elements	Permissive/suspected deposit type, criteria for selection, comments on deposit genetics
1	S€b	BLACKS SILTSTONE AND PHYLLITE (Silurian to Cambrian)--Black phyllite and metasiltstone, minor quartzite, graywacke, red, green, and purple phyllite, green chert, siliceous metatuff; and thin limestone beds. Abundant unmapped mafic sills.	Cu, Zn, (Pb, Co, Ni) Au, Ag, As, Sb,(Bi, Hg) Mo, W, (Sn)	[Area 1] A. Massive volcanogenic sulfide 1. Favorable host rocks: chert, phyllite, and andesitic volcanic rocks. 2. Favorable depositional environment. B. Sedimentary-hosted submarine exhalative Cu-Zn 1. Favorable host rocks: organic-rich, black shale and silt. 2. Favorable sedimentary and tectonic environment: marine euxinic sapropelic facies, possibly controlled by basement uplift. A north-south magnetic high suggests fault-bounded uplift of magnetic basement rocks. The faults could be conduits for hydrothermal solutions (Cady and Dillon, 1986). C. Epithermal precious-metal deposit 1. A geochemical anomalous suite of La, Nb, Y, and Th may reflect a buried felsic pluton (O'Leary and others, 1984; Los Alamos National Laboratory, 1983). 2. The geochemical suite of Au, Ag, As, Sb, (Bi, Hg), Mo, W, and (Sn) are commonly associated with felsic mesothermal to epithermal precious-metal deposits. 3. An aeromagnetic high coincident with this area allows a felsic pluton within the area.

TABLE 7.--Continued (Doonerak)

Area	Geologic map units	Description of geologic units	Anomalous elements	Permissive/suspected deposit type, criteria for selection, comments on deposit genetics
2	OЄv	VOLCANIC ROCKS (Ordovician and Cambrian?)--Andesitic to basaltic volcaniclastic rocks and local tuffaceous phyllite, gabbro and diabase, and black phyllite.	Cu, Pb, Zn, (Ba, Ni) Ag, As, Sb, Hg, (Bi) W, (Mo)	[Area 2] A. Massive sulfide in felsic and intermediate rocks 1. Favorable permissive host rocks: basaltic volcanoclastic rocks, tuffaceous phyllite, gabbro, and diabase. 2. Favorable depositional environment. 3. Heavy-mineral concentrates from stream sediments contain sphalerite, arsenopyrite, chalcopyrite, galena, barite, and pyrite.
	SЄb	See area 1.		

TABLE 8.--Summary of the geochemical anomalous areas within the Endicott geochemical lithologic subdivision (VI), Wiseman 1° x 3° quadrangle, Brooks Range, Alaska

[Anomalous elements shown in parentheses occur less frequently than those in parentheses; (IV) geochemical lithologic subdivision code; geochemical anomalous areas and geochemical lithologic subdivisions are shown on figure 3]

Area	Geologic map units	Description of geologic units	Anomalous elements	Permissive/suspected deposit type, criteria for selection, comments on deposit genetics
1	Dhf	HUNT FORK SHALE (Upper Devonian)--Black slate and phyllite, minor fossiliferous limestone; lithic wacke locally in upper part; basal quartz-chert clast conglomerate and sandstone.	Zn, (Cu, Pb, Co) Ag, Bi (W)	[Area 1] A. <u>Sediment-hosted exhalative Zn-Pb</u> 1. Favorable host rocks: euxinic black shales, silt, sandstone, phyllite, conglomerate, and wacke. 2. Favorable depositional environment: thick epicratonic or continental border-land marine basin with euxinic sapropelic facies, rapid facies change, and syndepositional conglomerates. 3. Favorable ore control: paleotopographic lows. B. <u>Polymetallic vein</u> 1. Exposed Pb-Zn veins and numerous quartz veins.
	MDkn	KANAYUT CONGLOMERATE AND NOATAK SANDSTONE (Upper Devonian and Mississippian?) KANAYUT CONGLOMERATE (Upper Devonian and Lower Mississippian?)--Nonmarine sandstone, conglomerate, and shale with minor marine tongues. NOATAK SANDSTONE (Upper Devonian)--Marine, partly calcareous, sandstone and shale.		
	T Cs	SEDIMENTARY ROCKS (Mississippian through Upper Triassic)--unconformably overlie basement rocks of the Doonerak fenster; elsewhere rest on Kanayut Conglomerate. In this area includes only: UPPER ENDICOTT GROUP KAYAK SHALE (Lower Mississippian fossils)--Black shale and minor limestone.		

TABLE 8.--Continued (Endicott)

Area	Geologic map units	Description of geologic units	Anomalous elements	Permissive/suspected deposit type, criteria for selection, comments on deposit genetics
2	Dhf MDkn	See area 1.	Pb, Zn, (Cu) Ag, As, Bi	[Area 2] A. Sediment-hosted submarine exhalative Zn-Pb 1. See area 1 (A1-A3). B. Lead vein 1. Exposed Pb-rich quartz vein. 2. Reported lead veins (Brosge and others (1960).
3	Dhf Dbc T Cs	See area 1. CONGLOMERATE (Middle or Upper Devonian)--Quartz and chert-pebble conglomerate. SEDIMENTARY ROCKS (Mississippian through Upper Triassic)--unconformably overlie basement rocks of the Doonerak fenster; elsewhere rest on Kanayut Conglomerate. In this area includes only: SADLEROCHIT GROUP (Permian and Lower Triassic fossils)--Black shale, buff calcareous siltstone. Occurs only in Doonerak fenster. SIKSIKPUK FORMATION (Permian)--Black, red, and green shale and siltstone; buff calcareous siltstone. LISBURNE GROUP (Mississippian and locally Pennsylvanian fossils)--Gray cherty limestone; black chert and shale.	Pb, (Zn) Au, Ag, Bi, (Sb, Hg) W, (Sn)	[Area 3] A. Sediment-hosted submarine exhalative Zn-Pb 1. See area 1 (A1-A3).

TABLE 8.--Continued (Endicott)

Area	Geologic map units	Description of geologic units	Anomalous elements	Permissive/suspected deposit type, criteria for selection, comments on deposit genetics
3		UPPER ENDICOTT GROUP		
		KAYAK SHALE (Lower Mississippian fossils)--Black shale and minor limestone.		
		KEKIKTUK CONGLOMERATE (Mississippian)--Quartzite and minor conglomerate. Felsic volcaniclastic interlayers and basal conglomerate. Occurs only in Doonerak fenster.		

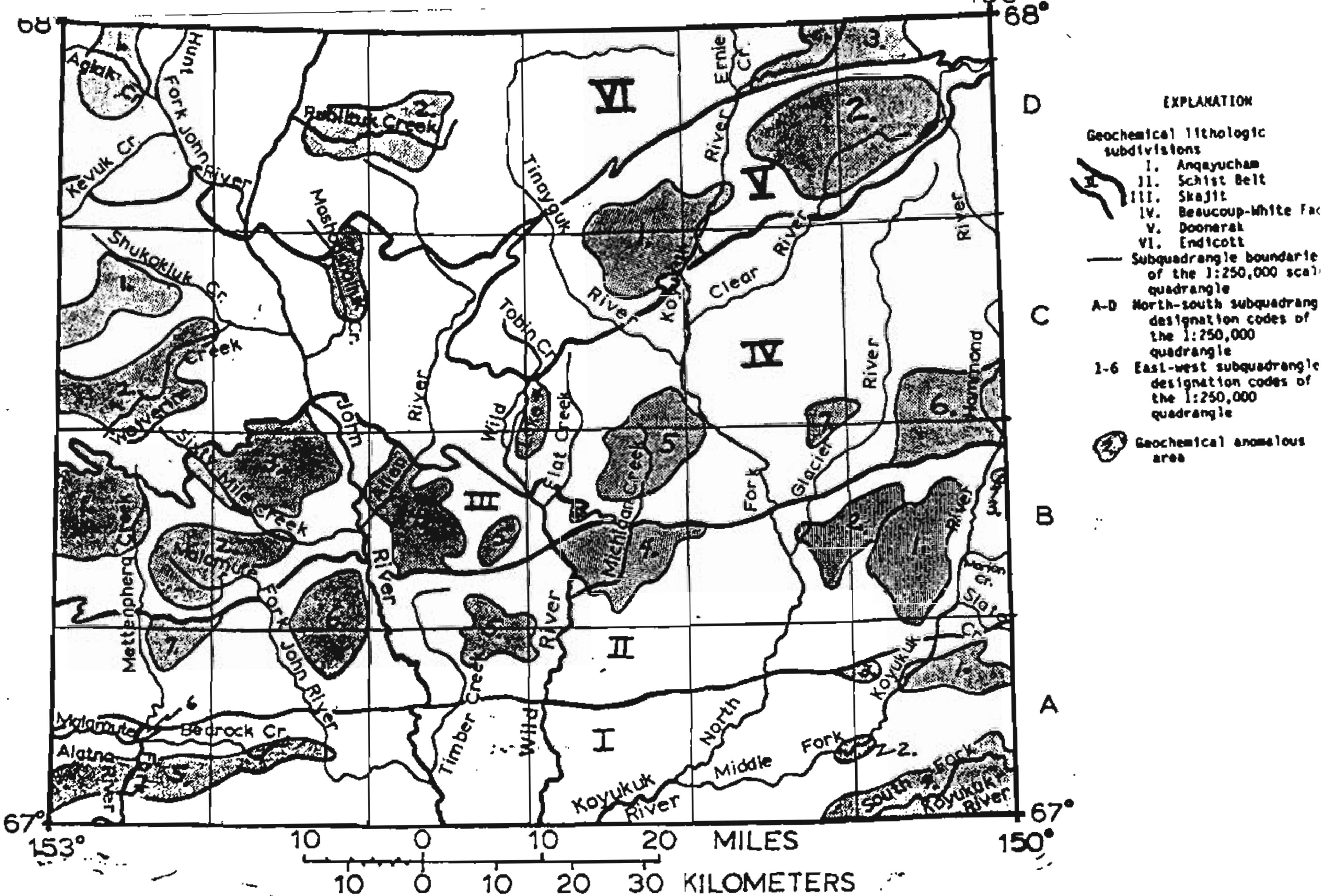


Figure 1.--Location of the areas of geochemical anomalies in their respective geochemical lithologic subdivision as illustrated in tables 3-8, Wiseman 1° x 3° quadrangle, Brooks Range, Alaska.

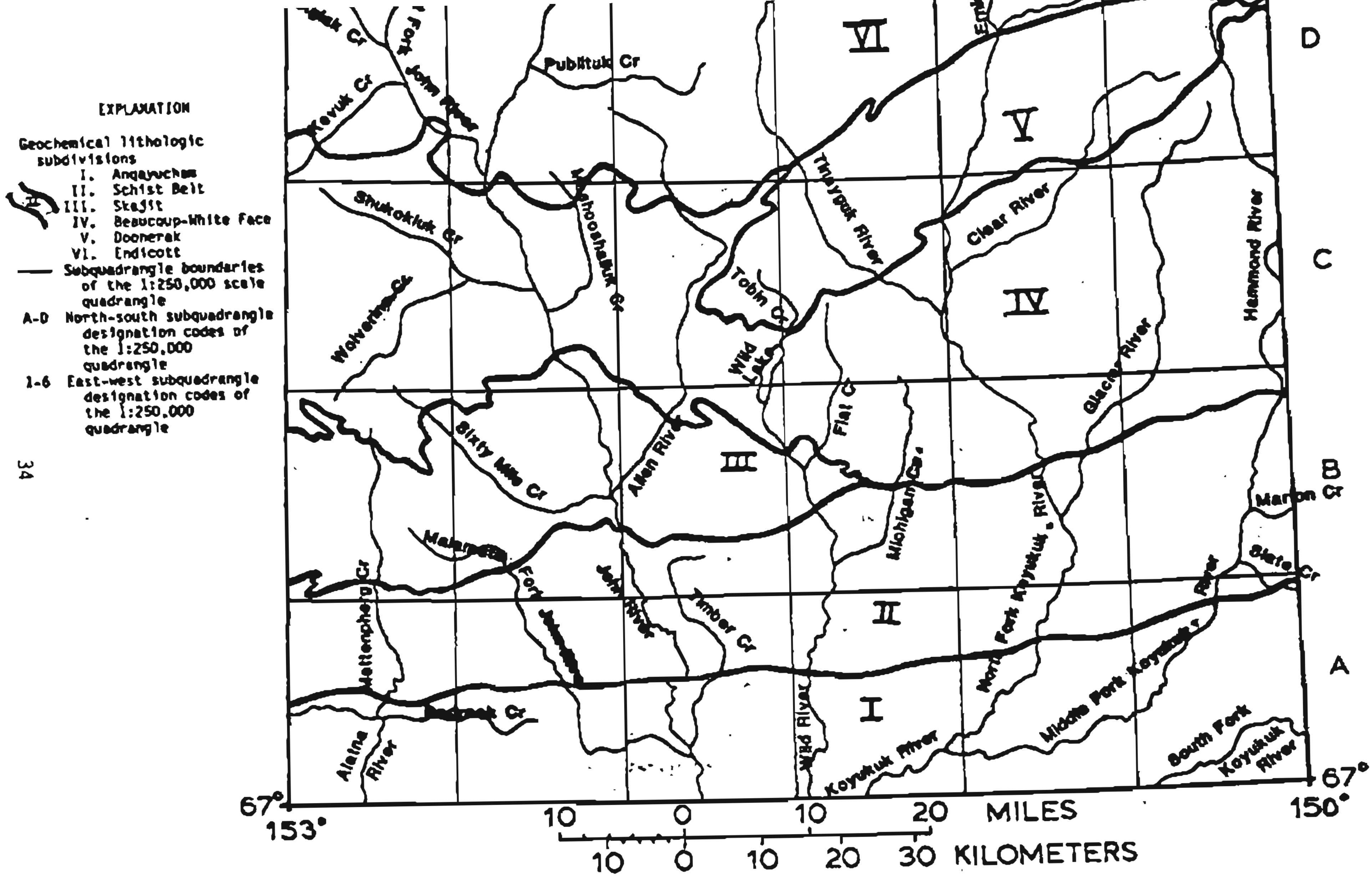


Figure 2.--Master template for use in orienting illustrations 3-34, Wiseman 1° x 3° quadrangle, Brooks Range, Alaska.

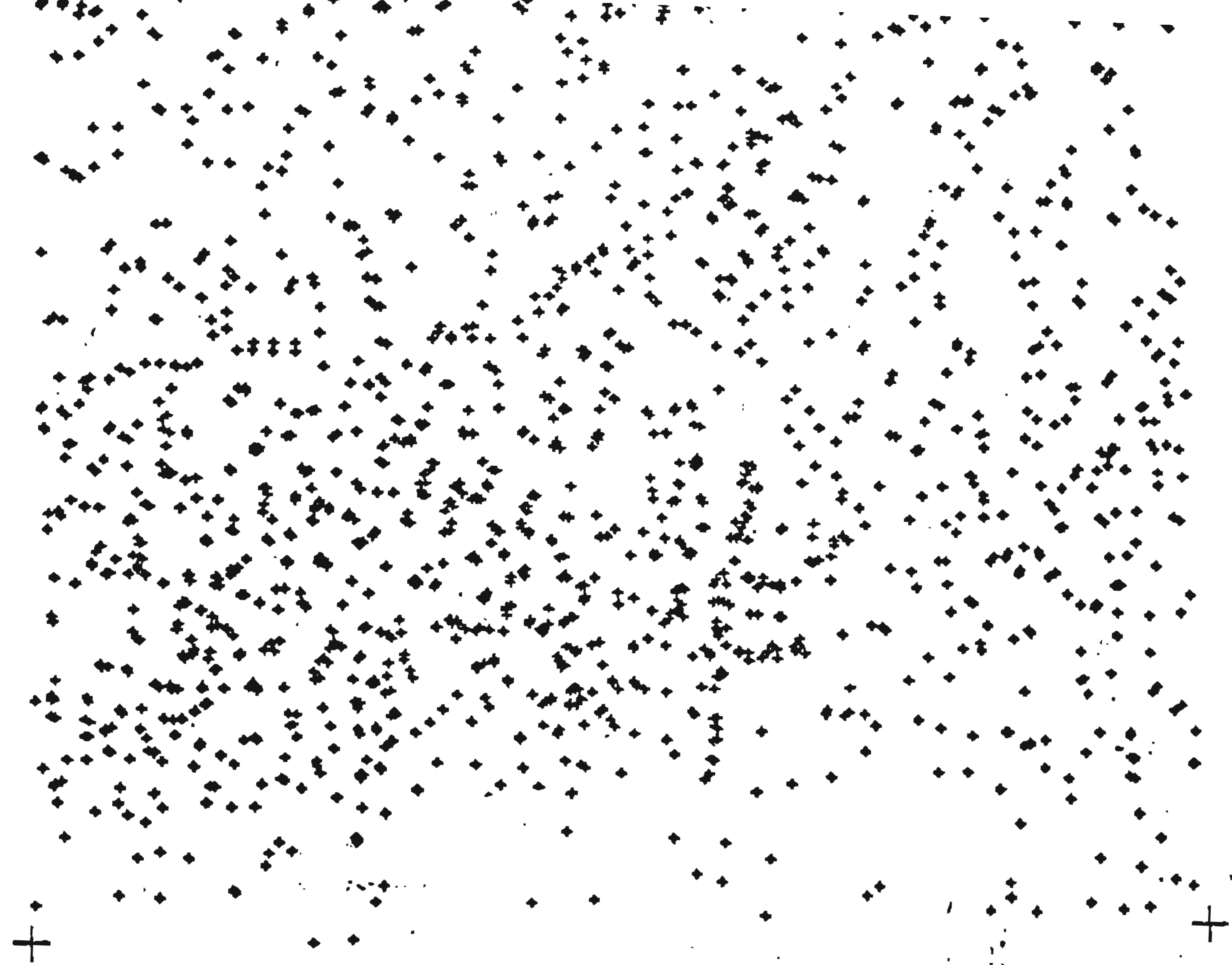
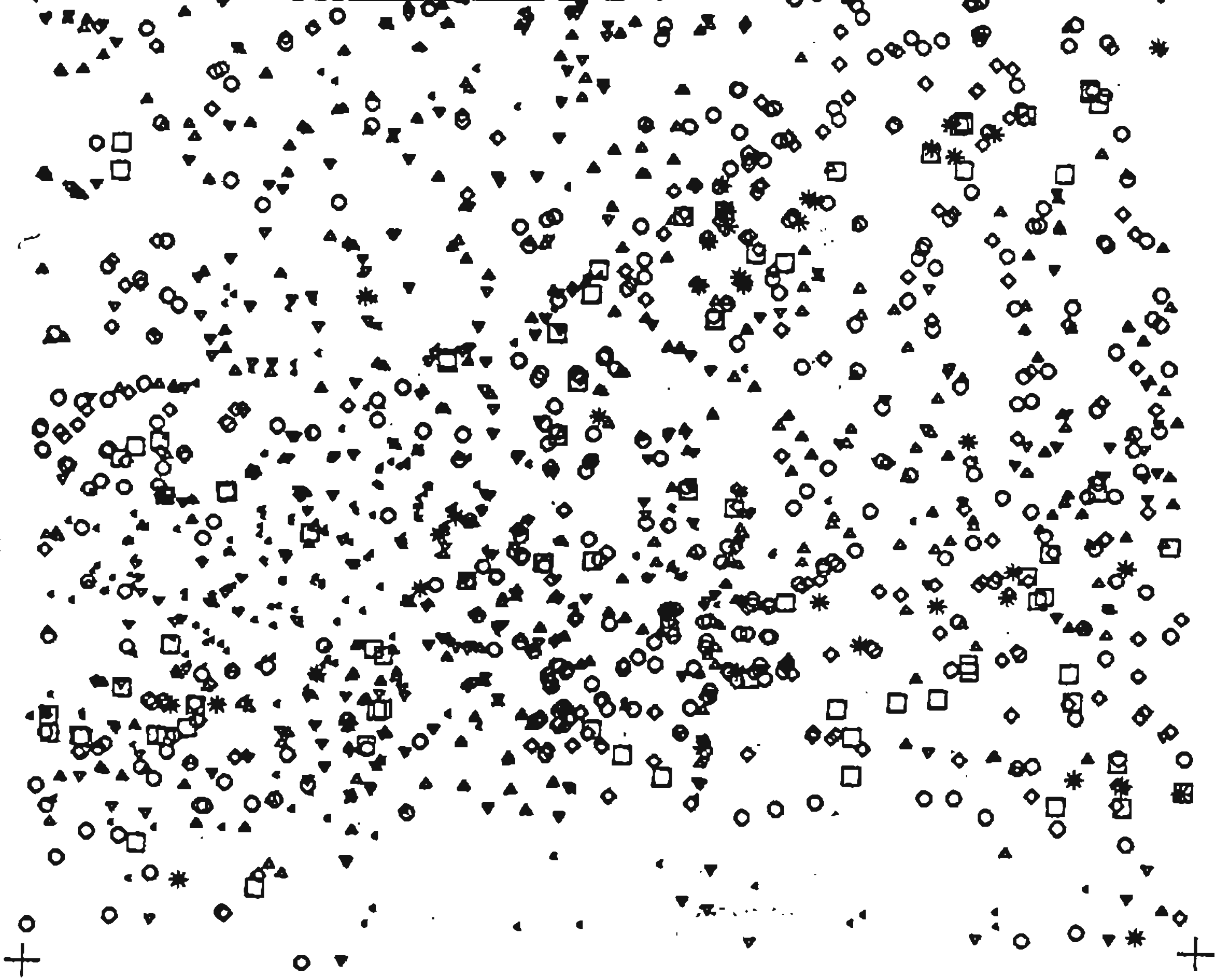


Figure 3A. Locality map showing sites at which stream sediments (-80 mesh) were sampled, Wiseman 1° x 3° quadrangle, Brooks Range, Alaska.

Figure 3B. Locality map showing sites at which heavy-mineral concentrates from stream sediments were sampled, Wiseman 1° x 3° quadrangle, Brooks Range, Alaska.

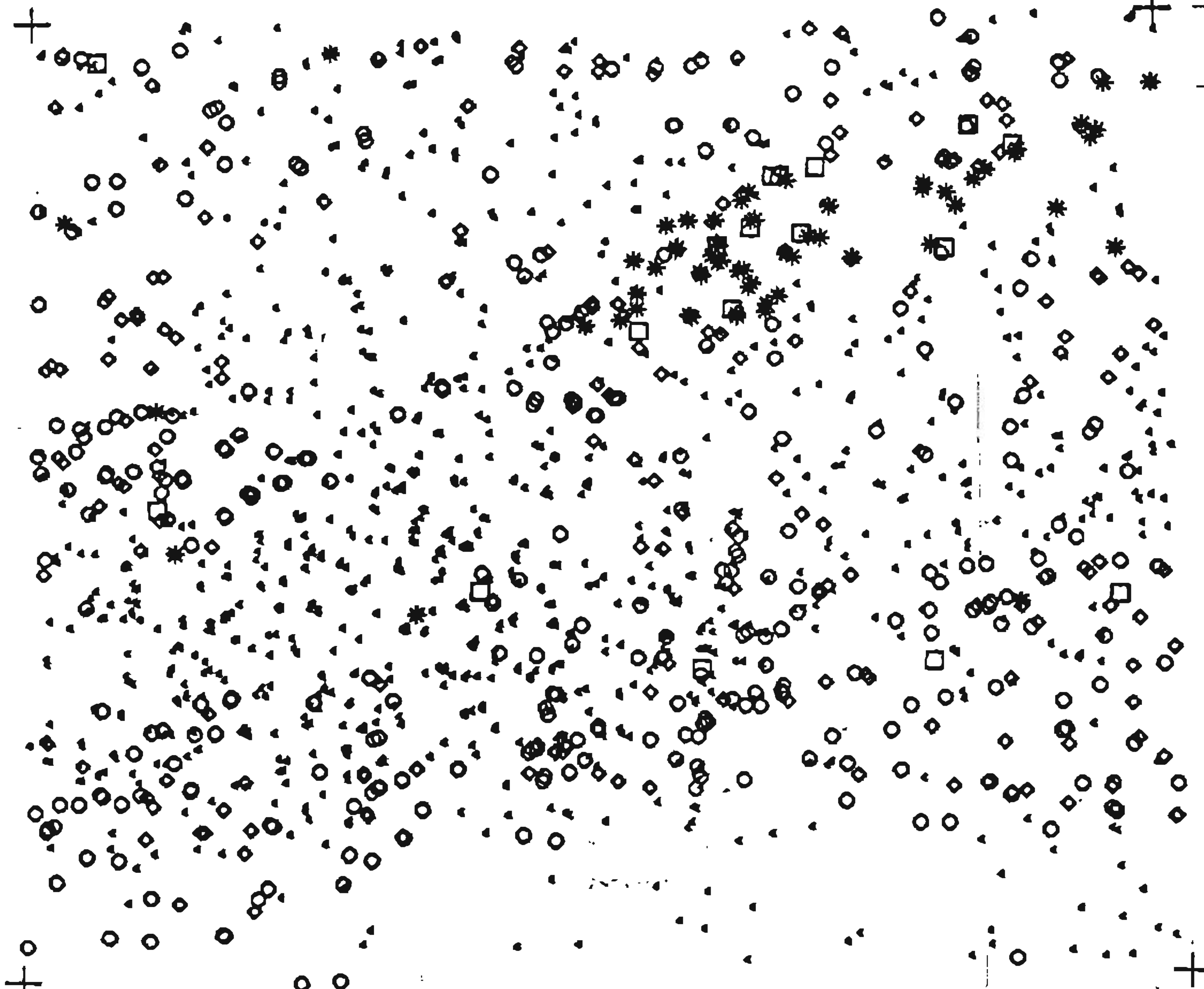


Percentile	Symbol	Concentration in parts per million
97.5	✱	≥ 150
95	□	100
90	◊	70
80	○	50
50	△	30
20	▽	20
<20	<	<20

Figure 4. S- Cu Seds.

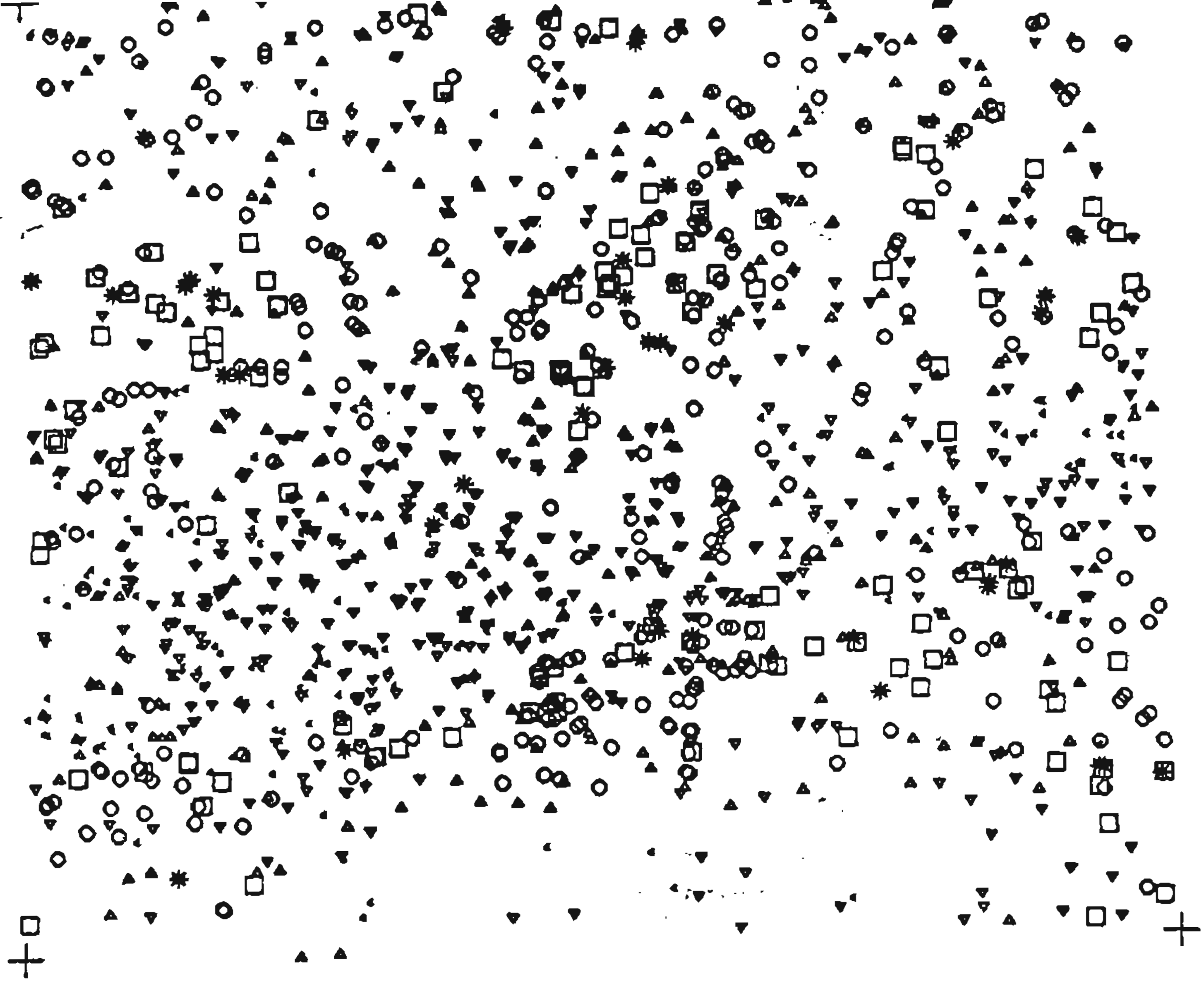
Percentile	Symbol	Concentration parts per million
97.5	*	≥ 50
90	◇	30
50	△	20
20	▽	10
<20	<	<10

Figure 5. S-Pb Seds



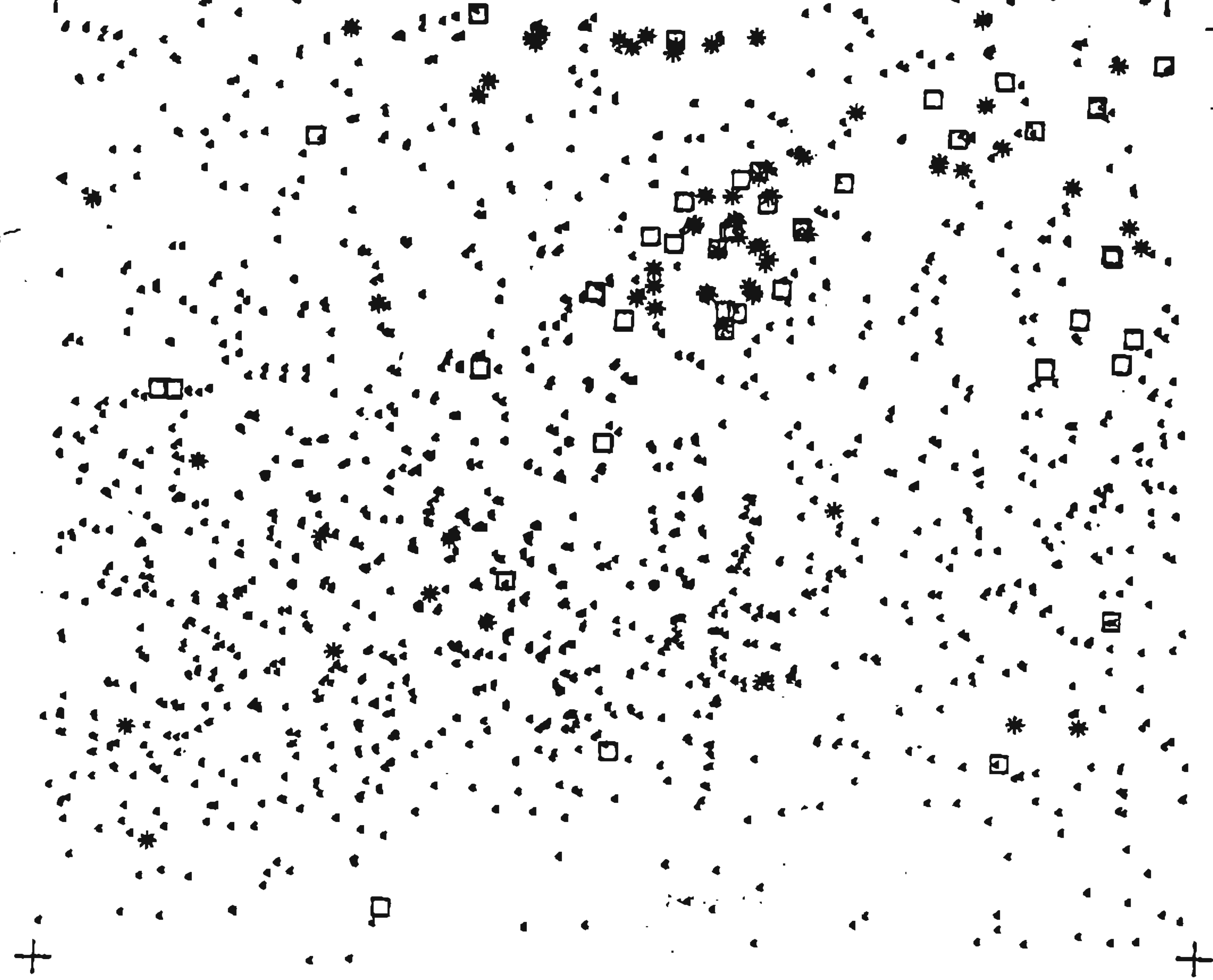
Percentile	Symbol	Concentration parts per million
97.5	*	≥ 700
95	□	500
90	◇	200
80	○	< 200
50	<	200 N

Figure 6. S-Zn Seds.



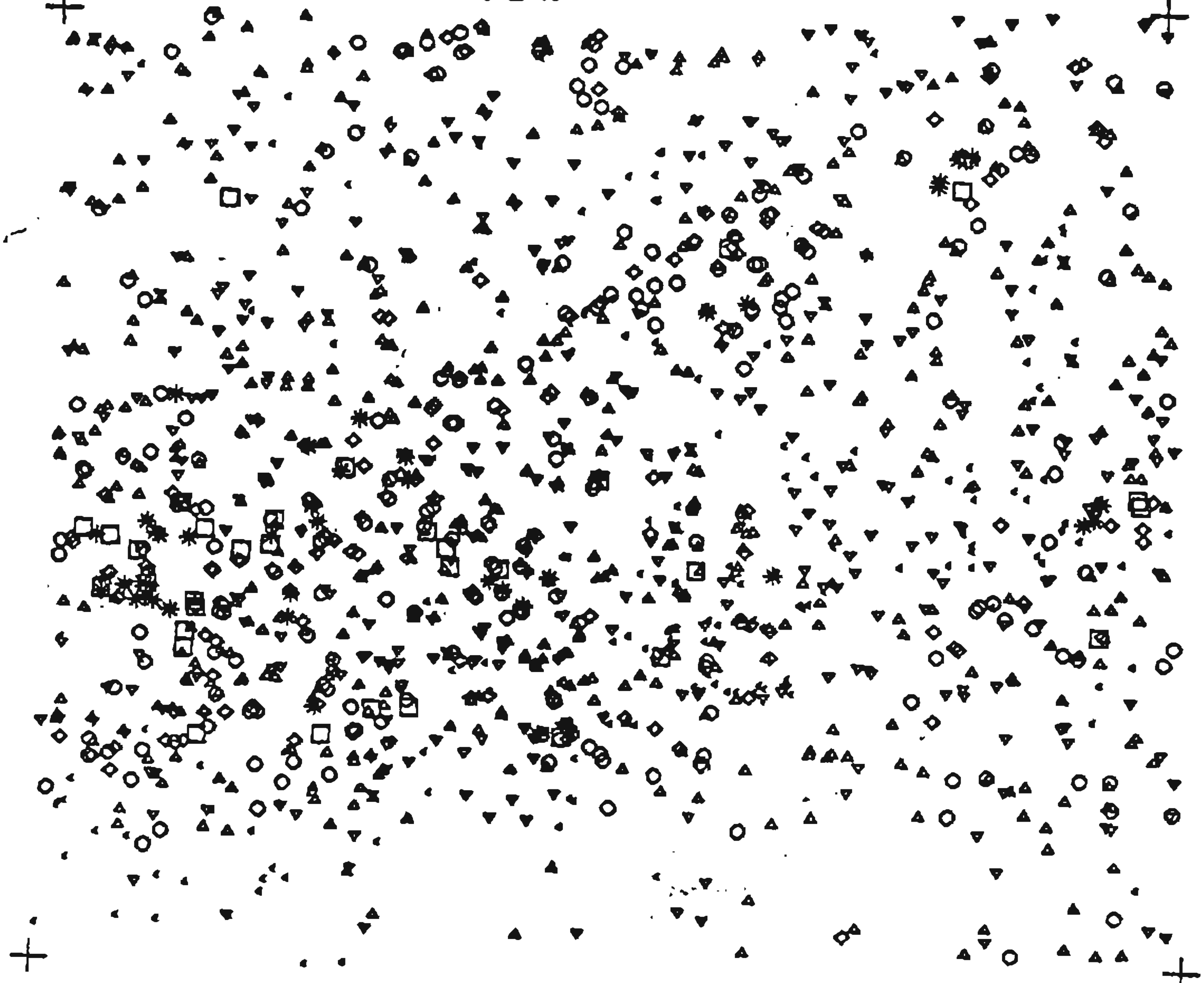
Percentile	Symbol	Concentration in parts per million
97.5	✱	≥ 1,500
95	□	1,000
80	○	700
50	△	500
20	▽	200
<20	‹	<200

Figure 7. S-Ba Seds.



Percentile	Symbol	Concentration in parts per million
97.5	*	≥ 0.5
95	□	< .5
90	<	.5N

Figure 8. S-Ag Seds.



Percentile	Symbol	Concentration in parts per million
97.5	*	≥ 40
95	□	30
90	◇	20
80	○	15
50	△	10
20	▽	5
<20	<	<5

Figure 9. AA-As Seds.

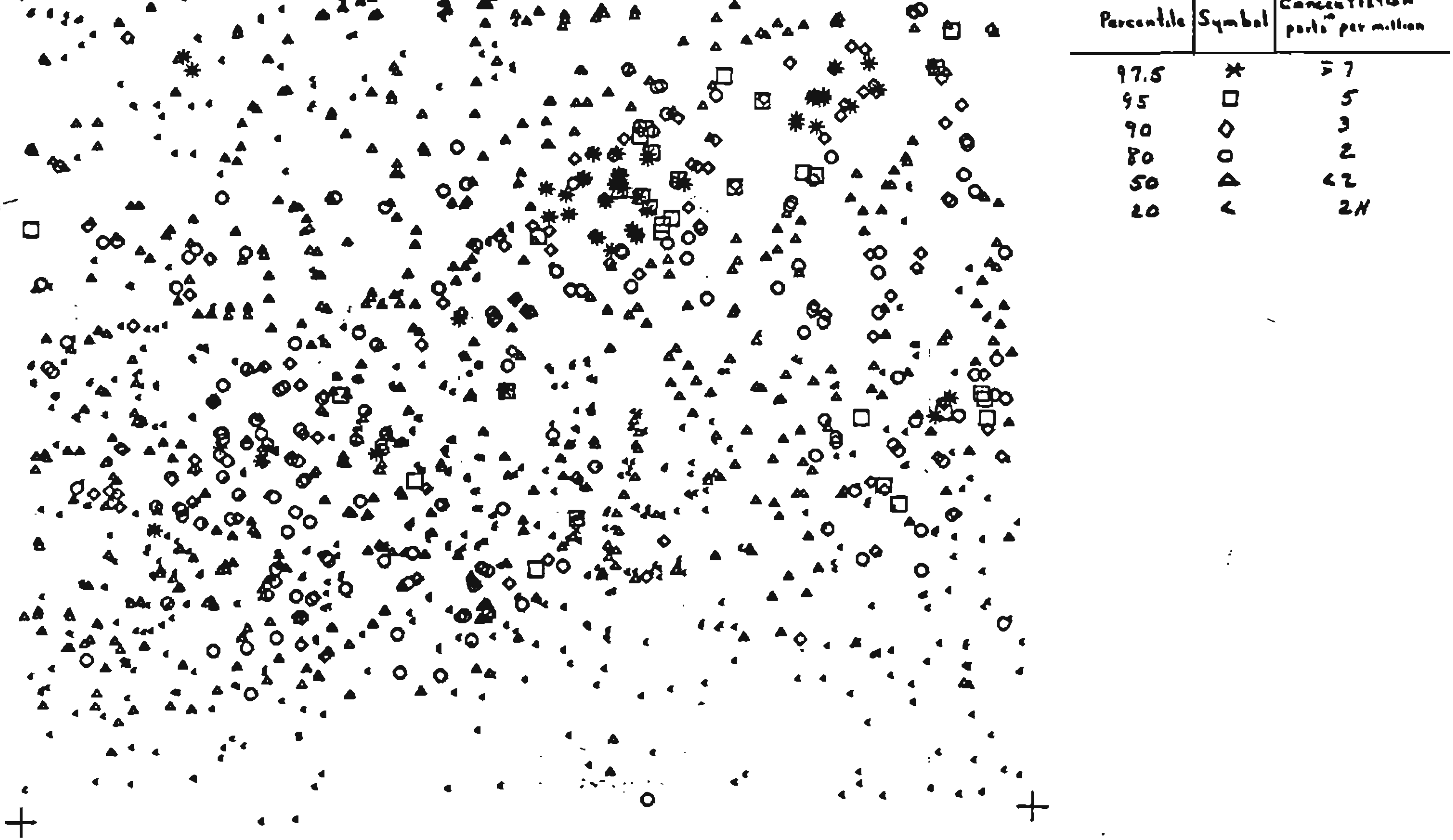


Figure 10. AA-Sb Seds.

Figure 11. S-Bi Seds.

Percentile	Symbol	Concentration in parts per million
97.5	*	> 0.18
90	◇	.14
80	○	.12
50	△	.06
20	▽	.04
<20	◁	< .04

Figure 12. Inst-Hg Seds.

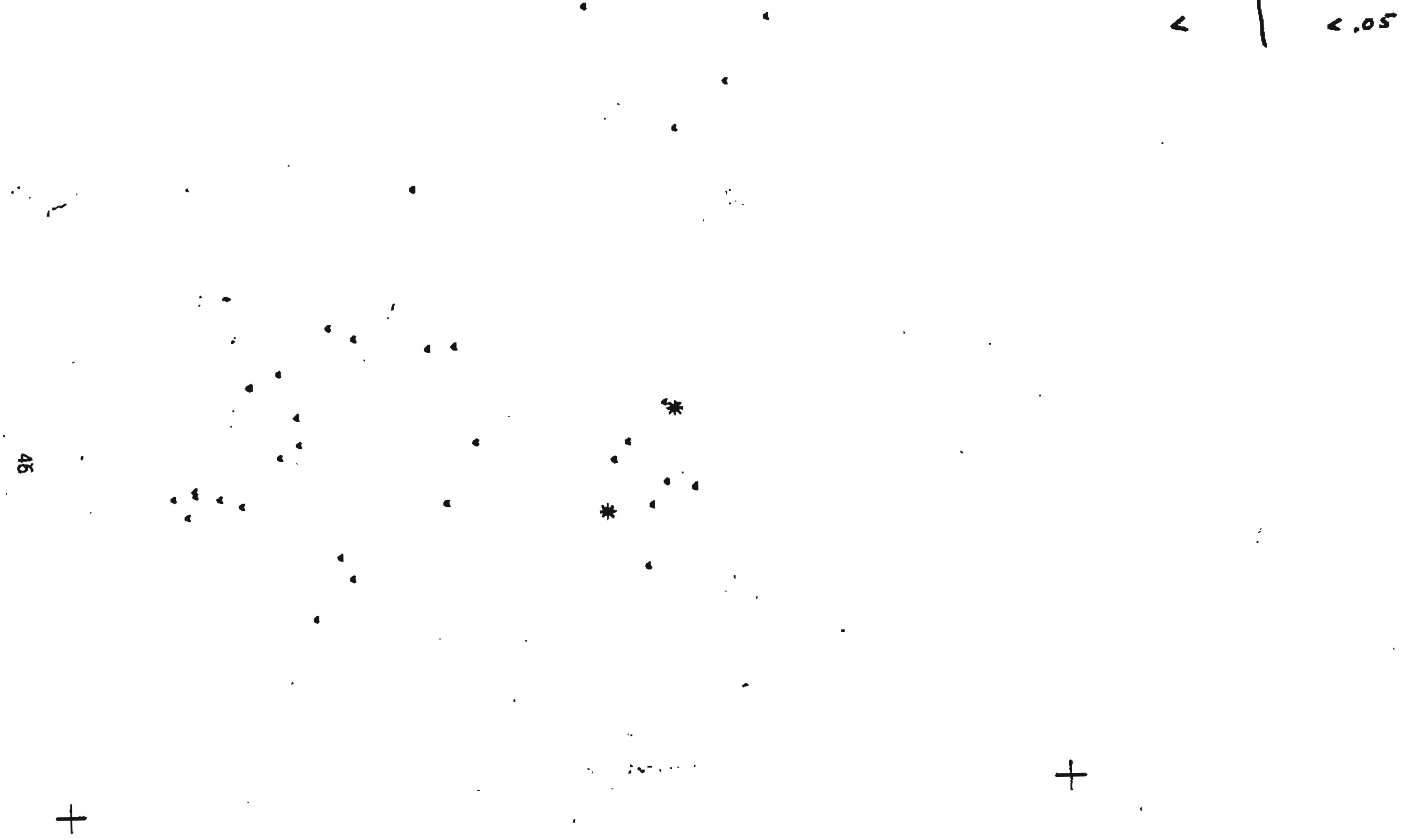
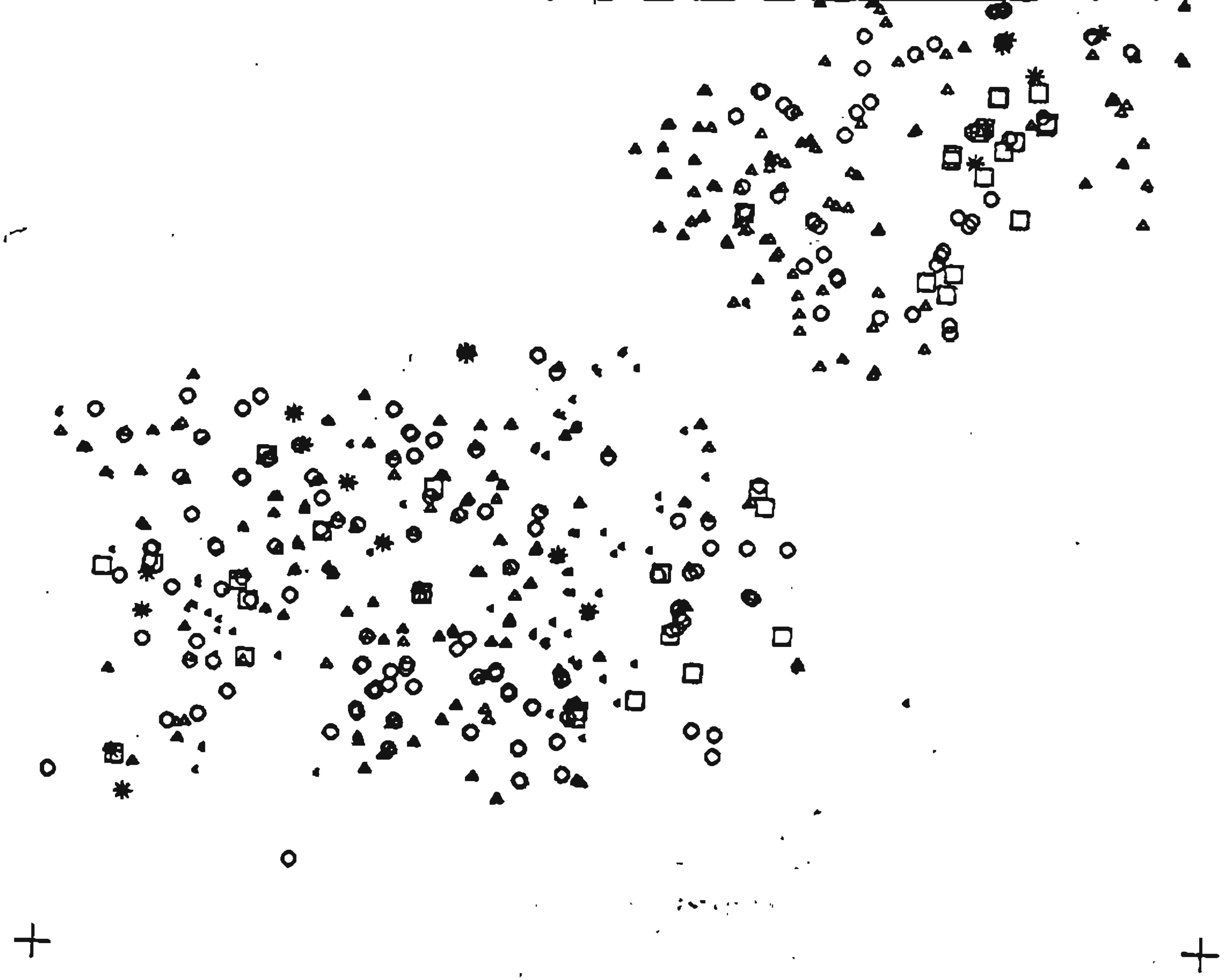


Figure 13. AA-Au Seds.

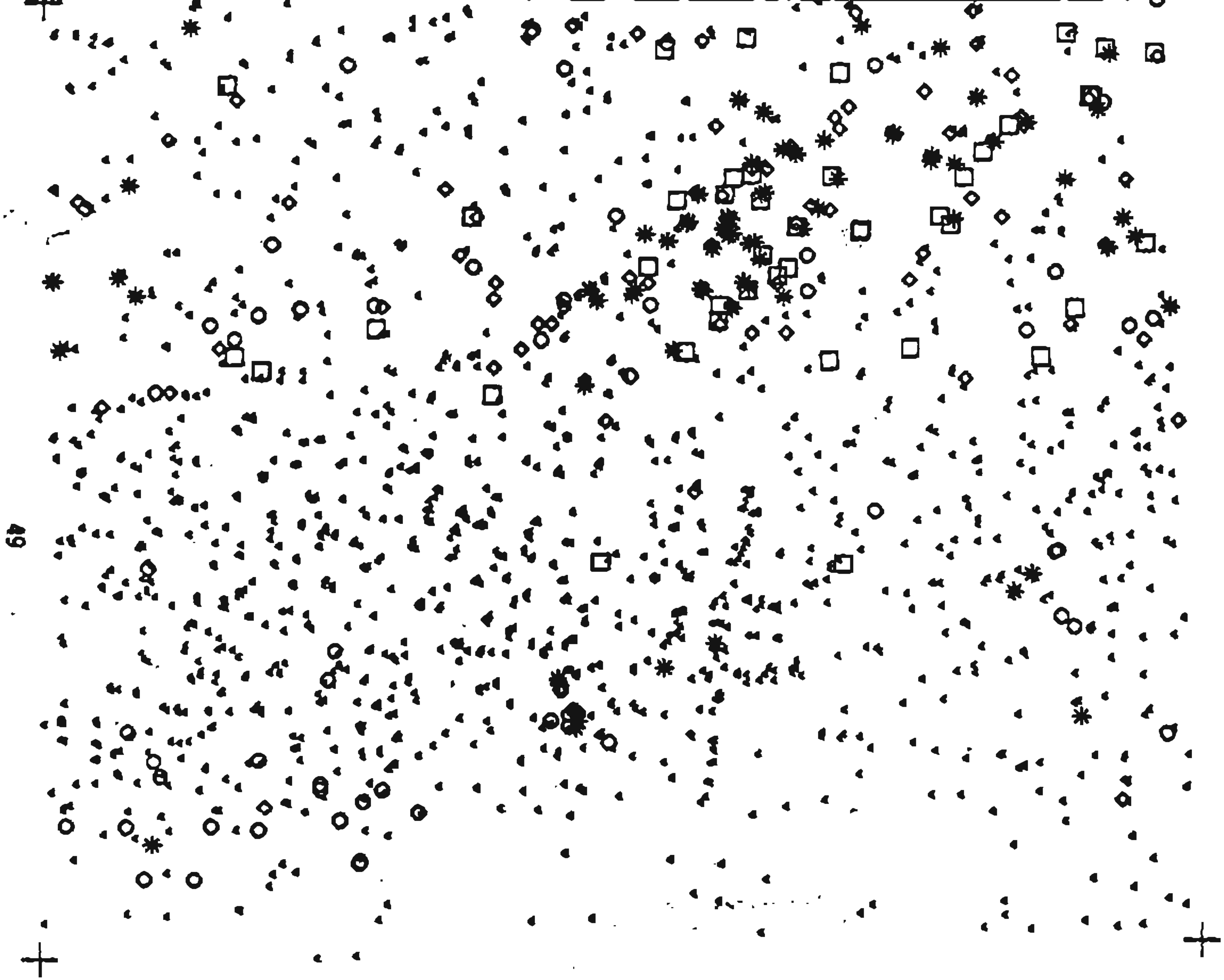
Symbol	Concentration in parts per million
*	≥10L
<	10N

Figure 14. S-Sn Seds.



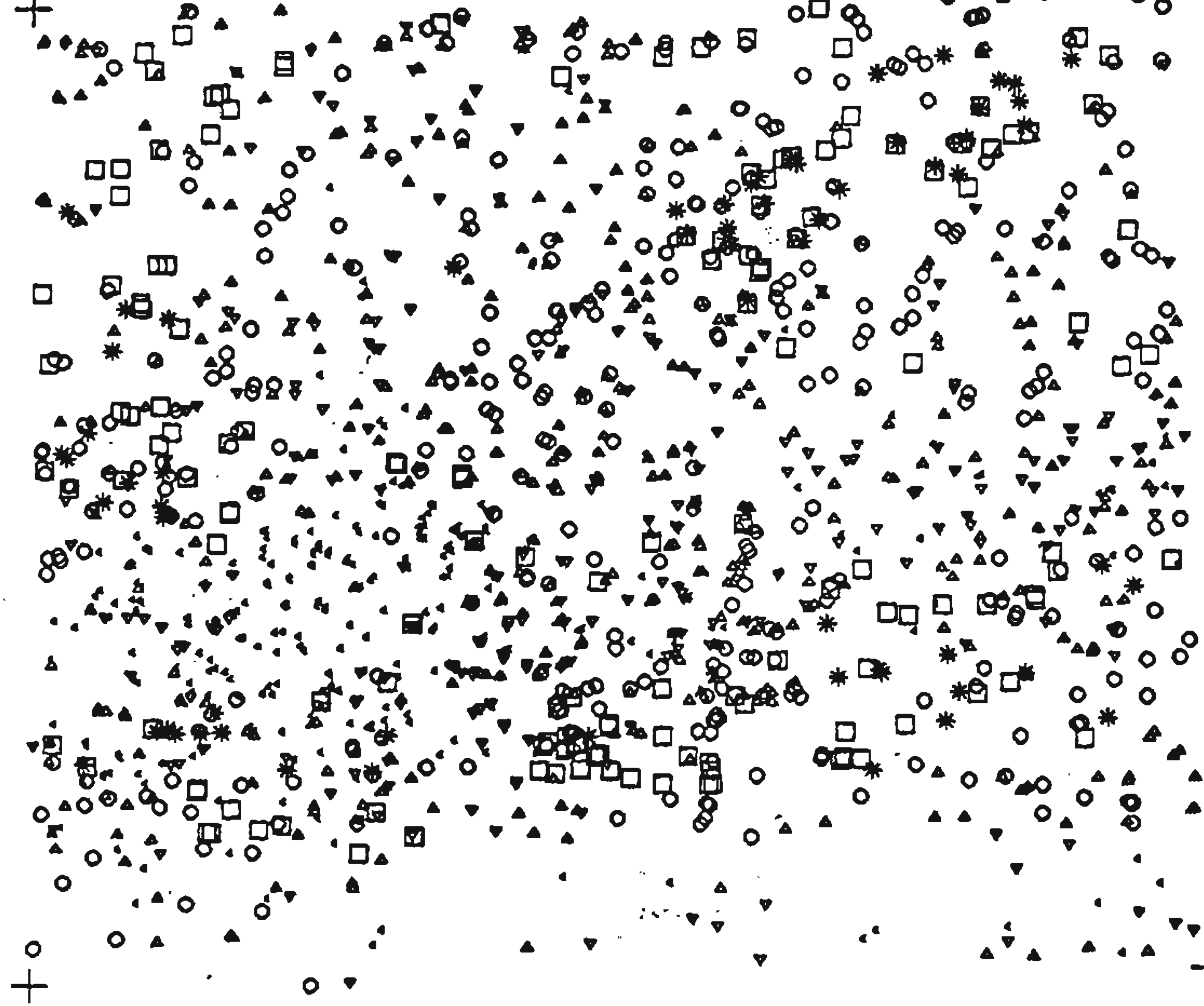
Percentile	Symbol	Concentration parts per million
97.5	*	≥ 4
95	□	3
80	○	2
50	△	1
<20	◂	<1

Figure 15. CM-W Seds.



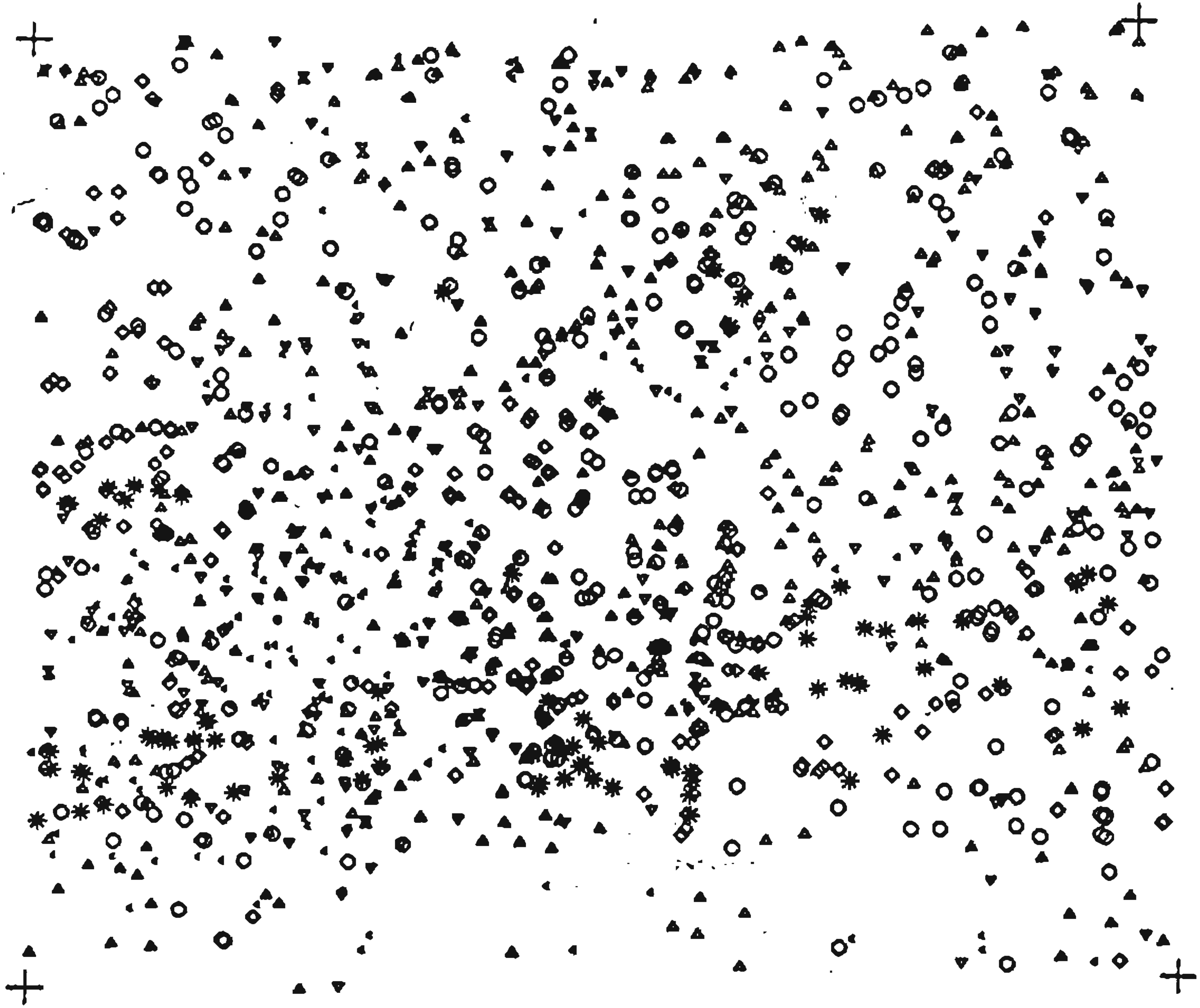
Percentile	Symbol	Concentration in parts per million
97.5	*	≥10
95	□	7
90	◇	5
>80, <90	○	<5
80	◂	SN

Figure 16. S-Mo Seds.



Percentile	Symbol	Concentration parts per million
97.5	✱	≥ 150
95	□	100
80	○	70
50	△	50
20	▽	30
<20	◂	<30

Figure 17. S-Ni Seds.

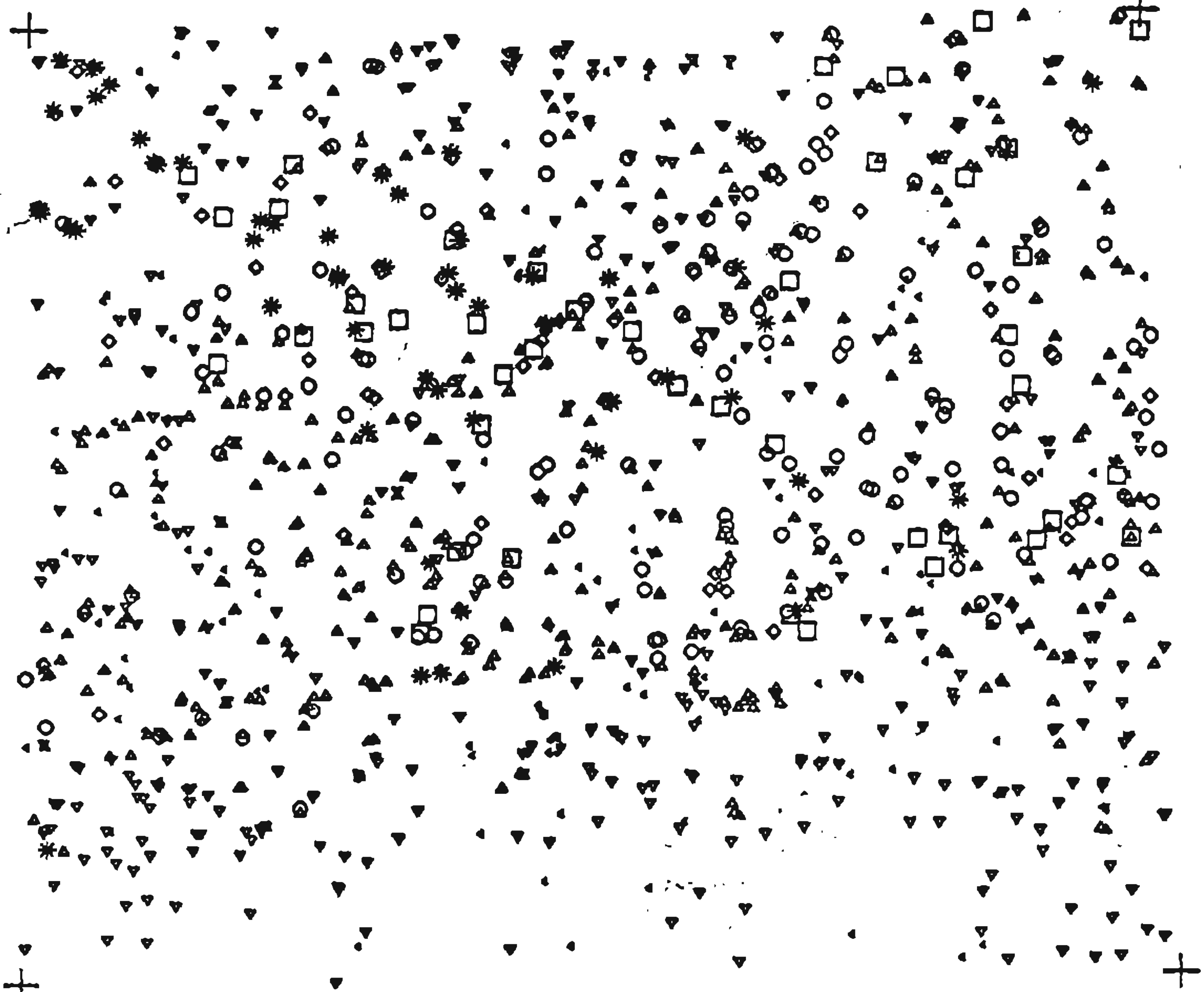


Percentile	Symbol	Concentration in parts per million
97.5	*	≥ 70
90	◇	50
80	○	30
50	△	20
20	▽	15
<20	<	< 15

Figure 18. S-Co Seds.

Percentile	Symbol	Concentration in parts per million
97.5	*	≥200
90	◇	150
50	△	100
20	▽	50
<20	<	<50

Figure 19. S-Cr Seds.



Percentile	Symbol	Concentration in parts per million
97.5	✱	≥ 3,000
95	□	2,000
90	◇	1,500
80	○	710
50	△	510
20	▽	50
< 20	<	< 50

Figure 20. S-Cu C3.

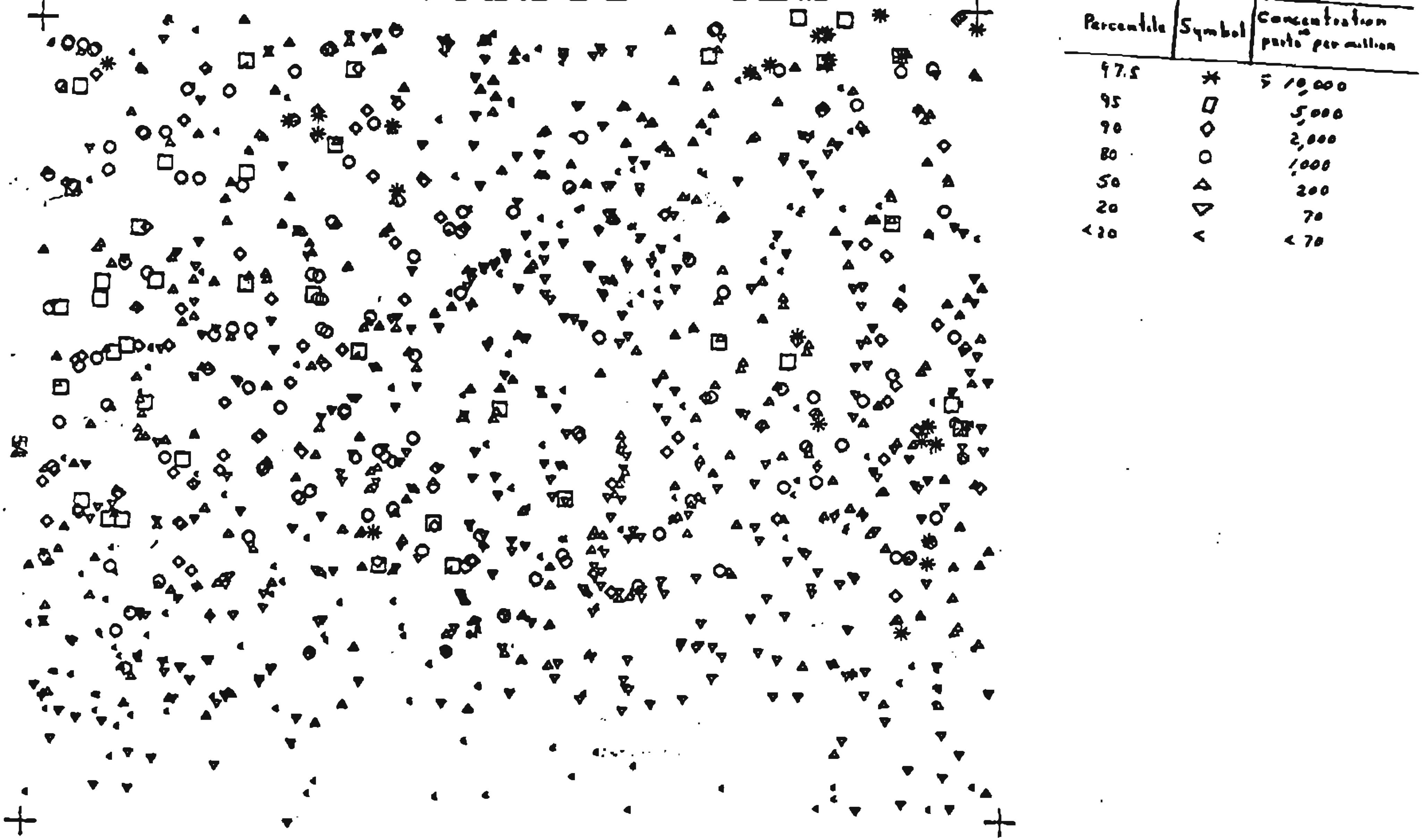
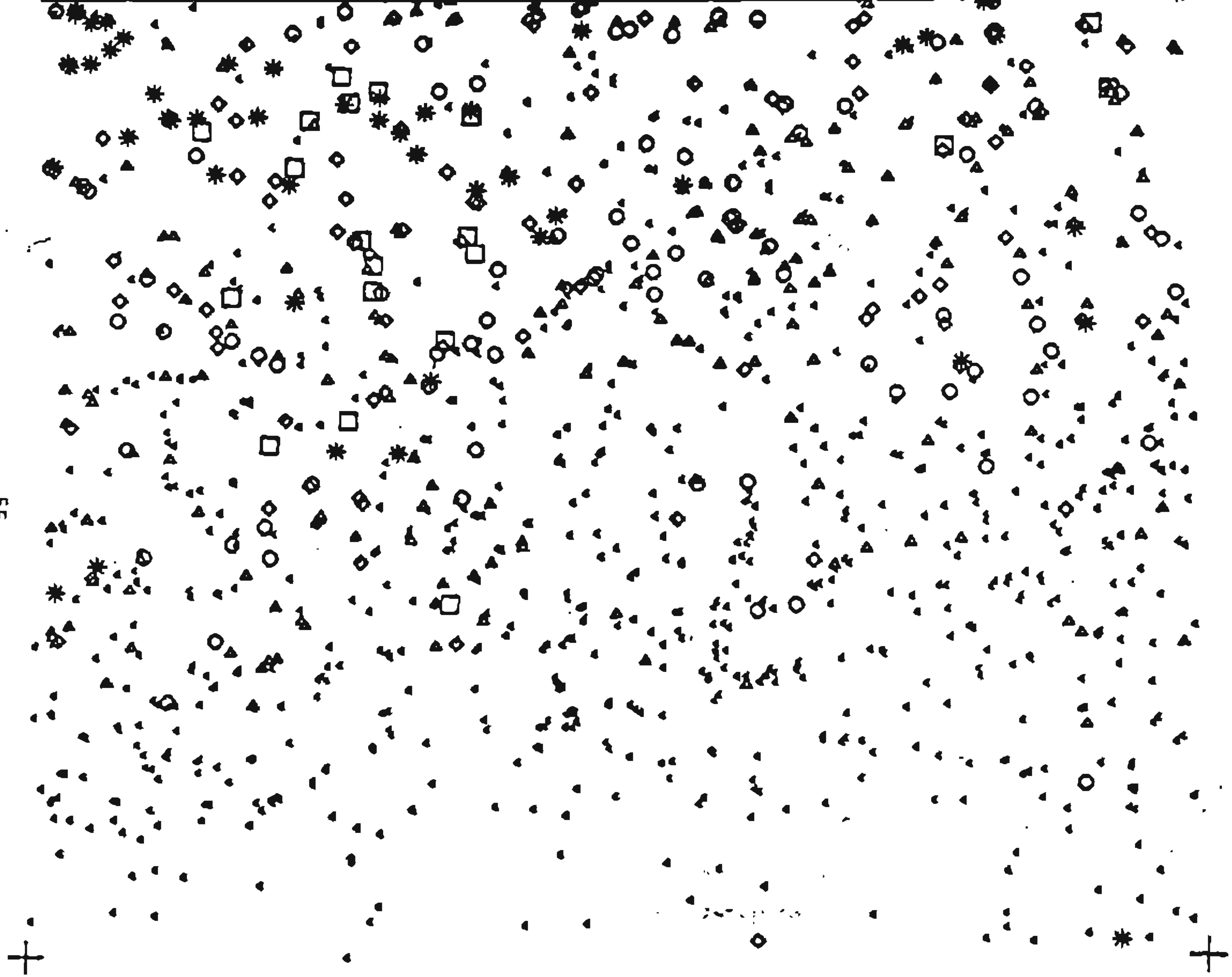
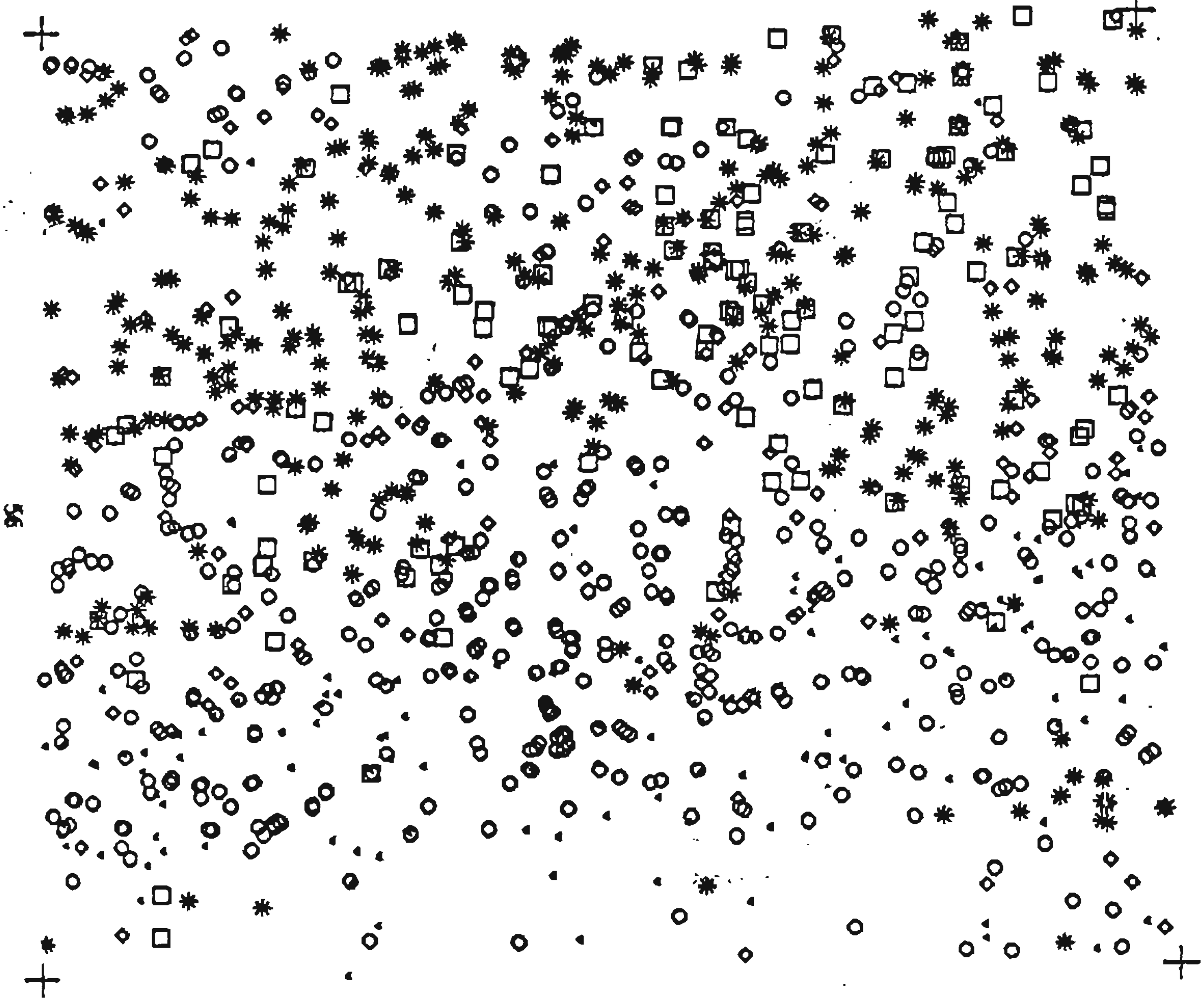


Figure 21. S-Pb C3.



Percentile	Symbol	parts per million
97.5	*	≥ 5,000
95	□	3,000
90	◇	1,500
80	○	1,000
50	▲	500
20	◂	500 N

Figure 22. S-Zn C3.

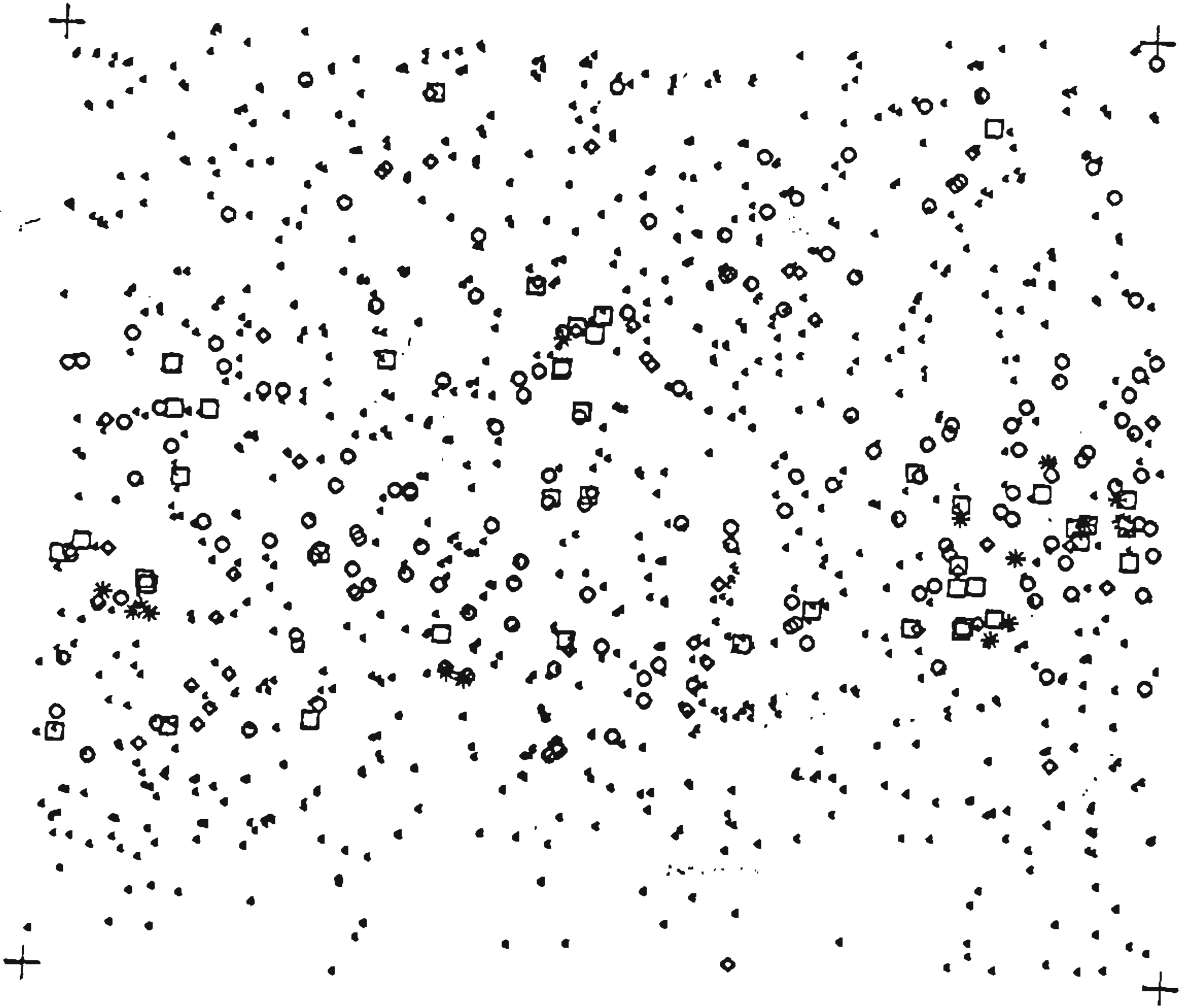


Percentile	Symbol	Concentration parts per million
71	✱	> 10,000
60	□	10,000
48	◇	3,000
13	○	500
< 13	◂	< 500

Figure 23. S-Ba C3.

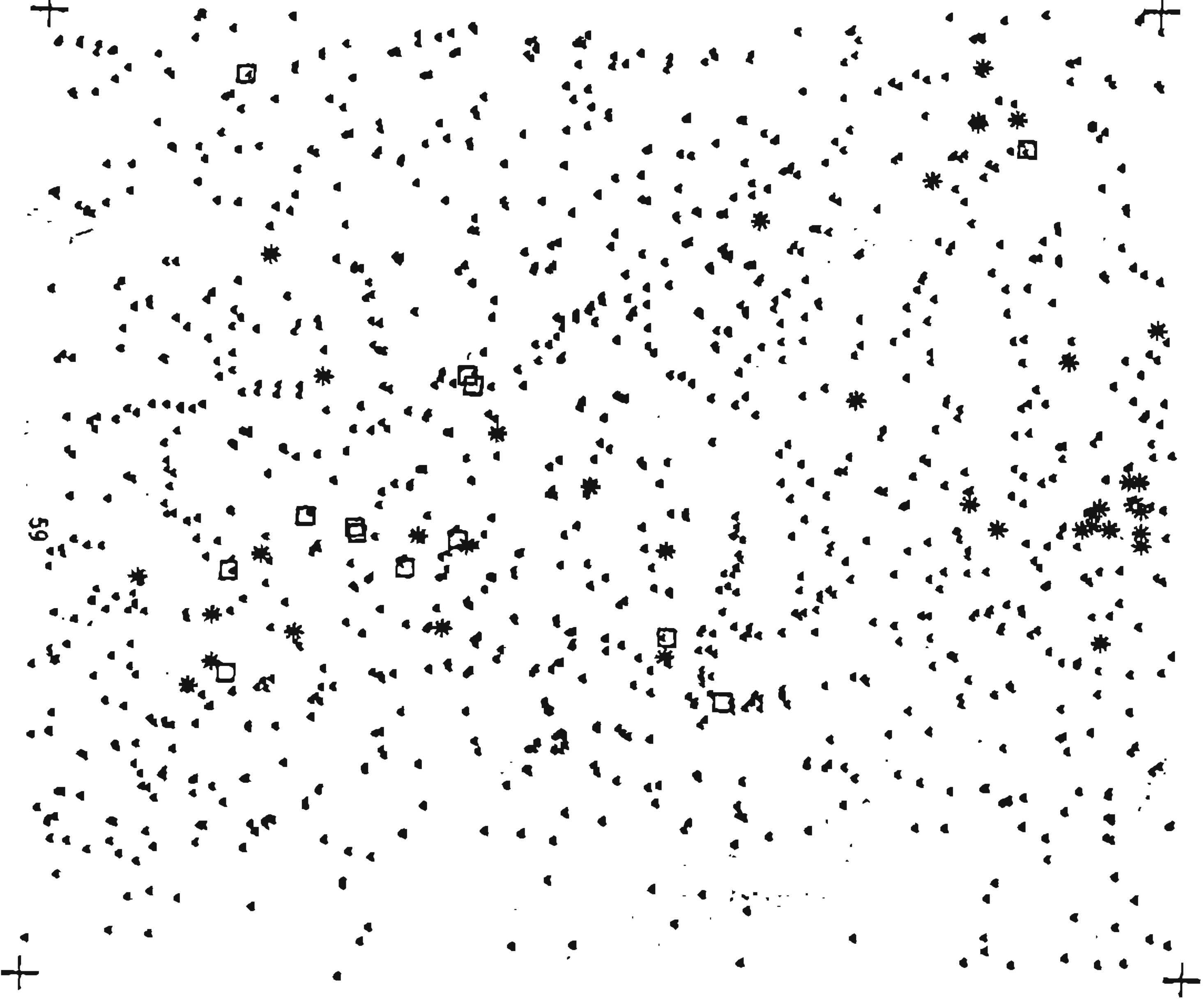
Percentile	Symbol	Concentration in parts per million
97.5	✱	≥ 50
95	□	20
90	◇	10
80	○	5
50	△	< 1
20	◂	1N

Figure 24. S-Ag C3.



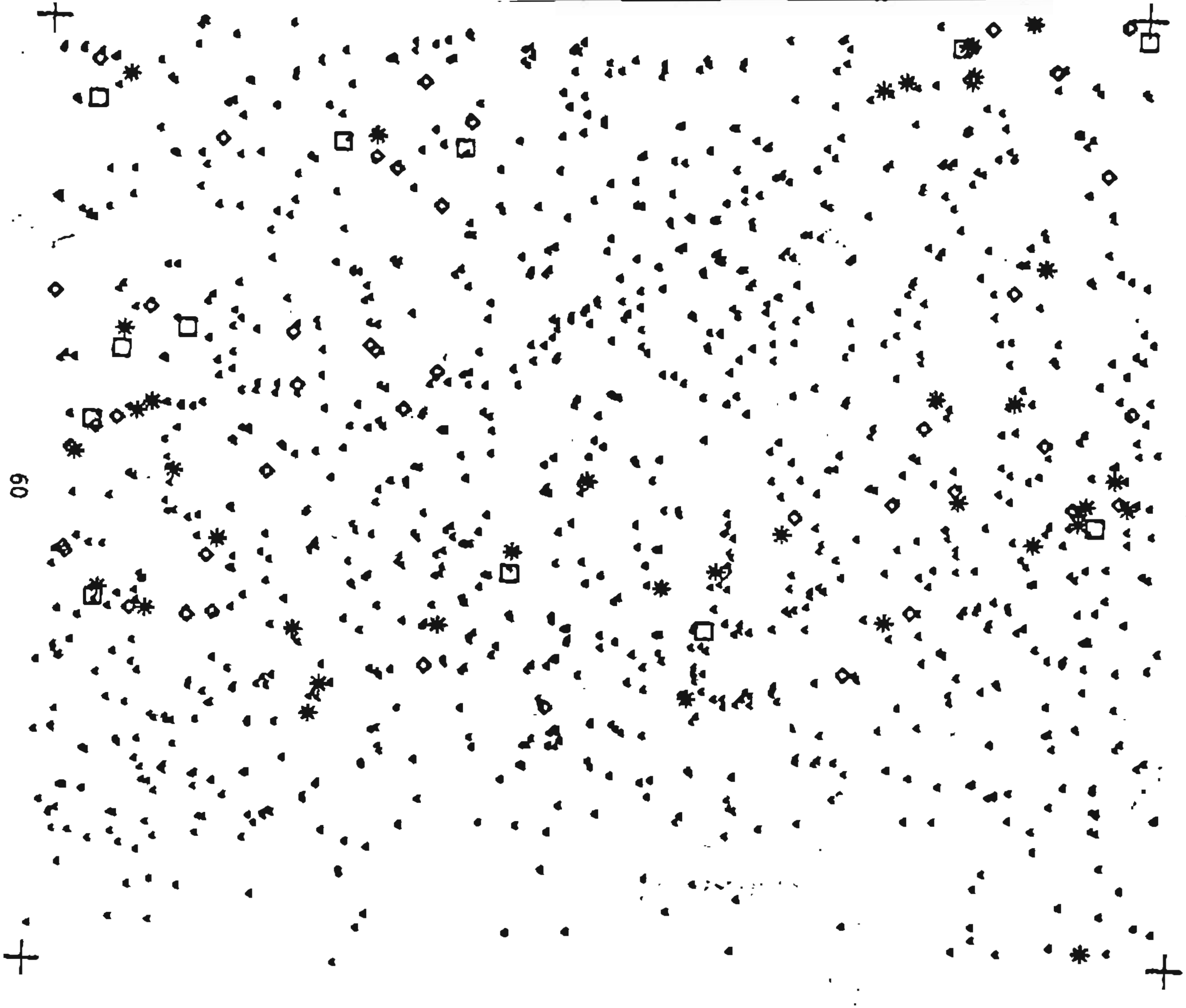
Percentile	Symbol	Concentration in parts per million
97.5	*	≥ 7000
95	□	2,000
90	◇	1,000
80	○	< 500
50	·	500 N

Figure 25. S-As C3.



Percentile	Symbol	Concentration in parts per million
97.5	✱	≥ 200
95	□	< 200
90	◂	200N

Figure 26. S-Sb C3.



Percentile	Symbol	Concentration in parts per million
97.5	*	≥ 50
95	□	30
90	◇	<20
80	<	20N

Figure 27. S-Bi C3.

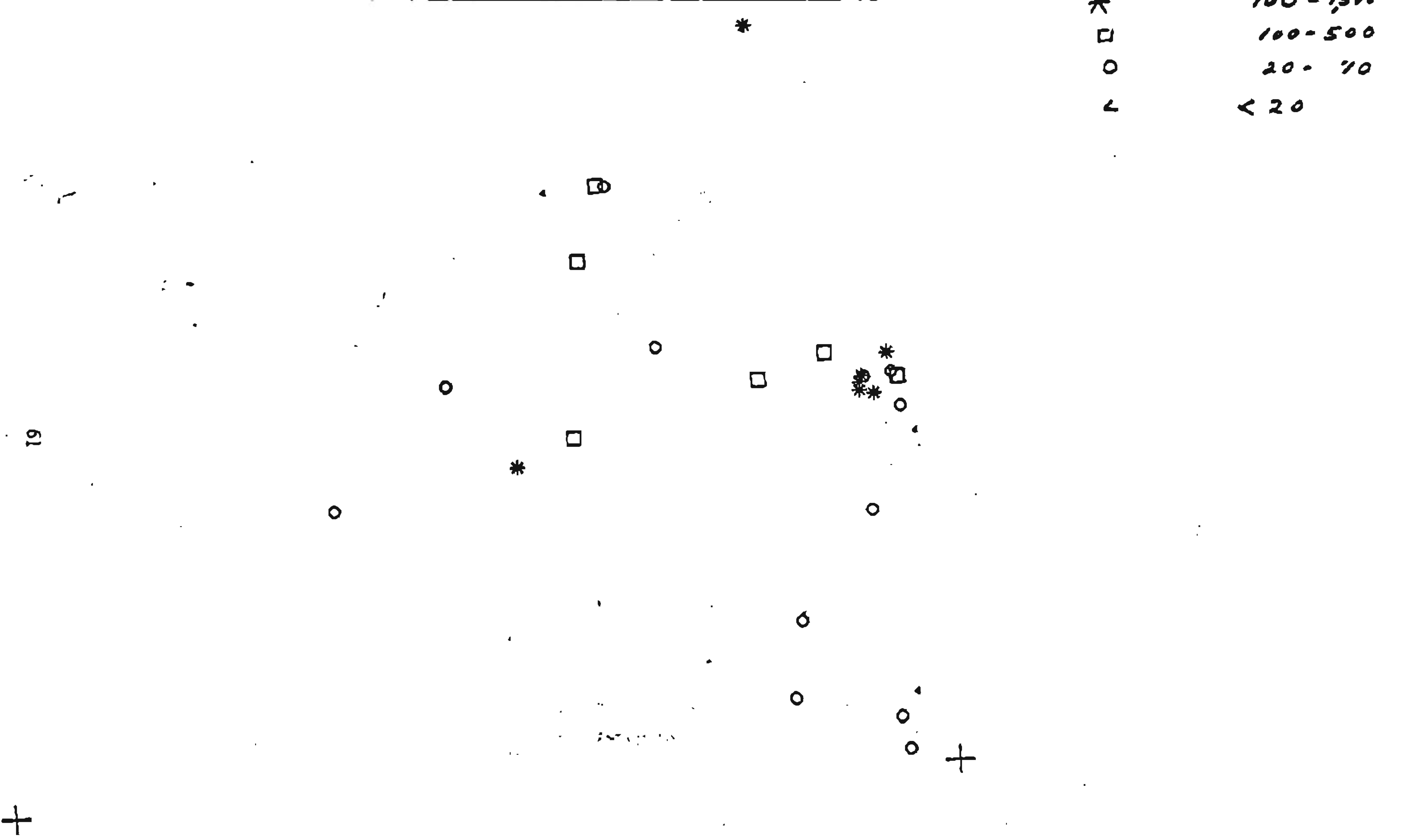
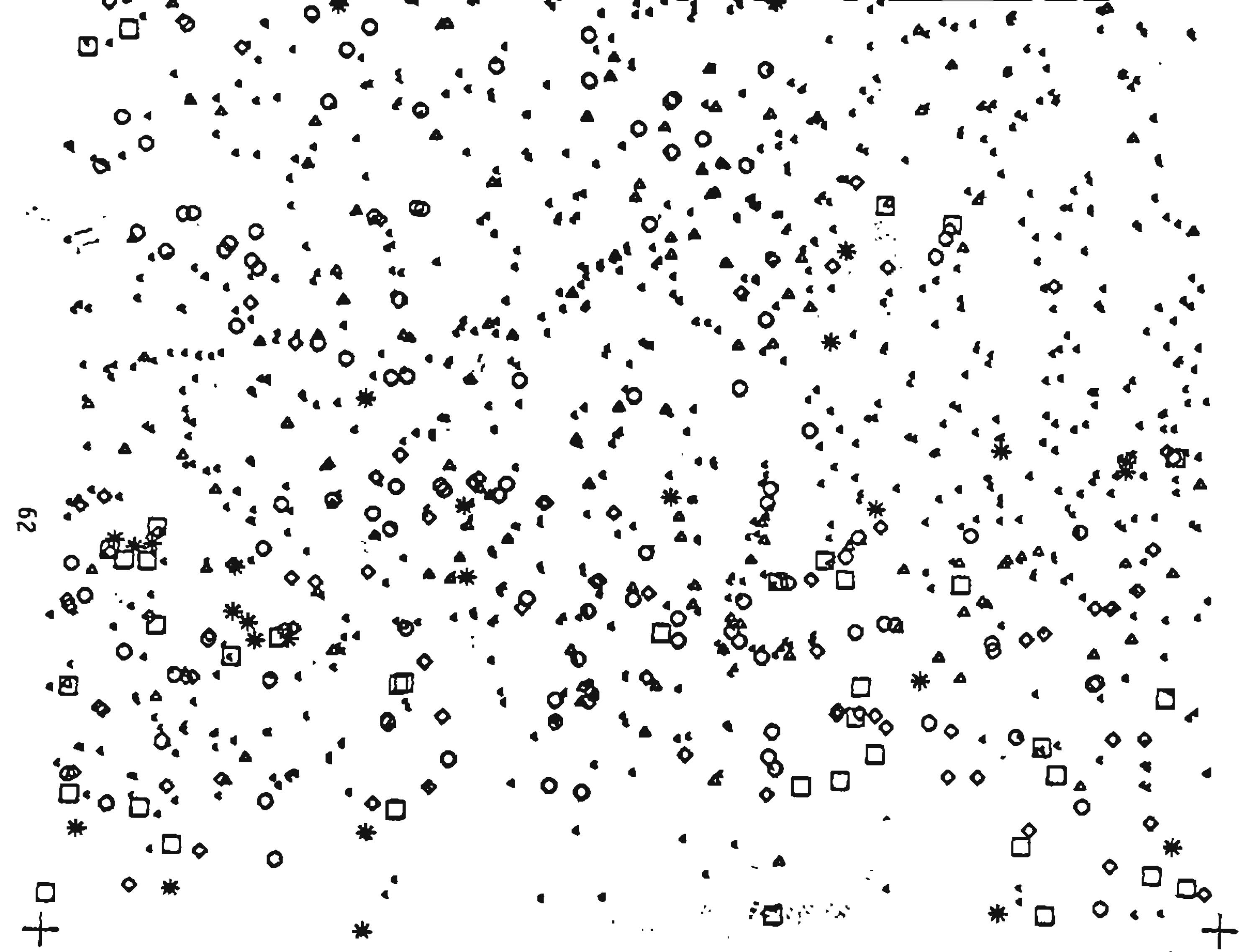
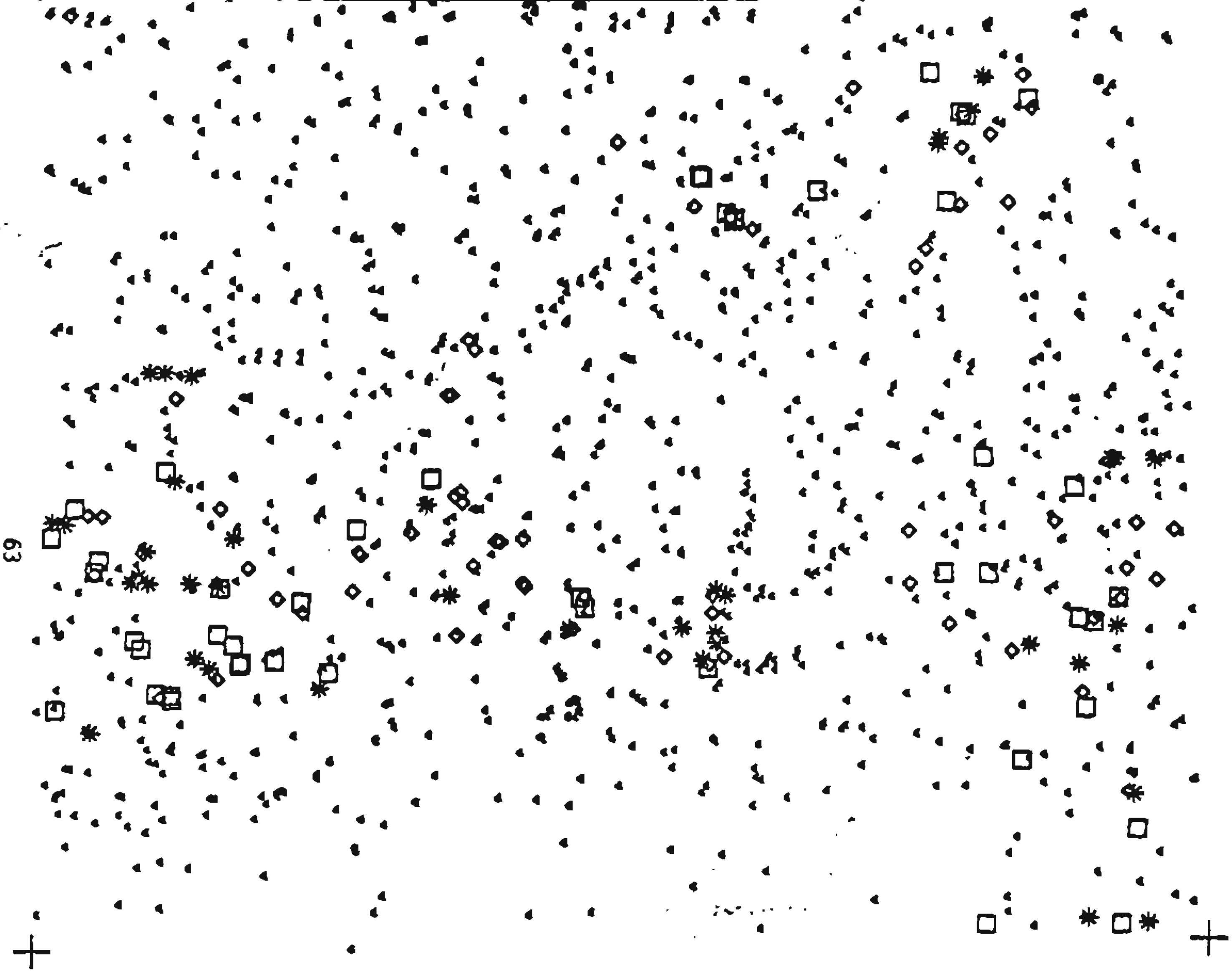


Figure 28. S-Au C3.



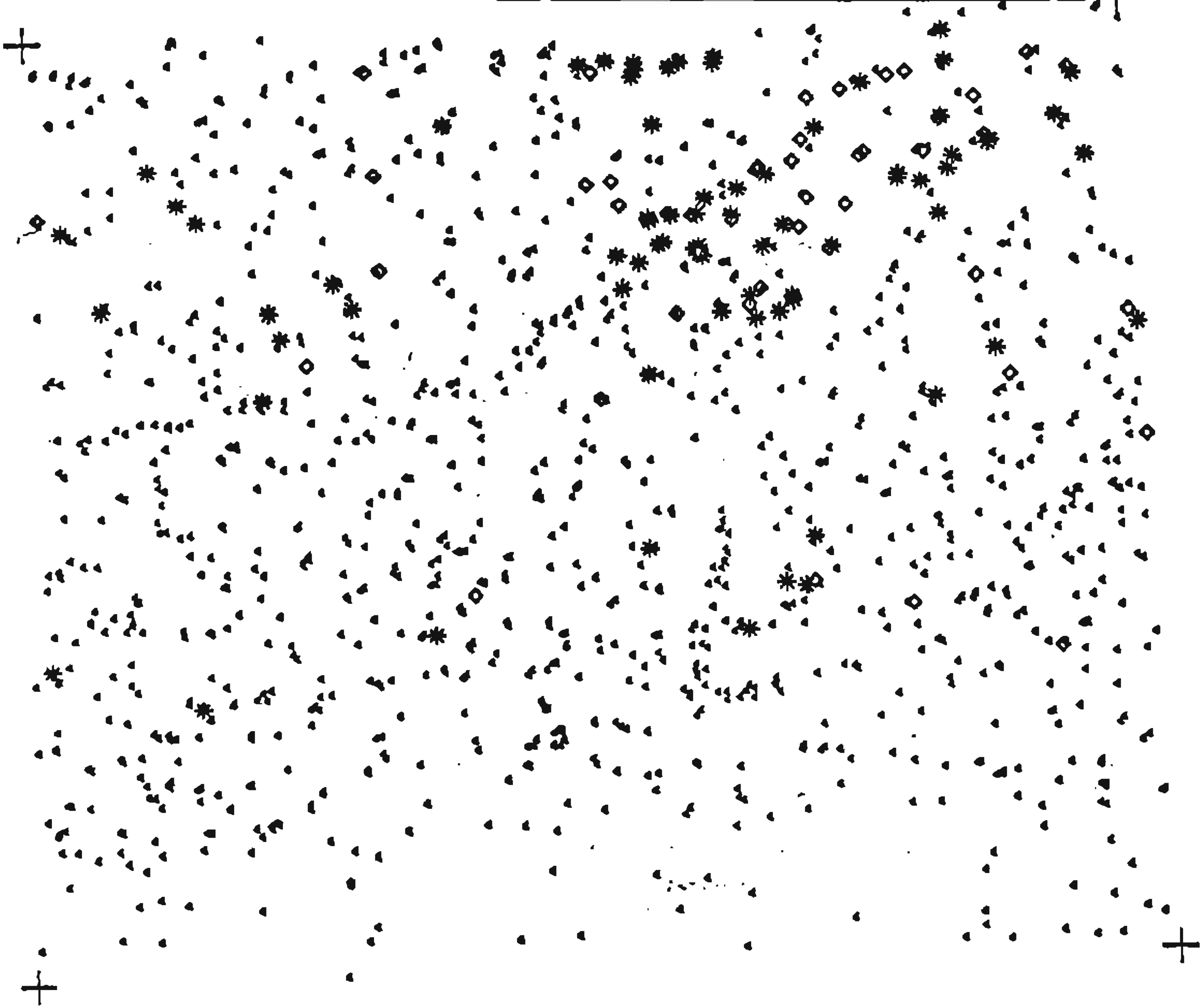
Percentile	Symbol	Concentration parts per million
97.5	✱	≥ 200
95	□	70
90	◇	30
80	○	20
> 50	△	< 20
≤ 50	<	20N

Figure 29. S-Sn C3.



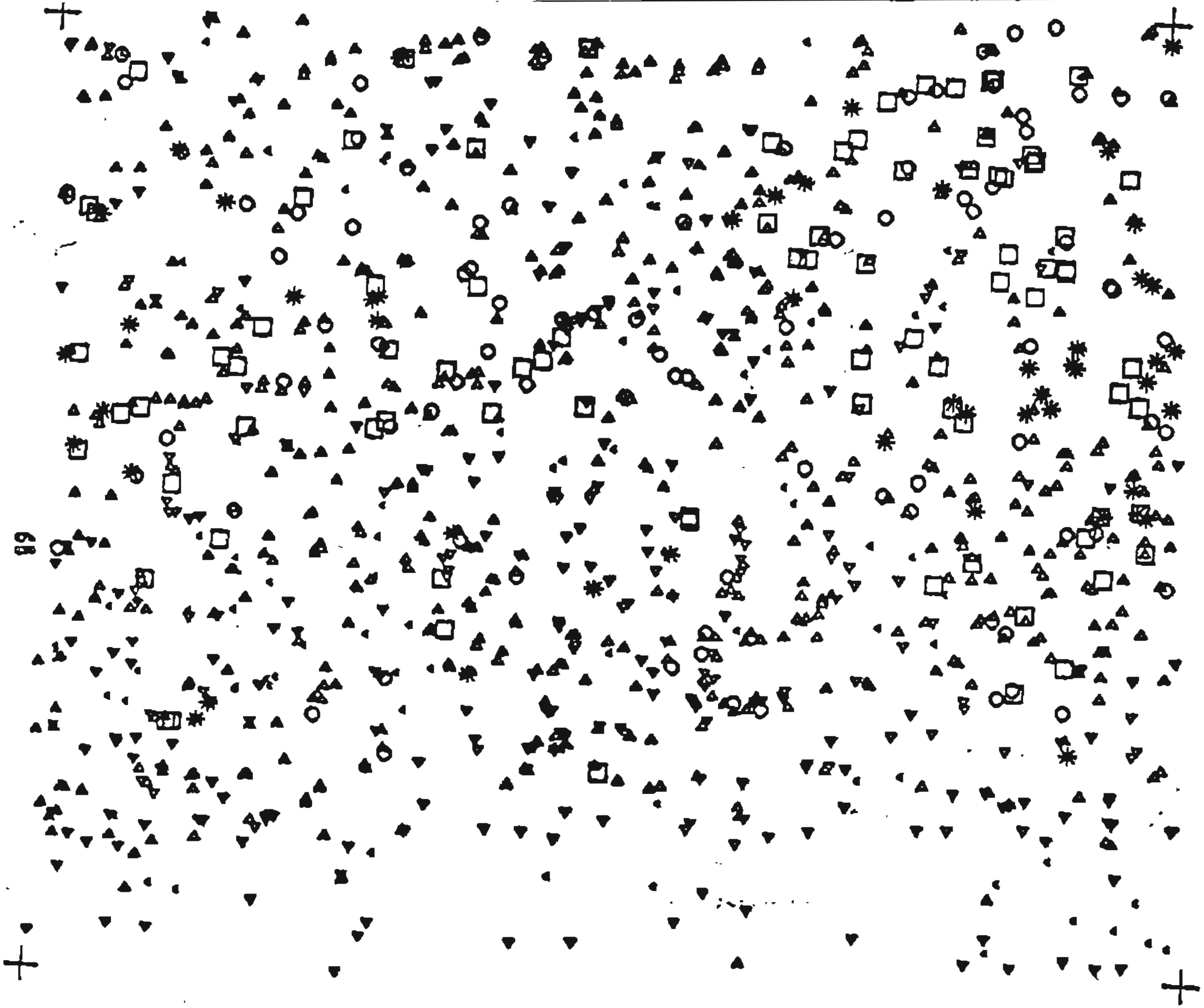
Percentile	Symbol	Concentration in parts per million
97.5	*	≥ 200
95	□	100
90	◇	< 100
80	<	101N

Figure 30. S-W C3.



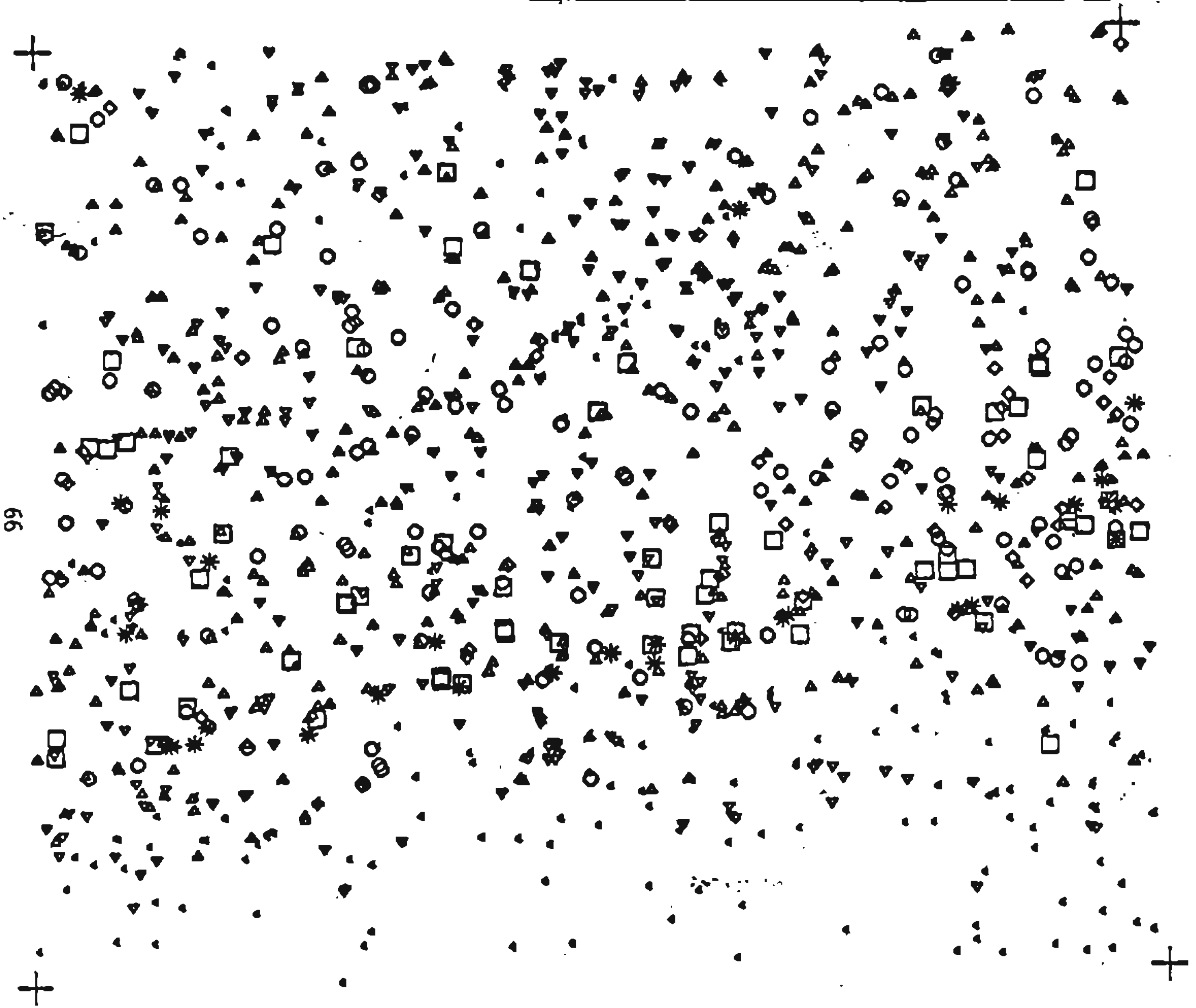
Percentile	Symbol	Concentration in parts per million
97.5	*	≥10
>90	◊	<10
≤90	◂	10N

Figure 31. S-Mo C3.



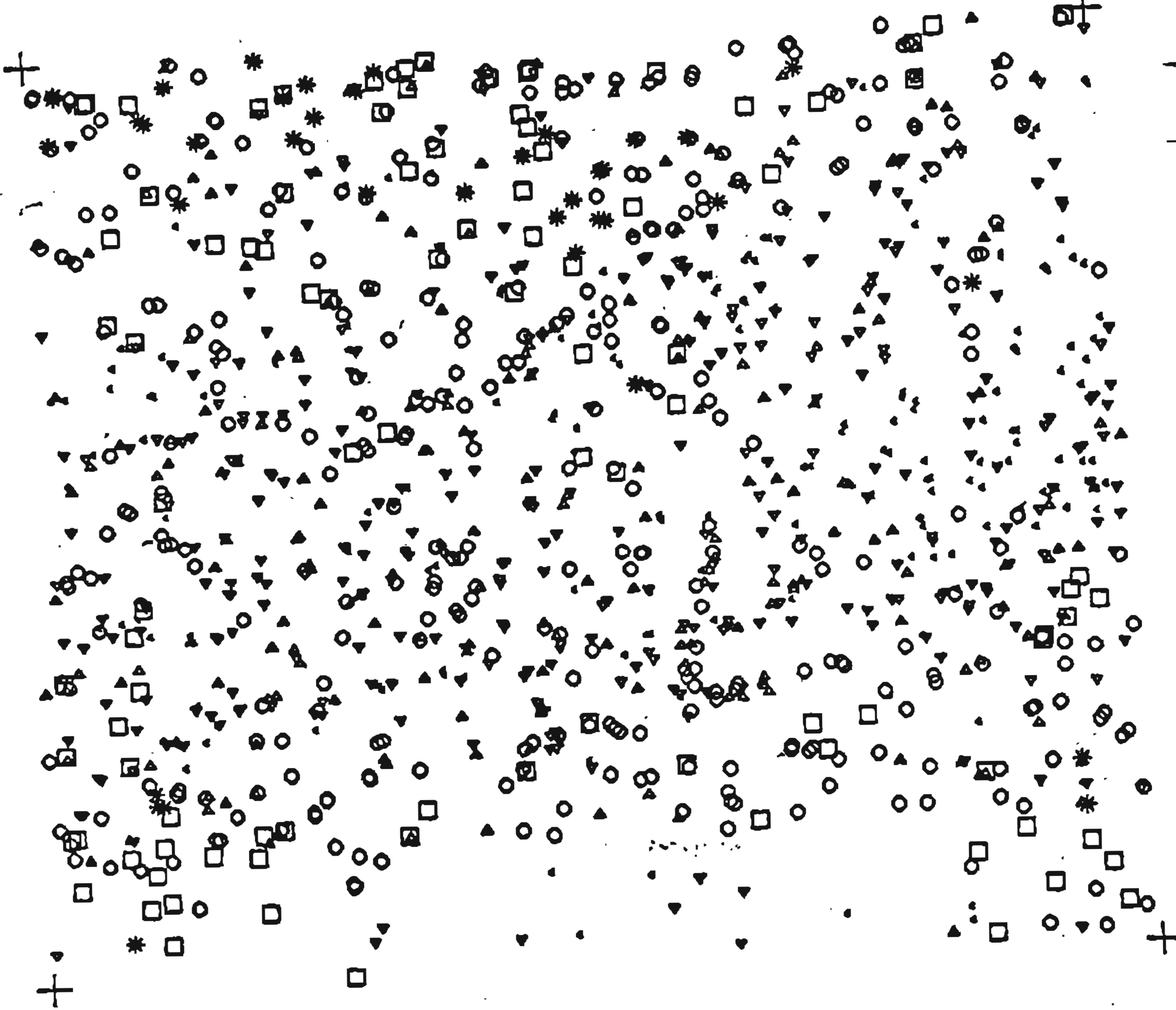
Percentile	Symbol	Concentration in parts per million
97.5	*	≥300
95	□	200
80	○	150
50	△	50
20	▽	20
<20	<	<20

Figure 32. S-N1 C3.



Percentile	Symbol	Concentration parts per million
97.5	✱	5500
95	□	200
90	◇	150
80	○	100
50	△	50
20	▽	15
<20	<	<15

Figure 33. S-Co C3.



Percentile	Symbol	Concentration in parts per million
97.5	*	≥700
95	□	500
80	○	200
50	△	150
20	▽	70
<20	<	<70

Figure 34. S-Cr C3.