A MICROPROBE STUDY OF PLACER GOLD AND ITS ORIGIN IN THE LOWER FRASER RIVER DRAINAGE BASIN, B. C.

by

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Abstract

The compositions, in terms of Au, Ag, Cu, and Hg, of about 1200 placer and lode gold grains from the Fraser River drainage were determined by microprobe analysis. The lode samples are from the Bralorne and Cariboo Gold Quartz mines. Seventeen placer samples are from the Cariboo district and the Bridge River, Fraser River and their tributaries. Bralorne gold and many placer grains contain Hg which ranges up to 6%. Evidence is presented to show that this Hg is primary. Placer gold grains also contain Cu, ranging up to 31%, but high-Cu gold has little Ag or Hg.

The compositional data were used to define populations on Hg-Cu-Fineness plots for each sample location. A comparison of the populations shows that placers located near lodes reflect these sources but that simple downstream transport of the gold cannot explain the populations found far from known sources. In order to explain the population found in downstream placers it is necessary to postulate contributions from undiscovered lodes, fossil placers, or other unknown sources. Many placer grains from the Fraser River have rims that are nearly pure gold. The rimming is thought to have taken place in an "intermediate collector" (fossil placer?) by leaching of Ag. Rimmed gold is not found in the Bridge River.

From the data on the composition of the gold one is able to divide the Fraser River drainage into two metallogenic provinces: a Cu-Hg-rich province that includes the Bridge River drainage and a Cu-Hg-poor province typified by the Cariboo

region. The data from the lode deposits suggest that the deposits can not only be uniquely characterised but that it may be possible to distinguish zoning within the lodes. In addition, it appears that much of the Cu- and Hg-rich gold is associated with ultrabasic rocks and major faults.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF FIGURES

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INTRODUCTION

PREVIOUS WORK

Previous workers have used the composition of natural gold (its fineness or trace element composition) to deduce the source of placer gold and to classify gold lode deposits. Most of this work has been based on emission spectroscopy and bulk assay results. Some work was based on wet chemistry, reflected light microscopy and atomic absorption spectroscopy.

Fisher (1934) and Fisher (1945) showed that the fineness of placer gold in the Morobe field of New Guinea can be used to characterise the lode sources and that the average fineness of the placer indicates the relative contributions of the sources supplying it.

Smith (1913) showed that placer gold fineness reflects the fineness of the source and does not in every example increase with distance of transport as is commonly asserted.

Mertie (1940) developed a model to explain the distribution of gold and its fineness in placers that took into account cyclical erosion and the changes in lodes with depth.

All these authors, especially Fisher (1950), and many others have tried to classify lode deposits and their variations using fineness. In general the classifications based on fineness are contradictory, a fact that is not surprising, considering more recent work on the variability of gold compositions (eg. Gay, 1963).

Trace element compositions have been used in more sophisticated attempts to characterise the sources. Gay (1963) provides a review of the data and conclusions up to 1963. One of the few firm conclusions he was able to draw was that gold in the oxidized zones of ore bodies is purer than the lode gold.

In the western world relatively little work has been done on trace elements in gold. Warren and Thompson (1944) made one of the earliest attempts and Antweiler and Campbell (1977) are among the most recent workers.

Valpeter's paper (1970) is typical of the Soviet methodology in attempts to use trace elements and fineness together to characterise placers and their sources. The Soviets typically use other variables such as morphology (internal and external) in their studies. The papers of Fayzullin (1971) and Davydov (1970) are typical.

The Soviets have also tried to classify lode deposits using fineness and trace element compositions but the results seem to suffer from the same inconsistencies as the earlier classifications based on fineness. No major generally accepted conclusions resulted from this trace element work.

The problem of new gold (gold precipitated in the surficial environment) and reworked gold (gold which has been through more than one cycle of erosion and transportation) should be mentioned. In many placer regions the possibility of new gold is demonstrated, then forgotten only to become the source of controversy for a later generation. Uglow and Johnston (1923) give good accounts of the manner in which this problem is rationalised.

Yablakova and Ryzhov (1972) showed that not only can a fossil placer supply gold to an active placer but that this reworked gold has commonly been altered. This and the possibility of new gold severely limits the validity of statements on distance of transport (Tischenko and Tischenko, 1974; and Tischenko, 1981).

The basic conclusions from fineness and trace element work are:

1) Fineness and composition of gold range widely in individual lodes and placers.

2) Both new gold and reworked gold may contribute to placer formation.

3) Gold fineness does not necessarily increase with distance from the source.

These three conclusions can be used to characterise sources but only in a generalised way.

Only the Soviets have tried to develop and apply these three conclusions to gold exploration in a sytematic way.

It is important to realise that all studies using the methods cited suffer from one or more of the following deficiencies:

1) Averaged data are used to draw conclusions for individual members of the average.

2) Contamination is not systematically accounted for.

3) The analytical method used yields only the average composition of particles or collections of particles, and includes inhomogeneities and mineral inclusions.

4) Samples may be necessarily small and unrepresentative.

5) Sample preparation may lead to the alteration of the composition of the gold.

These difficulties were largely overcome when the electron microprobe came into use because of its ability both to analyse small volumes, quantitatively and non-destructively, and to generally avoid inclusions. Using the microprobe Desborough (1970) was able to confirm the presence of rims of >980 fineness on some placer gold grains. Berman et al. (1978) showed that the total range of compositions in the Ag-Au series is found in nature. Naz'mova and Spiridonov (1979) and von Gehlen (1983) confirmed the observations of Trenina and Shumilov (1970) on natural gold amalgams from the Ukraine. However Foster et al. (1978) concluded that the amalgam they studied from California was formed when Hg was introduced into the placer during mining activity. The gold studied by both Trenina et al. and Foster et al. had visible Hg rims. Microprobe work such as that of Pokrovsii et al. (1979) and Novgorodva and Tsepin (1976) have broadened our knowledge of the Cu-Au phases that occur in nature. Nesterenko et al. (1982), Desborough et al. (1970) and (1971) and Fitzgerald et al. (1967) show how the probe can be used to refine the applications of gold analysis developed using other methods.

Phase Diagrams

The geochemistry and composition of synthetic gold alloys has been studied in some detail. Kikuchi et al. (1980) published a calculated Au-Ag-Cu ternary phase diagrams and Chang et al. (1977) published an experimentally derived Au-Ag-Cu phase diagram. Rolfe and Hume-Rothery (1967) published Hg-Ag and Hg-Au phase diagrams which show that from 0$C to 500$C a single phase is formed with as much as 15% Hg. All phase diagrams are for one atmosphere.

METHODS

SAMPLE COLLECTION

Some placer samples were collected at the locations shown in Table 1 and in Figure 1 by panning and sluicing, using a 1 metre sluice. Other samples were purchased or received as donations from placer miners or prospectors. Care was taken to ensure that the gold actually came from the location specified and had not been altered in any way by amalgamation or acid cleaning.

Lode samples were collected at the sites or were donated by the museum at the Department of Geology at the University of British Columbia. These samples are small and probably not fully representative.

SAMPLE PREPARATION

The smallest grain that can be picked and mounted has an intermediate axis of about 0.4 mm. For flattened particles the small axis was close to the analytical diameter of the beam but for equant specimens this dimension was much larger than the analytical diameter.

These grains were photographed, given a number, and mounted in plastic with their long axis vertical. The plastic was heated to 135$C for 15 minutes at atmospheric pressure then left to cool for 10 minutes at 29 MPa. The particles were ground and polished to a microprobe level of flatness at the approximate position of the plane including the intermediate and short axes This procedure ensured that a similar planar section from each specimen was exposed, thus reducing the possibility of errors caused by differences in depth of exposure between grains (important because of the possibility of rimming).

Some lode samples were mounted, cut and polished as is normally done for rock specimens in probe work. For others the rock was crushed and visible gold picked by hand, then treated as was the placer gold.

All specimens and standards were coated with approximately 250 nm of carbon (determined by the interference colour on brass) by vacuum evaporation.

SAMPLE ANALYSIS

Instrument Setup

The samples were analysed on an A.R.L. SEMQ microprobe. Specimen current was set at 100 nA on aluminium. The specimen current was chosen as large as possible to reduce the counting time for the minor and trace elements, but sufficiently small that the vaporization of Hg was avoided. The accelerating potential, 15 kV, was chosen to minimize interference problems between elements. A 200 #m aperture and as small a beam as possible (as seen on benitoite) was used.

At the start of this study a review of the literature showed that the number and amount of the elements found in natural gold were poorly known at the microprobe level. A series of test analyses of the 15 elements (As, Pt, Au, Hg, Pb, Bi, Ag, Sn, Sb, Te, Fe, Ni, Cu, Zn, Mn) most commonly reported in emission spectroscopy studies of gold was carried out on samples from the Cariboo and Bridge river areas. Au, Ag, Cu and Hg were the only elements that were consistently present. Values for Ni, Fe, Sb were obtained but the amounts were low, and erratic. They were not considered further. The remaining elements were below the detection limit. Table 2 shows the spectral lines used and table 3 lists standards. Counting time on each background was 10 seconds and on the peak was 20 seconds. The lines and background stepoffs were chosen after analysing artificial alloys of gold containing about 1% each of the 15 elements to be analysed for, except for Ag. For Ag, pure Ag and Ag-Au alloys were used.

For Hg and Cu the background stepoff is larger for standards than for samples because interference is not expected from other elements in the standards. For the analysis of samples, a smaller stepoff was chosen to avoid element interference. This procedure was considered permissible because the Hg and Cu values expected in the samples were mostly less than 1 wt%. It appears that this stepoff became a problem only for values greater than about 10% Hg and was not a problem for Cu.

Analytical Procedure

Spot analysis was done at a point as near as possible to the middle or core of each grain, well away from the rim. The number of core analyses per sample is given in table 1. Where possible, the rims of rimmed grains were analysed. Very few of the analyses are considered to be either a mixture of rim and core compositions or rims represented as cores or visa-versa as the rims were nearly all visible in reflected light.

The decision to analyse each grain only once was rationalised as follows. Primary intragrain inhomogeneity was expected to be the norm rather than the exception so that under this assumption a high precision on a single grain would have less value in defining a population than a number of low precision analyses on random grains. If the primary intragrain inhomogenity is systematic, that is, the grain is concentrically zoned, it was thought that this would be largely disrupted (through removal and distortion) by the time the grain reached a placer. The evidence from the rimmed grains showed that this is reasonable for all but the most angular grains. Therefore analysing a grain once in its centre was considered a random representative sampling of the population. For the very angular (undisrupted) grains the sampling is of the core only. This allows the population to be represented on element-element and element-fineness plots by the distribution of the analysis points.

The method was to standardise on each of the standards listed above and then run an Ag-Au standard alloy as a check on the system. The background stepoffs for Hg and Cu were then changed and the standards rerun. Bence-Albee factors generated by Magic IV were used in the data reduction program.

Accuracy

Some instrumental errors were detected by checking the background counts and the total weight percent of each sample. The most common error was caused by beam current drift which resulted in a low total weight percent. This error occurred despite a beam normalizing routine in the program. Experience showed that totals of about 100% +-2% gave the same fineness value before and after restandardizing to correct for the beam drift. Generally drifts larger than this gave unreliable results, and therefore only values within this tolerance were considered acceptable. This tolerance is high but no realistic way around this problem was found.

Beam drift was not found to affect significantly the minor elements except where their values were unusually high. The accuracy of the high Hg values is not considered to be good, because of the small background stepoff and the possible vaporisation of Hg. In the case of high Cu analyses, many of the totals were inexplicably high.

Previous studies have shown that Hg and Cu values would be expected to occur in amounts generally less than 0.1%. From a single analysis, at the conditions outlined above, the detection limits for these elements are given in table 4. To be consistent the higher limit was chosen as the practical detection limit.

Precision

Each grain was analysed once except when inhomogeneities were being checked. No check on the precision of the analyses was done but, the narrow scatter seen in some populations such as AU48, (Stirrup) shows, bearing the instrument checkout procedure in mind, that population separations, to this degree of scatter, are meaningful. This conclusion is considered to be true for all the samples. For Hg-rich varieties the precision is poor, presumably because of the vaporisation of Hg (eg Table 5, samples AU43-3-5 and AU45-1-5).

Homogeneity

For some specimens duplicate analyses (Table 5) were made on nearly the same spot. Analyses originally run in search for rim compositions are also considered as duplicates (Table 6). These analyses show that the grains are generally homogeneous. The variability of the minor elements is small except when their values are high. The variability of Hg values from a single source can be large. This appears to be common (Ku'znetsov et al., 1982). The variability of Cu values from a single source is large for specimens with high Cu values and appears to be common (Ramdohr, 1969, p. 324). It is low for low Cu varieties. In general, as expected from the phase diagrams (Figure 2a), Cu values increase with fineness, and high Cu values are limited to gold of high fineness. It should not be concluded from Figure 2a that the gold was formed at a temperature between 200 and 300$C because the diagram is for 1 atmosphere and the theoretical and empirical phase diagrams do not agree in detail.

The temperature of mounting is not thought to have significantly altered the Hg distribution. The fine structure preserved in the rimmed grains with Hg (eg. AU52-2-4) and the preservation of very high Hg values (eg. AU11-2-10) support this conclusion although the homogeneity of the intragrain Hg values might be considered to contradict this.

DATA PREPARATION

The data are displayed in terms of 'fineness', ((Au/Au+Ag)*1000), together with weight percent Cu and weight percent Hg (Figures 5 to 29). This is preferable to normalizing Au, Hg, Ag and Cu to 100% because fineness is a familiar convention. No information is lost by this treatment of the data. The reader should be aware that the term fineness is used to refer to gold composition, not grain size and that the term 'grain' is used to refer to a sedimentary particle, not to a unit of weight for gold.

SAMPLE RELIABILITY

Does the sample represent the source or lode population?

It seems reasonable to assume that a source area supplied gold with a large size range to the placers and that the majority of the grains should be expected to be small. Therefore a sample made up of small grains should be reasonably representative of the source. Some authors report that there is a systematic change in composition with grain size but others dispute this finding (Gay, 1963; Desborough et al., 1970). In reality this is not a problem because as Yeend (1975) showed the larger grains are abraded during transportation to produce a large number of smaller grains. The possibility of different sources having different sized gold grains cannot be ruled out.

It is important to show that the sample is representative of its average size fraction. From Figure 2b (Wang and Poling, 1983) the recovery is about 50% for the lower limit and 80% for most of the sizes of placer particles of the present study. Pure Au has a density of 19.3, Ag of 10.1 and magnetite, (the heavy mineral most commonly associated with gold in placers) a density of 5.2. Most of the gold recovered has a density above 15, significantly above that of magnetite. The large density difference between gold and magnetite suggests that density alone cannot account for the imperfect gold recovery and implies there is likely to have been very little sorting of the various gold types by density. The other important sorting factor is shape. Small flat grains will have the lowest collection efficiency because of the large surface to mass ratio compared to small spherical grains or large angular grains. Because these small flat grains make up the bulk of the samples where the shape would become a problem, sorting is not thought to have affected the sampling reliability.

There is an additional sampling problem. Smaller grains are expected to travel farther than larger grains (because of their larger surface to mass ratio) so that the farther a sample is from the source the smaller the size that represents the source. The size of grains in the sample thus limits the distance from the source that the sample can represent the source. As a small size is used in the samples taken and not a range in sizes, no firm conclusions can be drawn from the present data about this problem. Bearing these assumptions in mind it can be concluded the samples represent not only the deposits at the locations from which they were collected but also the sources from which they were derived. An attempt was made to verify this by comparing the fineness data reported by Holland (1950) with the average fineness calculated for what were considered to be the same locations, Table 7. The numbers are in the right range but inconclusive. The affect of rims on the averages is noted but there are too few data to warrant an attempt to compensate for it.

Many of the gold grains analysed contain Hg. The maximum value is close to 10%. Most authors ascribe its presence in placer gold to contamination from the amalgamation process used in placer mining. A few grains from this study area show narrow Hg rims which are probably the result of contamination (see also section on Hg rims). Naz'mova and Spiridonov (1979) argue for a primary origin for Hg in placer gold and their view is supported in this study by the following: Gold from Bralorne veins, collected underground, contains up to 3.96% Hg; one grain of placer gold (AU52-2-4) has an Hg-rich core and a Hg-free rim of high fineness. If Hg was the product of contamination, the contamination occurred before the rims were formed.

It can be demonstrated that Hg is not transfered from Hg rich contamination rims to cores of nearby grains during the polishing process of the sample preparation procedure. Two samples demonstrate this: Grain AU52-2-4 which has an Hg rich core has an Hg free rim (Table 8). Placer grain AU11-2-10 has about 10 wt% Hg. Grains on either side of this grain were analysed, AU11-2-10 removed, the sample repolished and these grains reanalysed. The Hg content of these grains did not change. See Table 9.

Another kind of error could result from the analysis of a very small grain with a thin Hg rim where the excitation volume encroaches on the Hg rim. This error appears to be unimportant because the distribution of grains with significant Hg is systematic and independant of the number of Hg contaminated grains in a particular sample.

TEXTURE

GRAIN SHAPE

No detailed size-shape study was attempted but the following observations were made.

The samples can be divided into three general types based on the overall sample appearence.

Smooth, flat: AU50, 51, 52, 11, 43, 75, 01 (Plate 1b)

Smooth, slightly flattened: AU15, 45, 12, 13, 60

Angular, unflattened: AU42, 14, 18, 19, 48, 59, (Plate 1a)

The flat gold is thought to have travelled the greatest distance and the angular gold the least distance after being released from its lode source. Yeend's work (1975) may modify this conclusion slightly. It is important to note that the flatness need not always mean distance from source because of the possibility, especially with flat grains, that they could have been eroded from intermediate collectors which were formed when the drainage pattern was different. Flatness is a more reliable function of the energy expended on the grain during transport than distance of transport. Soviet geologists (e.g. Fayzullin and Turchinova, 1972) have introduced the name "intermediate collectors" to apply to temporary resting places for gold deposited in the surficial environment. For example, in preglacial times, drainage patterns were at least locally different from those of the present so that gold could have been supplied from one direction to a gravel deposit but in modern times eroded from it and transported in a second, perhaps opposite, direction. Similarly, during glacial times gold was carried by ice far from its source and modern streams have been reconcentrating this gold from glacial drift. The gravel and glacial drift in these examples would be referred to as intermediate collectors.

The following three generalizations can be made:

1) All the flat gold is found in the Fraser river.

2) All the lower Bridge and AU15, (Relay) samples are slightly flattened.

3) Samples thought to be near the source (except AU15, (Relay) and AU43, (Yale)) are angular.

4) None of the Cariboo samples is flat.

In general these data are interpreted to mean that the gold in the Fraser has probably had a longer history in the surficial environment than the other samples. Longer history could mean either distance from lode or erosion from an intermediate collector. The fact that the Fraser gold is obviously flatter than the other gold at least indicates more 'working'. The gold in the Bridge River is thought to have a much simpler history than that in the Fraser River.

INCLUSIONS AND STAINING

Inclusions and staining were seen on some grains. Occasional large inclusions (primary?) were seen in the angular grains. The flattened grains, particularly AU52, (Fountain Bar) commomly have numerous small inclusions, generally around the edge. It is thought that these were incorporated into the gold grains during transportation. Occasional large inclusions were seen in the flattened grains. In general the flattened grains were dirtier looking than the angular grains. Oxide staining was seen on some of the more angular samples. It appears to be a precipitate deposited on the gold in the placer. Its significance is unknown.

RIMS

Rim is the word used in the literature to refer to the outer zone of a concentrically zoned gold grain. This convention is maintained in this study. Rims, described by Desborough (1970), were observed only in the samples from area 3. In reflected light (on the carbon coated prepared polished samples) rims are light blue in contrast to the dark blue of the cores. The rim most difficult to see is either a very thin one or one in which the change in composition between core and rim is small. The backscattered electron photographs provide finer detail than the reflected light images and show that the few low fineness values (<970) for rims are probably due to the analysis of two phases (Plate 2a).

Only a few grains show complete rims. Some grains have lighter areas in embayments, along cracks and in folds. These are interpreted as preserved rim remnants. Rim analyses of AU52 grains, AU52R (Fountain Rim), appear to be typical and are given in figure 26. Rim core pairs of analyses are given in table 8. Analyses show that:

1) the rims are Au-Ag alloys with no Cu and no Hg,

2) rims fall in the fineness range 970-992 (ignoring two rims), with a mean fineness of 985.9; and

3) rim composition is independent of the initial core

composition. Note especially AU52-2-4, AU52-2-23 (Table 8) which show Hg-rich cores with Hg-poor rims.

Desborough (1970) gives three possible origins of rimming:

1) Formed during the primary (lode) deposition of the gold;

2) Formed by the addition of gold and silver in the surficial environment; and

3) Formed by the removal of silver and copper (this writer would include Hg) in the surficial environment.

Although some lode gold is inhomogeneous, it is difficult to see why primary inhomogeneities would appear so frequently as rims on detrital grains. One would expect grains with randomly oriented boundaries between phases. The rimming seen is therefore not considered to be primary.

The debate over addition of Au and Ag versus the removal of Ag is an old one. Desborough (1970) favours removal of Ag and evidence from the present study supports this view:

1) In all cases the high Ag - low Ag contact is sharp. Along its length the contact is smooth or wavelike with the cusps either towards or away from the contact. In these examples, simple addition of a rim to a core is not reasonable because the core does not have the shape of a placer particle. The contact resembles a 'reaction front'. See examples AU52-3-6, AU52-2-9, AU52-5-15 (plates 2a, 2b, 2c).

Because the Au-Ag system shows complete solid solution with no phase reactions, removal of Ag by diffusion from a grain of arbitary Au-Ag composition would be expected to produce a gradational interface between the Ag-rich and Ag-poor portions of the grain. Data presented by Desborough, (1980) shows that the boundary is sharp and between 4#m and 10#m wide, (depending on the core composition). He concluded that the boundary must have formed at <100$C because the diffusion rate at 300$C is too large for such a sharp boundary to be preserved. The sharpness of the boundary could explained if the diffusion rates of Ag through the rim were significantly faster than through the primary grain. This might be the case if the loss of Ag were due to diffusion through a rim-zone crowded with defects due to previous leaching of the alloy. The interface would thus represent a contact between a defect-riddled rim with a high diffusion coefficient and a well-annealed primary core with few defects and a low diffusion coefficient. If this process can be verified or understood there is the possibility that the time needed for rim formation could be calculated and placer reworking histories deduced.

2) AU52-1-18 and AU52-1-21 (Plates 2d and 3a) show formation of high fineness gold along cracks. Although it is obvious that the fine gold in some of the cracks is the result of folding of rimmed gold grains, for most grains, which are unfolded, it is difficult to imagine a process by which gold is deposited along cracks.

3) The uniform thinness of the rims along straight sections and the thickness at sharp external bends in particular support the removal of Ag model, for example AU52-4-26 (plate 3b).

4) Islands of the original gold are separated from each other by relatively large distances in some grains, such as AU52-3-12, AU52-4-13, AU52-2-20 (plates 3c, 3d, 4a). This

configuration would be difficult to achieve by deposition.

Backscattered electron images reveal lenses of gold of rim composition within some gold particles, such as AU52-4-15 (plate 4b). These lenses may be explained by alteration along defects in the gold particle or by the compaction of a particle such as AU52-1-18 (plate 2d) after rimming.

Rimming by removal of Ag or other elements takes place in the environment of oxidation around an orebody or in intermediate collector where water composition and conditions are favourable.

As rimmed gold is found only in the Fraser river it is thought that rimming took place in an intermediate collector near the Fraser or was rimmed at the lode or at a more distant intermediate collector and transported to its present location. In any event no rimming site is presently known in the Bridge river area presumably because of glacial scouring. Because of the state of preservation of the rims both of the transported rimmed gold hypotheses are considered unlikely for all but the thickest rims, or the shortest distances of transport. Obvious candidates for rimming sites along the Fraser river are the outwash gravels (compare with the description of intermediate collectors given by Yushmanov (1972)) or an earlier Fraser river placer, such as described by Lay (1940).

The data in table 10 were collected using reflected light in order to provide more information about the rims and therefore, indirectly, information about the rim forming intermediate collecters. Although gold does not become rimmed only in intermediate collectors, this is generally the case

(Desborough, 1971; Yablakova, 1972; Zaritskii, 1980;). The limiting factor appears to be time. Thus the percentage of the total number of grains which are rimmed is interpreted to mean the percentage of grains from an intermediate collector. The percentage of rimmed grains in which more than 20 percent of the rim is preserved (as seen in polished section under the microscope) is interpreted to indicate the nearness to the intermediate collector. The further the rimmed grains have travelled from the intermediate collector the more the rim is disrupted, and the fewer the grains that will have well preserved rims. From the few backscattered electron images it appears that the number with well-preserved rims is slightly underestimated (Table 10). It also appears from the backscattered data that there are two types of rims, a very thin rim which cannot have travelled far without being disrupted and a thick rim. A placer deposit whose grains have been completely altered by the rimming process will show fineness of 970-1000 as Zaritskii (1980) has pointed out. The possibility of completely altered grains is important in discussions on the fineness of fossil placers, in particular Archean placers.

The percentage of the total number of grains that are more than 20 percent rimmed is interpreted to indicate the influence of a nearby intermediate collectors on supplying gold to the sample. The greater the number of grains more than 20 percent rimmed the greater the contribution from the nearby intermediate collector.

If a placer is formed by erosion of an intermediate collector only, all the grains (except for those grains whose rims are completely removed during transport or which are totally altered) would be rimmed. If a placer is formed from a primary (lode) source which has supplied an intermediate collector which is also now acting as a source, a much higher percentage of the grains would be unrimmed. If no rimmed grains are present, the placer was formed from a primary source or an intermediate collector in which no rimming has taken place. Grain shape may provide a criterion to destinguish between these two sources.

It is possible for gold to be mobilized and precipitated in the surficial environment remote from the original source of the gold. This is called new gold. The criteria presently used for identifying new gold is dependant on a combination of location, association and form of the gold and do not depend on composition, (although the gold is inferred to be pure). Although the role of new gold will not be considered further in this compositional study it may play a role in the origin of placer gold of unknown source.

The evidence (Warren, 1979) for calling the gold from AU48 new gold is ambiguous. Crystal faces do not necessarily indicate new gold (Petrovskaya, 1971) and although new gold is argued to be of a high fineness, the importance of Hg and Cu in new gold is unknown. In addition the presence of Bi, Te; Bi, Te, S; Pb, S (galena); and Cu, S, Sb minerals (identified using the Scanning Electron Microscope), and the presence of numerous vugs in the gold indicate that this gold has a shallow depth (epithermal) lode origin.

The often reported increase of fineness with transport distance (eg. Colin, 1946) is thought by this writer to reflect the change in fineness caused by rimming, as rim thickness increases with time (distance). The fluvial system studied is too complex to reflect this change in fineness with distance. The work of Koshman and Yugay (1972) provides a good overview of the possible causes of fineness variation in placers.

Hg Rims

Hg rims were seen most commonly in specimens from the Fraser river. They are easily seen as they give the grains a silvery appearance, but in polished section (carbon coated) they are less evident and are obviously very thin. In polished section they are dark blue, commonly with an embayed outer margin. Extremely Hg-rich grains are porous (spongy). Grains rimmed by Hg were generally not mounted or analysed.

DISCUSSION

The following features can be used to assign the samples to one of these areas.

Area 1-Cariboo: Low Cu and Hg; wide variation in fineness.

Area 2-Bridge River: High Hg and Cu populations; fineness somewhat restricted.

Area 3-Fraser River: Some high Cu, some high Hg; fineness has a continuous spread from 600-1000. High percentage of rimmed grains, high percentage of flattened grains.

GOLD GROUPINGS

It was hoped that in all samples it would be possible, on compositional grounds, to define populations which reflect the origin of the gold. The proportions of the populations would suggest the relative importance of each source, and the shape, size, rimming and inclusions would aid in the source interpretation and modification history.

In theory this should be done strictly on statistical grounds using a technique such as cluster analysis or probability plots but, because of the small number of data points for each sample and the variability in the data distribution between samples, it was concluded that these methods would not improve on the empirical observations. Preliminary tests, using probability plots, support this conclusion. In addition, attempts to seperate poorly defined or overlapping populations would probably not be meaningful because, at the expected level of confidence with which this could be done, it would not be possible to eliminate the geologically reasonable interpretation that these data, for this study, form a single population. In practice the separation has been done by inspection with consideration given to the statistical and geological limits applicable to each sample.

As mentioned before high Hg and Cu gold and their sources are observed to have a larger variation than populations where these values are low.

It is also expected that the closer the sample is to the original source of the gold the more restricted the distribution of those population members would become.

INTRODUCTION

In the following discussion of placer gold and its origins it is assumed that gold from Bridge River lodes has travelled down Bridge River to the Fraser River and that Cariboo lodes and placers have also contributed gold to placers in the Fraser River. It is also assumed that local sources (lodes, fossil placers, etc) have added to the complexity of placer composition at any point in the watershed.

It is difficult in downstream placers which have been modified by downstream additions, such as those of the lower Fraser River, to distinguish individual contributions from distant headwaters. Ideally, for studies like this one, placer gold samples from the lower parts of river systems should consist of many more grains of gold than those collected from their headwaters because contributions from many sources must be distinguished in downstream samples; such thorough sampling has not been possible in this study. In addition contributions from tributaries could be revealed by more closely spaced samples.

A distinction is made in this model between source gold and downstream gold. Source gold includes lode gold and placer gold occurring highest in the Fraser River drainage system. Downstream placers are assumed to be fed not only from the upstream sources but also from nearby lodes and gold derived from them by weathering and erosion.

In source sample plots it is commonly possible to determine concentrations or clusters (AU33, 34, 37, (Bralorne lodes), figures 14, 15, and 16), or well delimited zones of restricted fineness and large Hg spread (plumes) (AU14a, (Yalakom placer), figure 10). These concentrations or zones within a sample are referred to here as populations. In downstream placers, such populations are less well defined because of mixing and dilution. In some plots, such as AU01, (Lytton), (fineness vs Hg plot) the pattern appears to be nearly random, with, in this example, a single weak population near fineness 1000. In "downstream" placer samples one can test for the presence of a particular "source" gold, using the assumption, for example, that Cariboo gold population has a fineness of 715-960, Hg less than 0.05% and Cu up to 0.1% at high finenesses. On this assumption, AU01,(Lytton) (referring to the fineness-Hg plot, figure 5), could be said to have a population of 14 grains of Cariboo gold although these 14 grains do not form a concentrated restricted population. But, since Bralorne gold shows a population fineness of 720-900, with Hg values up to 4%, some Hg free grains assigned to the Cariboo population could equally well be assigned to a Bralorne population. Rimming provides another basis for discerning populations. About one third of the placer grains from Fraser River are rimmed with gold of high fineness so that for each sample two populations can be distinquished (see table 10).

Yalakom AU14a and Relay AU15a are examples of populations which have a large spread in Hg values over a restricted fineness spread. These populations, or plumes, could represent contributions from many different deposits but it is also possible that each plume shows the variability of composition of a single deposit, a single vein or even a part of vein. Examples of such variability within lodes are common: AU33 (Bralorne vein), 4 grains, shows a wide range of Hg values. Kusnetsov et al. (1982) report that "Native gold from some regions of the Ukraine contains Hg 1-6% .... Microprobe analysis showed that the Hg was rarely evenly distributed in the gold grains .... . The Hg and Au crystallized simultaneously". Novgoroda and Tsepin (1976) describe gold from the southern Urals which is a mixture of several varieties, including copper-rich (up to 46%), silver-rich (up to 49%) and mercury-rich (up to 9%), all of which may be intergrown in a single aggregate.

AREA 1 (CARIBOO)

Samples

Lode

A single specimen from the Cariboo Gold Quartz mine (AU17) has a fineness of 955.6 and neither Hg nor Cu, see table 11.

Placer

AU18 (19 grains), AU19 (43 grains), AU59 (20 grains) and AU60 (20 grains) have a fineness range from 710-960, absence of Hg, except in AU60 (3 grains), and presence of detectable Cu (up to 0.25%), mainly in gold of fineness greater than 900. The samples are small (figures 12, 13, 27, 28).

Interpretation

The samples are small and cannot be said to be representative of the area.

AREA 2 (BRIDGE RIVER)

Source Samples

Lode samples

Bralorne Area: Samples from the Bralorne mine incude:

1) A suite of vein samples:

AU21,AU22 and AU25 (single specimens), (Table 11). AU22 has an unusual composition of 1.08% Cu and a fineness of 966. The location of these samples within the Bridge River camp is not exactly known.

AU33, AU34 and AU37, 4,7, and 8 grain samples extracted from three different veins on the 500-level (figures 14, 15, 16). These three samples have distinct populations: AU33, fineness 780-820, up to 4% Hg; AU34, fineness 800-840, 0.2-0.3% Hg; and AU37, fineness 760-835, up to 0.1% Hg.

2) Bralorne mill findings (AU40) which, it is believed, represent late production from deep parts of the mine, agree closely in fineness (850) with 1961-72 production (figure 3). AU40, fineness 800-890, shows a "plume" of Hg values to 4.55% (figure 18).

Placer Samples

Relay Creek (AU15) ; (40 grains; figure 11) is characterized by two populations:

AU15a (10 grains): Fineness 900-1000, Cu 1.2-22.6% and Hg to 0.3%.

AU15b (24 grains): Hg plume, fineness 760-890 Hg to 2.08%, <D.L. (detection limit) Cu.

Yalakom River (AU14) ; (45 grains; figure 10)

AU14a (29 grains): Fineness 760-835 with an Hg plume rising from 0.4 to 6.5%, Cu up to 0.1%.

AU14b (11 grains): Fineness 860-910, up to 0.1% Hg and up to 0.1% Cu.

Stirrup Creek, (AU48) ; (54 grains; figure 22)

AU48a (47 grains): Fineness 910-960, up to about 1% Hg and about 0.3% Cu.

AU48b (5 grains): Fineness 880-920, 1.8-3% Hg, up to 0.1% Cu. (Possibly AU48a and b are part of the same population).

Downstream Placer Samples

Cadwallader (AU42) ;(70 grains; figure 19)

AU42a (48 grains): Fineness: 780-900, up to 0.3% Hg, <D.L. Cu.

AU42b A broad, weak concentration at fineness 720-810, up to 0.6% Hg.

Upper Bridge (AU45) ;(87 grains; figure 21)

AU45a (11 grains): Fineness 910-1000, Cu 2%-16.5%, Hg to 0.08%.

AU45b (14 grains): Fineness 760-870, up to 0.3% Hg, <D.L. Cu.

AU45c (7 grains): Fineness 830-885, up to 0.15% Cu, up to 0.15% Hg.

AU45d (11 grains): Fineness 928-970, up to 0.25% Cu, up to 1% Hg.

AU45e (68 grains): Hg plume, fineness 760-970, up to 4.89% Hg, high gold side of plume is relatively Cu-rich

Bridge-Yalakom Junction (AU13) ;(34 grains; figure 9)

AU13a (10 grains): Fineness 960-1000, Cu 2.24%-23.9%, Hg to 0.1%.

AU13b (4 grains): Fineness 890-940, up to 0.15% Hg, up to 0.15% Cu.

AU13c (7 grains): Fineness 780-870, 0.2-1.5% Hg, Cu up to 0.13%.

AU13d (15 grains): Fineness 760-860, Hg plume rising to 1.5% Hg, <D.L. Cu.

Lower Bridge (AU12) ;(69 grains; figure 8)

AU12a (11 grains): Fineness 910-1000, up to 31% Cu, up to 0.17% Hg

AU12b (21 grains): Fineness 780-840, up to 0.3% Hg, up to 0.13% Cu.

AU12c (25 grains): Hg plume, fineness 780-880, to 3% Hg, Cu <D.L..

AU12d (6 grains): Hg plume fineness 880-1000, with up to 0.4% Cu, up to 1.4% Hg.

Interpretation

Introduction

Three sources, Bridge River lodes and Relay Creek and Yalakom River placers, provide samples near the headwaters of the Bridge River watershed. The lodes from which the second and third sources were derived are unknown. The compositional populations are distinct for all three. Tentatively the conventional view is adopted that gold from these three (and other unknown) sources has been carried downstream to contribute to the four downstream placers that have been sampled.

Correlation of populations between placers is far from perfect. Some differences would probably be resolved by more extensive sampling. Some difficulties are due to the vagaries of sedimentation - nothing is known of the stratigraphy of the deposits. New concentrations appearing downstream may represent new sources. Where populations disappear downstream, they may have been diluted beyond recognition by other gold, or may be derived from recently uncovered veins whose gold has not yet reached the downstream site.

The concept of continuous travel of gold in the present downstream direction is overly simple. Although the importance of intermediate collectors, such as glacial drift and gravels, in the Bridge River drainage has not been assessed, there is no doubt that some of the difficulties of trying to correlate gold populations between placers are due to the contributions from intermediate collectors and the effect of the associated changes in dispersal patterns.

Topographic maps show that Bridge River between Marshall Creek and Gun Creek (some 25 km), meandered over a flat up to 2 km wide before it was flooded for a power project. It is doubtful that such a river would be capable of transporting gold, yet Bralorne gold is tentatively identified in this study, at Bridge-Yalakom Junction and Lower Bridge. Was this gold transported in a swift pre-glacial Bridge River whose high gradient has been lowered by faulting with recent activity near Carpenter dam (map 13-1973, Roddick and Hutchison, 1973), or was Bralorne gold carried north and east by ice, later to be washed out of drift and concentrated in lower Bridge River? Alternatively, the gold identified as coming from Bralorne could have come from a different source.

It is apparent that detecting and correlating gold populations from different placer deposits is subjective, and two observers may not agree.

Cadwallader (AU42)

AU42a seem to have been derived largely from the Bridge River lodes (AU21, 25, 33, 34 and 37) - agreeing in range of fineness, range of Hg values, and absence of Cu. Early production records show a fineness of about 740-820, possibly seen as AU42b. Two high Hg values (about fineness 840) in AU42 could represent AU33 (vein) and AU40 (mill findings).

Upper Bridge (AU45)

The high copper population (AU45a) could be derived from Relay Creek (AU15a). An alternative view may be taken that, as high-copper gold occurs typically in ultrabasic rocks, and as the Bridge River drainage area includes many areas of such rocks, it is quite possible that the high copper gold of the Bridge River placers is derived from many such sources and is not necessarily related to the Relay Creek source.

AU45b may have been supplied by the Relay (AU15b) or by the Bralorne lodes (the latter via Cadwallader (AU42a)). AU45c and AU45d cannot be related to any known am lodes or placers. AU45e may include Relay AU15b but includes a copper-rich zone on the high fineness side of the Hg plume (cf. AU12d). It is noteworthy that AU45e, has a broad Hg plume that is not visible in Cadwallader (AU70),possibly indicating a high Hg source similar to that supplying AU14a.

Bridge-Yalakom Junction (AU13)

AU13a is tentatively correlated with Relay AU15a but AU13a shows a narrower range of fineness than AU15a. AU13b may be related to Yalakom, AU14b, being similar, but not identical in fineness, Hg and Cu. AU13c may include some Bralorne and 2 grains (measurable Cu, low Hg) could be from AU45c (Upper Bridge). AU13d is a Hg "plume" that may be a mixture of Relay (AU15b) and Bralorne AU40 and AU33. That Bridge-Yalakom Junction contains a higher ratio of high copper values to low Cu values than does Relay (AU15) and a more restricted fineness range, weakens the argument for deriving the one from the other. The sample, however, contains only 34 grains. This might also explain the difference in plume fineness range between AU13d and AU45e.

Lower Bridge (AU12)

AU12a resembles Relay (AU15a), Bridge-Yalakom Junction (AU13a) and Upper Bridge AU45a. Seventeen grains (low Cu) of AU12b (total 24 grains) could be derived from Bralorne. They may form the base of a Hg plume AU12c. AU12d (Hg plume with measurable Cu values) resembles Upper Bridge AU45e. AU12 overall very closely resembles Upper Bridge (AU45), with AU45c removed. AU12b forms an unusually well defined population, not obvious at

Bridge-Yalakom Junction (AU13) but apparently present at Upper Bridge (AU45) and Cadwallader (AU42).

Gold for which no source can be suggested includes Upper Bridge AU45c, 45d and the pair AU45e and Lower Bridge AU12d, the subsidiary plume formed by high Hg, relatively high Cu values on the high fineness side of a Hg plume.

AREA 3 (FRASER RIVER)

Downstream Placer Samples

Upper Fraser (AU50) ;(94 grains; figure 23)

AU50a (39 grains): Rimmed, fineness 690-880, Hg to 0.9%, <D.L. Cu.

AU50b (55 grains): Unrimmed, fineness 700-1000, Hg to 4.86%, Cu to 0.1% above fineness 880, 4 grains showing moderate to high Cu.

AU50c (6 grains): Fineness 600-650, variable Hg, belong to a group found only along Fraser River (cf. AU51c), and includes both rimmed and unrimmed grains.

AU50d (3 grains): Fineness 960-1000, with Cu ranging up to 11.68%, no Hg.

Big Bar (AU51) ;(39 grains; figure 24)

AU51a (11 grains): Rimmed, fineness 720-920, Hg to 0.6%, may be two populations.

AU51b (28 grains): Unrimmed, fineness 750-990, Hg to 0.4%.

AU51c (3 grains): Fineness 610-640

AU51d (18 grains): Fineness 950-1000, <D.L. Cu, Hg to 0.5%. Rim compositions, (see Figure 26).

<u>Fountain Bar (AU52)</u> ;(144 grains; figure 25)

AU52a (53 grains): Rimmed, fineness 720-940, Hg plume-like, to 6.38% Hg, Cu mostly <D.L..

AU52b (27 grains): Unrimmed, fineness 770-1000, Hg to 1.5% and not forming a well-defined plume, Cu mostly below 0.1%.

AU52c (43 grains): Fineness 715-960, Hg <D.L., Cu detectable at high fineness. Would overlap with AU52a and AU52b.

AU52d (11 grains): Unrimmed, fineness about 600-670, Hg to 5.35%, Cu <D.L..

<u>Lillooet (AU11)</u> ;(62 grains; figure 7)

AU11a (6 grains): Fineness 980-1000, up to 24% Cu, <D.L. Hg.

AU11b (25 grains): Unrimmed (excluding high copper grains), fineness 700-900, Hg plume(?) to 2.36% Hg, Cu <D.L., (to 0.1% at high fineness values).

AU11c (18 grains): Rimmed, fineness 730-860, Hg to 0.9%, Cu <D.L..

AU11d (6 grains): Fineness about 600-670, variable Hg, <D.L. Cu.

<u>Lytton (AU01)</u> ;(73 grains; figure 5)

AU01a (22 grains): Rimmed, fineness 760-880, Hg to 1.63%, Cu mostly <D.L..

AU01b (41 grains): Unrimmed, fineness 800-1000, Hg to 1.3%, Cu to 0.9%.

AU01b' (17 grains): Unrimmed, fineness 850-1000, Cu 0.05-0.9%, Hg mostly <D.L., but ranging to 1.26%.

AU01c (6 grains): Fineness 600-650, range of Hg, <D.L. Cu.

<u>Yale (AU43)</u> ;(75 grains; figure 20) Some 5 grains show

rimming.

AU43a (39 grains): Fineness 770-900, Hg to 0.4%, Cu <D.L.

AU43a' (50 grains): Fineness 770-900, Hg "plume" to 2.42%, Cu <D.L..

AU43b (2 grains): Fineness 980-1000, Cu 6% and 22%, Hg <D.L..

AU43d (3 grains): Fineness less than 660, Hg to 5.8%.

Hope (AU75) ;(58 grains; figure 29)

AU75a (15 grains): Rimmed grains, fineness 720-890, Hg to 0.7%, Cu near <D.L..

AU75b (45 grains): Unrimmed, fineness 695-1000, Hg to 1.2%, Cu <D.L., rising above fineness 850 to 0.18%.

AU75c (2 grains): Fineness 660

Interpretation

In general, concentrations of values on fineness-Hg plots are fewer and the range of fineness larger in Fraser River samples than in Bridge River samples. This dispersion is probably due to mixing of gold from many different sources.

All Fraser River samples include rimmed and unrimmed gold in various proportions (see table 10). On the average about 37% of the grains are rimmed. In the following discussion it is assumed that rims formed on detrital grains of gold in surficial deposits (intermediate collectors such as soils and gravels) by preferential leaching of silver by groundwater. This process is thought to be slow. Eventually the collector was eroded, and the now rimmed gold mobilized, finally coming to rest in the present

Fraser River placers, mixed with unrimmed, probably recently eroded gold.

Where was the intermediate collector in which the rims formed? One possibility is Tertiary or older conglomerates such as those in Fraser River near Quesnel (Lay, 1940), upstream from all Fraser River samples. If it were assumed that all of the rimmed gold comes from Quesnel, the original source unknown, the proportion of rimmed grains should decrease and that of badly worn rims should increase regularly downstream however both seem to change erratically, suggesting the existence of several intermediate collectors.

A second possible intermediate collector is pre-glacial gravel near Cariboo lodes. It is possible that after rimming had taken place, rimmed gold found its way down the Cariboo and Quesnel rivers to Fraser River placers. This hypothesis could account for some 22% of the rimmed gold on the assumption that Cariboo samples (AU18, 19, 59 and 60) represent the source. For the same reason as that given for the first possible intermediate collector this percentage must be considered a maximum. Note that when reference is made to the composition of rimmed gold, the reference is to the core of the grain, not to the rim.

A third possibility is that the gold became rimmed while in pre-glacial regoliths near the Bridge River lodes. Bridge River gold could have been transported to sites on upper Fraser River (eg. Upper Fraser) in a Tertiary drainage system (cf. Lay, 1940) that drained northerly, or by glaciation, the direction of ice travel being northeasterly. The distance that this gold would have had to travel suggests that the rims would have been entirely removed, making this suggestion less attractive, but it should be remembered that no data are available on rim growth or removal.

The problem with all these possible rim forming intermediate collectors is that they require that the rimmed gold be transported long distances to its present location with little disruption to the rim. It seems more reasonable to assume that gold was transported prior to the formation of the rim and that the rim forming intermediate collector was close to the present placer location. The observed variation of rim percentage and rim content (Table 10) supports this idea. Much of the glacial outwash and other suitable sedimentary rocks along the Fraser River can therefore be considered as possible rim forming intermediate collectors.

Although unrimmed gold has a higher average fineness than rimmed gold in all samples, there is considerable overlap in composition so that rimmed and unrimmed gold of the same composition occurs in the same sample. These observations suggest that certain lodes may have supplied gold to placers over a long period of time. Possibly the lodes were vertically zoned with respect to fineness of gold, the difference in fineness being related to shallow derivation of old gold but deeper derivation of young gold.

The total unrimmed population shows a concentration of compositions with fineness greater than 900 which is absent in the rimmed population - a range that includes most of the Cariboo gold (AU18, 19, 59 and 60). In addition, most of this concentration occurs in the unrimmed gold from Fraser River upstream from the mouth of the Bridge River. The reader is referred to the section on rimming and table 10 for further information on the significance of rim forming sources in the formation of the Fraser River placer samples.

The proportion of gold that could be assigned a Cariboo origin diminishes slightly from the Upper Fraser sample site to Fountain Bar, is reduced markedly at Lillooet (due to dilution by Bridge River gold?), maintains this reduced level to Yale, and unexpectedly rises significantly at Hope.

All Fraser River samples contain gold of fineness near 600, widely ranging Hg values, rimmed and unrimmed, and these scattered grains may be from a single source dispersed downstream but seems more likely to represent different sources of the same type because the number of grains remains constant over a long distance.

Because of the wide range of compositions of Fraser River gold, rimmed and unrimmed, the scarcity of concentrations in fineness-Hg-Cu plots, and the lack of information about possible sources, it is only possible to make a few generalizations about the origins of the gold.

In the Upper Fraser sample, AU50d resembles high Cu gold from Relay Creek. None of the Cu-rich gold in the Fraser River is rimmed suggesting a local origin.

The sample (an unusually large one) from Fountain Bar (AU52), shows wide dispersion and a pronounced Hg plume rising to 6.38%. About 30% of the gold (AU52c), including rimmed and unrimmed grains, could be of Cariboo origin. The high Hg gold is of unknown provenance, but conceivably unrimmed grains could be either of Bridge River origin, carried by ice to the Upper Fraser and concentrated in outwash deposits (non rim forming) which are being reworked by the Fraser River, or from a source resembling those feeding the Bridge River but located along the Fraser River. The source of the rimmed, high Hg gold is unknown.

The most striking feature of the Lillooet sample is the sudden appearance of AU11a, a high Cu gold that is found in all samples between Relay Creek (AU15) and Lillooet and the drop in the number of rimmed grains. The source could be Relay Creek (AU15). An alternative view is that high copper gold is being provided by gold lodes associated with ultrabasic rocks exposed along Bridge and Yalakom rivers. The proportion of possible Bralorne gold (AU11b) is high but is reduced if the part with <D.L. Hg is assigned a Cariboo origin. The proportion of rimmed gold is low (29% as compared to Fountain Bar with 58%) (Table 10) but increases downstream.

The sample from Lytton (AU42) shows well the difference in fineness between rimmed and unrimmed gold. AU1b', with significant copper, appears to represent a new source.

The Yale (AU43) sample contains few rimmed grains. AU43a and AU43a' (they overlap) resembles Bralorne and Cadwallader (AU42). AU43b, high Cu, resembles AU11a (Relay).

In the small Hope (AU75) sample, showing wide dispersion, rimmed grains make up 25%.

SUMMARY OF THE HISTORY OF PLACER TRANSPORT

Bralorne lodes have apparently fed the placer at the mouth of Cadwallader Creek and have probably contributed to placers downstream to Lillooet and perhaps beyond. High copper gold of the Relay Creek type appears at every sample site between Bridge River and Lillooet but is absent at Fountain and not recognized in the lower Fraser River, except possibly at Yale where there are potential ultrabasic sources.

Rimmed grains have been found only in Fraser River, occurring at every placer site, and are interpreted to be reworked gold which has been leached over a long period of time before entering the modern Fraser River sediments. Much Fraser River placer gold, especially unrimmed gold, has compositions that suggest derivation from the Cariboo but the ultimate origin of rimmed gold, gold with notable mercury, and gold of low fineness, remains unknown.

SOURCES: Speculations about the Lodes

Although the lodes that supplied most of the placer are unknown it is possible to make some deductions about the character of the lodes based on possible lode sources, previous work and the composition-fineness features of the source placer. The core analyses are considered to represent the primary composition of the gold grains.

As mentioned earlier the study area can be divided into three regions on the basis of the geochemistry of the placer gold. This and the river drainage forms the basis of dividing the area into two gold metallogenic provinces.

AREA 1: CARIBOO

This area produces gold with low Hg and low Cu. Because of the small sample size no conclusion can be drawn about the lode sources.

AREA 2: BRIDGE RIVER

The Bridge River area produces gold with high Hg and high Cu percentages. The lodes are tentatively divided into two types, the Bralorne and the high Hg-high Cu type.

Bralorne Type

Mineralization in the area upstream of AU42 (Cairnes, 1937) consists of gold-quartz veins associated with faulted plutonic and ultrabasic rocks. These veins probably make up the source area for AU42.

The most productive vein system was that of the Bralorne-

Pioneer mine. Samples from this mine are taken to be examples of the Bralorne camp and support the following conclusions:

1) The gold from different veins shows a wider variation in composition (especially fineness) than gold from a single vein. Gold from a single vein may have a restricted composition.

2) Each vein appears to have its own 'fingerprint' of fineness and Hg content.

3) As the vein samples were taken at one location on the vein no direct information on the variations along strike and with depth was obtained but a mill sample provides useful data.

AU40 is a sample from the crushing room floor of the 1961-1972 Bralorne cyanide only mill. During this period of operation a restricted number of veins were mined over a considerable depth. Individual vein populations can be distinguished in the AU40 diagram. The fineness range is small, indicating that the change in fineness with depth is probably small. This conclusion is supported by the bullion fineness-depth plot for the mine (figure 3). Although the data are not very reliable (Sharwood, 1911) because of poor records, changes in recovery techniques and mixing of gold from different veins, it nevertheless suggests that the fineness ranged very little with depth for gold mined during the period 1961-1972. The significance of the small increase with depth is unknown. The average fineness for AU40 is 851.16, which is similar to the bullion data from figure 3.

The generally restricted spread of the Hg values in the veins is intriguing. It has been noted above that the Hg values can vary quite widely from particle to particle and within a particle.

AU38 is unreliable because contamination from a placer is suspected. The plot for the Pioneer bullion data is also unreliable for this purpose because the history of mining and milling is more confused than that of Bralorne.

The exact location of AU21, 22 and 25 are unknown. They confirm the observation that the vein compositions range widely (Table 11). AU22 is unusual in composition.

In summary, AU42 is made up of gold from quartz veins, each of which appears to have its own characteristic fingerprint. Even though these veins have a close spatial association they have different fingerprints, implying a unique history of ore deposition for each. The collective array of compositions gives the AU42 distribution.

The similarity of AU43 to AU42 is striking. Veins a few kilometers to the north of Yale are a possible source. The lack of rimmed gold and and the geological setting support this conclusion but the flatness of the gold argues against it.

High Hg - High Cu Type

It has been observed that Cu-rich gold has a high fineness, usually >900.

Data from a number of deposits containing Hg or high Cu are listed below.

1) Tulameen (British Columbia): Cu-rich gold (to 30%) is found in the Tulameen River and is inferred to have been eroded from lodes in nearby ultrabasic rocks (Raicevic and Cabri,

1976).

2) Karabash deposit (Urals): Novgorodova and Tsepin (1976) classified this deposit as a pyrite deposit with chalcopyrite. The deposits are located in one of the most tectonically altered zones of the Urals. The ore bodies were deposited in contact zones between rocks of different mechanical properties during the middle part of the upper Devonian tectonic-magmatic event. Mineralization occurred several times. Rakcheyev (1977) notes that the host rock is a "chlorite-pyroxene-garnet" rock. Samples show a wide range of intragrain variation of gold composition. Cu is high and ranges widely and a Cu free amalgam is associated with it.

3) Zolotaya Gora (southern Urals)(may be the same as the above): The Zolotaya Gora deposits are hosted by "metasomatic chlorite-garnet-pyroxene after ultrabasic rocks" (Pokrovskii et al., 1974). Two discrete phases, Au-Cu and Au-Ag-Hg, were detected (Pokrovskii et al., 1979).

4) Kazakhstan deposit: Kazakhstan deposits are pyrite-Cu and pyrite-barite-polymetallic deposits with Au generally finely disseminated in sulphides. Supergene Au is present. (Nesterenko et al., 1983). Au from a Au-Sb deposit contains 4-8%Hg (Naz'mova et al., 1979).

5) Donetsk Basin (Ukraine): High Cu gold is reported by Kuznetsov et al. (1977) from the Donetsk Basin. Kuznetsov (1982) reports Hg-rich gold in pyrite-arsenopyrite quartz, ankerite veins from Uleraine (sic) in the Ukraine. The Hg is unevenly distributed in the gold.

6) San Antonio mine (Manitoba): The San Antonio mine is a

gold-quartz vein intruding a diabase sill (Boyle, 1979). Ferguson (1950) concluded from indirect evidence that the gold is Cu-rich.

7) Beni-Bousera (Morocco): Oen and Kieft (1974) report a high-Cu gold associated with Ni-rich minerals from the ultrabasic hosted ore bodies.

8) Bushveld Igneous Complex (South Africa): Cu-rich gold occurs in a hortonolite-dunite pipe in the Bushveld Igneous Complex (Ramdohr, 1969).

9) Barberton (South Africa): von Gehlen (1983) reports Hg from gold occurring in rocks of the Barberton series. He also reports Hg-rich gold from the Witwatersrand deposit.

10) New Guinea: Stumpfl and Clark (1964) and Stumpfl (1964) report Cu-rich placer gold associated with placer platinoids in rivers with headwaters in an ultrabasic complex.

11) Goodnews Bay (Alaska): Desborough (1970) reports Cu up to 2% in gold found in placers with platinum minerals.

In summary the association of Cu-gold with basic-ultrabasic rocks seems to be common. Hg is commonly but not invariably associated with the Cu-rich gold and vica versa. Although no Pt was detected in the initial 15-element study, the Pt, Cu-rich gold association is noted.

In the study area the association between Cu and Hg-rich gold in the Bridge River area is strong, in particular for sample AU15. The AU48, AU15, and AU14 source placers are thought to represent lode sources which for the most part come from Cu and Hg-rich type of lodes. It is possible that the high Cu and high Hg populations in AU15 may come from a single source rather than two separate sources.

It seems to be a safe deduction that prospecting for the lode sources of Cu-rich placer gold should concentrate on areas with abundant ultrabasic rocks. Prospecting for the Hg rich types should be concentrated along major faults or in nearby intrusives. If Hg and Cu are both present then a combination of the above is indicated.

The structural controls are probably the faults (thrusts and shears), extending at least to the upper mantle, that are commonly associated with the ultrabasic rocks. This is supported by the general concensus that Hg is associated with deep faults (Jonasson and Boyle, 1972) and is derived from the mantle, and that deep faults are common in the Bralorne area (Potter, 1983). The basic features of Keays (1984) model to explain Archean lode gold deposits appear to be applicable to the Bralorne area. In particular the partitioning of gold into sulphide segregations in ultrabasic rocks and the subsequent remobilization of the gold during serpentinization, after transport to higher levels by faulting (obduction), could explain both the gold compositions observed and the rock association inferred. The element associations demonstrated in this thesis provide a tool for discovering deposits of this type.

In addition to the above the following are noted:

1) It is possible that there is a high-Cu source associated with the ultrabasics of the lower Bridge river. The Cu populations are not adequately explained by derivation from Relay (AU15).

2) The presence of the Cu-rich gold in the Tulameen river

area (Raicevic and Cabri, 1976) indicates that this type of deposit is not limited to the Bridge river area.

3) There may be a connection between the Bralorne type and the high Hg-high Cu type. The Bralorne type has the same association with a major fault and ultrabasic rocks as that expected for the high-Cu types but the gold composition and fineness distribution is different. The albitite at Bralorne may provide a key to this connection as this rock type is mentioned by Keays (1984) as a way of identifying certain gold deposit types in the Archean. However it should be remembered that 'same rock names' need not always mean 'same rocks'.

4) Ultrabasic rocks are located along lineations and faults between Yale, Tulameen and the Bridge River areas, suggesting that this whole area could be considered both a high Hg-high Cu, and Bralorne type metallogenic province. There is also the possibility of an extension of this NW-SE trending belt along the eastern margin of the Coast Plutonic Complex both north and south.

CONCLUSIONS

1) The microprobe is the best tool for the study of gold particles because each phase making up the gold grain can be analysed separately and bulk analysis errors avoided.

2) Using the Ag, Cu, and Hg composition of gold it is possible to characterise lode gold deposits and to recognise gold from these lodes in nearby placers. The degree of flattening of placer grains reflects the degree of working and indirectly distance from and time since release from the lode source.

3) Although the transport of gold downstream has played a major role in the dispersion of gold in this area, a simple transport model cannot account for all the populations of the placers found on that river. The role of undiscovered sources, intermediate collectors, alternate transport mechanisms, changes in drainage and alteration of the gold must all be considered in attempts to understand gold dispersion and the origins of present day placer gold.

4) The rimmed gold found in placers in the Fraser River formed in intermediate collectors by leaching of Ag. Intermediate collector sources are probably most important along the Fraser River. The role of intermediate collectors in the other areas is unknown.

5) Two metallogenic provinces can be identified: The Bridge River with high Cu and high Hg, and the Cariboo with low Cu and low Hg.

6) Within the Bridge River area two types of lode are postulated: The Bralorne type, and the high Hg-high Cu type.

High Cu-high Hg lodes seem to be related to ultrabasic rocks. High Hg gold (eg. Bralorne Type lode) seems to be associated with major faults. The association of both types of lode with ultrabasic rocks and major faults suggests that there is a genetic relationship between them.

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TABLE 1: Sample Details

Sample Number	Sample Name	No. Of Analyses	Location	Source & Comment
Au 01	Lytton	73	W. Side of Fraser just above Lytton ferry	Panned
Au 11	Lilloett	62	Just below old bridge into Lilloett On Horsebeef Bar	Sluiced. Collected in Nov. & Feb.
Au 12	Lower Bridge	70	Half-way between Moon & Applespring Ck. On Bridge River	Donated. From a 10' bench
Au 13	Bridge Yalakom Junction	34	On S. Side of Bridge R. directly opposite Yalakom R. mouth	Donated. From a 50' bench
Au 14	Yalakom	45	On Yalakom R. Above Yalakom Ck.	Donated.
Au 15	Relay	40	On Relay Ck. Just above Paradise Ck.	Donated.
Au 17	Cariboo Gold Qtz. Mine	1	Details unknown.	UBC Geol. Museum. No. 1153
Au 18	Bassford Ck.	19	Bassford Ck. At Peters Ck.	Donated.
Au 19	Lightening	43	Wingdam/Stanley on Lightening Ck.	Donated.
Au 21	Coronation	1	Coronation Group, Bralorne Details unknown.	UBC Geol. Mus. No. S-74-1113
Au 22	Bralorne	1	Bralorne Mine, Details unknown.	UBC Geol. Mus. No. S-74-1131
Au 25	Pioneer	1	Pioneer Mine, Details unknown.	UBC Geol. Mus. No. S-74-1204

Table 1, continued

Sample Number	Sample Name	No. Of Analyses	Location	Source & Comment
Au 33	King Curve	4	King Curve vein 1/2m quartz vein on 800' level Bralorne Mine	Large specimen.
Au 34	Alhambra	7	Alhambra vein, 2150' in on 800' level Bralorne Mine	Large specimen.
Au 37	851 vein	8	851 vein 1m quartz vein on 800' level Bralorne Mine	Large specimen.
Au 38	Pioneer Mill	21	Old Pioneer Mine Mill below lower crusher near settling tank	Indications of Placer having been through system
Au 40	Bralorne Mill	41	Drainage Channel below crushers	Mill worked 1961-71
Au 42	Cadwallader	76	Will Crawford's claim On N. Fork of Hurley R., above Haylemore	Donated.
Au 43	Yale	75	West end of town, N. Shore	Purchased.
Au 45	Upper Bridge	87	1-1/2 km up Bridge R. from Moha	Purchased.
Au 48	Stirrup	55	Stirrup Ck. From half-mile stretch at 5600'	Donated.
Au 50	Upper Fraser	94	1/2 km above Williams Lk.-Alexis Ck. Rd. Bridge On the Fraser R.	Sluiced.
Au 51	Big Bar	39	N. End of Bar, south Of ferry & farmhouse On Fraser R.	Sluiced.

Table 1, continued

Sample Number	Sample Name	No. Of Analyses	Location	Source & Comment
Au 52	Fountain	145	Water level sample at Fountain Bar on Fraser R.	Purchased.
Au 52R	Fountain Rim	18	As above	As above.
Au 59	Nelson	20	Nelson Ck., Cariboo, Details unknown	Donated.
Au 60	Sovereign	20	Sovereign , Cariboo, Details unknown	Donated.
Au 75	Hope	58	On west shore, Fraser, Opposite N. Point of Hope Is. Approx. 2km, below bridge	Sluiced.

TABLE 2: Element Lines and Analytical Crystals

Element and Line	Crystal	Background Stepoff (On unknowns)
$AuM\alpha_1$	PET	600
*$HgM\beta$	PET	150
$AgL\alpha_1$	PET	600
$CuK\alpha_{1,2}$	LIF	300

* This line gave best interference free counts at low levels.

TABLE 3: Standards

Element	Composition	Source	Background Stepoff (On Standards)
Au	100%	NBS Standard reference material 481	600
Hg	HgTe	Cominco Electronics material	400
Ag	100%	NBS Standard reference material 481	600
Cu	100%	Metallurgy U.B.C. 481	500

TABLE 4: Detection Limits at 99% confidence for 1 analysis

	Wt%	Hg[1]	Cu[1]	Hg[2]	Cu[2]
Low Density (Low Fineness	600)	.059	.042	.063	.048
High Density (High Fineness	990)	.060	.045	.062	.052

<u>Detection Limit Formula</u>

[1]Det Lim = $\dfrac{3 * \text{Background Unknown} * \text{Wt\% STD}}{\text{Counts/sec STD}}$

[2]Det Lim = $\dfrac{2.326\sqrt{2} \times \text{Background (Cps)}}{\text{CPS per Wt\%, STD} * \sqrt{\text{Counting Time, unknown(=20)}}}$

From Le Maitre R. Numerical Petrology, Elsevier, 1982.

TABLE 5: Core-Core Duplicates

	First Analysis						Second Analysis					
Sample No.	Au	Hg	Ag	Cu	Total	Fineness	Au	Hg	Ag	Cu	Total	Fineness
Au 50-4-1	100.11	0	.34	.02	100.47	996.6	97.63	.23	1.23	.1	99.19	987.6
Au 20-1-1	83.63	.02	16.69	0	100.32	833.79	81.78	0	16.99	.02	98.79	827.98
Au 20-1-2	82.58	0	18.52	.01	101.12	816.81	81.12	.01	18.29	.04	99.45	816.0
Au 20-1-5	85.92	.01	15.59	.06	101.58	846.41	82.37	.03	15.67	.04	98.11	840.17
Au 20-1-18	80.85	0	20.35	.02	101.22	798.91	77.14	.02	22.55	.03	99.74	773.79
							78.69	0	20.5	0	99.19	793.32
Au 43-3-5	35.51	2.84	62.06	0	100.41	363.96	35.47	2.09	61.49	0	99.05	365.82
AU 48-1-24	96.27	0	5.6	.1	99.98	943.93	94.76	.02	5.67	.11	100.56	943.54
							94.5	.04	5.33	.09	99.96	946.60
Au 43-3-22	88.76	.03	11.42	.01	100.22	886.00	88.45	.05	11.54	.05	100.1	884.59
Au 42-2-20	85.04	.09	13.94	.08	99.07	859.16	87.71	0	13.12	.02	100.84	869.8

Table 5, continued

Sample No.	First Analysis Au	Hg	Ag	Cu	Total	Fineness	Second Analysis Au	Hg	Ag	Cu	Total	Fineness
Au 42-1-5	85.25	.15	15.27	.01	100.68	848.09	85.23	.17	15.47	0	100.88	846.37
							84.2	.28	15.85	0	100.33	841.57
							84.78	.13	15.55	0	100.45	845.01
Au 42-1-8	81.71	.09	18.56	.01	100.37	814.9	82.67	0	9 17.49	.03	100.18	825.37
Au 45-1-5	89.19	2.99	7.11	.06	99.35	926.16	89.28	2.53	7.22	.07	99.09	925.18
Au 45-1-8	84.7	.02	15.13	.04	99.88	848.44	83.48	.05	15.09	.07	98.69	846.91
Au 45-1-9	79.01	.23	20.18	.06	99.49	796.55	78.8	.2	20.43	.02	99.46	794.12
Au 45-1-10	88.06	.31	10.84	.06	99.28	890.39	87.51	.24	10.8	.05	98.6	890.14
Au 45-4-2	88.6	.91	9.99	.02	99.53	898.67	88.2	.85	10.23	.04	99.32	896.06
Au 45-4-22	91.35	.65	6.58	.08	98.66	932.81	91.46	.61	6.72	.06	98.85	931.55
Au 45-1-4	77.37	.12	23.22	.02	100.74	769.16	79.7	.12	23.23	.01	100.07	767.53
Au 43-2-11	90.0	.35	9.28	.07	99.69	906.53	90.31	.15	9.18	.06	99.69	907.73

Table 5, continued

	First Analysis						Second Analysis					
Sample No.	Au	Hg	Ag	Cu	Total	Fineness	Au	Hg	Ag	Cu	Total	Fineness
Au 52-4-7	81.49	.26	17.4	.02	99.17	824.04	81.77	.33	17.38	.04	99.51	824.71
Au 52-4-8	89.67	.04	9.87	.04	99.62	900.84	88.47	.12	9.81	.06	98.46	900.18
Au 52-4-9	92.21	0	7.76	.07	100.04	922.37	92.6	0	7.81	.07	100.49	922.22
Au 52-4-10	95.37	0	4.55	.09	100	954.46	94.67	0	4.61	.03	99.31	953.56
Au 75-3-12	94.8	0	5.62	.15	100.58	944.04	95.58	0	4.43	.15	100.15	955.70
Au 33-1-1	80.59	.06	19.27	0	99.94	807.03	80.75	.08	19.45	0	100.28	85.88

TABLE 6: Core-Rim Duplicates

	Core						Rim					
Sample No.	Au	Hg	Ag	Cu	Total	Fineness	Au	Hg	Ag	Cu	Total	Fineness
Au 48-1-25	92.22	.11	7.36	.09	99.77	926.09	90.99	.96	7.21	.06	99.22	926.57
							91.51	.01	7.37	.14	99.03	925.46
Au 48-1-24	94.27	0	5.6	.1	99.98	943.92	92.94	.24	5.36	.09	98.63	945.47
Au 43-3-26	89.36	.15	10.95	.05	100.51	890.84	88.81	.11	10.63	.03	99.59	893.10
Au 42-1-5	85.25	.15	15.27	.01	100.68	848.09	84.4	.32	14.34	0	99.05	854.77
Au 42-1-4	76.48	.07	24.21	.04	100.8	759.55	76.74	.04	23.31	.01	100.11	767.01
Au 42-1-3	77.95	.22	22.39	0	100.55	776.86	77.23	.26	22.41	.01	99.99	775.09
Au 42-1-8	81.71	.09	18.56	.01	100.37	814.9	84.19	.14	15.46	.01	99.79	844.85
Au 01-4-28	81.41	.07	19.83	.05	101.43	804.12	80.92	.07	19.74	.05	100.83	803.89
Au 12-2-8	70.71	.01	.26	31.07	102.05	996.33	68.85	.04	.27	30.91	100.07	996.09

Table 6, continued

	Core						Rim					
Sample No.	Au	Hg	Ag	Cu	Total	Fineness	Au	Hg	Ag	Cu	Total	Fineness
Au 12-2-7	83.92	1.55	14.19	.03	99.69	855.36	83.89	1.2	14.31	.04	99.45	854.27
Au 12-2-6	84.7	.03	16.31	.06	101.09	838.53	84.7	.11	16.29	.07	101.17	838.69
Au 12-2-5	85.56	2.45	12.23	.07	100.31	874.93	84.31	2.52	12.5	.06	99.4	870.88
Au 45-1-25	87.24	.14	12.51	.15	100.05	874.58	86.76	.19	12.64	.06	99.65	872.83
Au 50-2-21	84.02	.08	16.01	0	100.12	839.94	83.98	.08	16.06	0	100.12	839.46
Au 50-2-24	82.98	.25	16.89	.04	100.14	831.04	83.27	.28	16.43	.02	100	835.20
Au 43-1-19	72.93	.35	26.59	.01	99.88	732.81	73.14	.36	26.76	0	100.27	732.13
Au 43-1-17	79.69	1.18	18.08	.02	98.97	815.07	78.83	1.17	17.7	.01	97.21	815.68
Au 43-1-12	88.11	1.62	9.81	0	99.53	899.81	88.62	1.61	9.9	.02	100.15	899.5
Au 43-1-5	87.77	.03	11.66	.02	99.48	882.73	86.94	.01	11.6	.03	98.58	882.28
Au 43-3-5	35.51	2.84	62.06	0	100.41	363.94	35.34	4.08	61.76	0	101.17	363.95

TABLE 7: Fineness Comparison

Sample Name	*Bulletin 28 Name	Average Fineness This Work	Bulletin 28 Fineness
Au 48	Watson Bar	930	892
Au 43	Siwash	843	868
Au 12	Marshall	863	846
Au 11	Fraser River	826	855

* Holland, S.S., B.C.D.M. Bull. No. 28, 1950.

TABLE 8: Rim-Core Compositions

	Core						Rim					
Sample No.	Au	Hg	Ag	Cu	Total	Fineness	Au	Hg	Ag	Cu	Total	Fineness
Au 52-3-6(B)	80.89	.18	19.89	.03	100.99	802.63	97.35	.01	2.82	.02	100.21	971.85
Au 52-3-11(B)	77.2	.25	23.47	.04	100.96	766.86	98.05	.14	.85	.02	99.07	991.40
Au 52-3-12(B)	90.62	.05	9.81	.03	100.52	902.32	98.64	.01	.64	0	99.29	993.55
Au 52-2-3(B)	82.08	.08	18.27	0	100.44	817.93	97.5	.04	1.18	.01	98.72	988.04
Au 52-2-4(B)	75.41	.56	24.08	.01	100.05	757.96	98.69	.01	1.39	.02	100.1	986.11
Au 52-2-9(B)	80.41	.5	18.37	.02	99.3	814.03	99.13	0	.85	.02	100	991.49
Au 52-2-13(B)	80.53	.12	18.54	.01	99.2	812.86	96.9	0	2.88	0	99.78	971.13
Au 52-2-23(R)	80.75	.94	17.97	.02	99.67	817.97	98.92	0	.77	0	99.69	992.27
Au 52-1-7B	88.46	.02	10.47	.04	98.99	894.16	98.16	0	.79	.04	98.95	992.01
Au 52-1-17B	88.74	0	12.3	.08	101.13	878.26	98.24	.01	1.29	0	99.55	987.04
Au 52-1-19B	82.3	.07	16.89	0	99.26	829.72	97.93	0	1.93	.04	99.9	980.67

Table 8, continued

	Core						Rim					
Sample No.	Au	Hg	Ag	Cu	Total	Fineness	Au	Hg	Ag	Cu	Total	Fineness
Au 52-1-22B	90.67	.06	8.35	.08	99.16	915.67	98.13	.03	1.34	0	99.5	986.53
Au 52-5-8B	87.16	1.27	10.92	.01	99.37	888.66	94.3	.54	5.48	.03	100.35	945.08
Au 52-5-11B*	79.58	.51	20.27	0	100.37	796.99	55.91	37.	.88	.02	93.81	984.50
Au 52-5-15B	85.48	.12	14.67	.02	100.32	853.34	97.33	.03	2.56	.02	99.93	974.37
Au 52-6-6B	76.64	.14	22.66	.02	99.45	771.80	99.27	0	1.1	0	100.38	989.04
Au 52-4-13B	84.6	.97	13.56	.03	99.17	861.85	98.09	0	1.19	.04	99.31	988.01
Au 52-4-26	86.25	.01	12.73	.03	99.03	871.39	95.44	0	3.57	.02	99.03	963.94
Au 01-4-28	80.92	.07	19.74	.05	100.83	803.89	100.13	.02	.63	.09	100.89	993.75
Au 02-2-24	90.89	.03	9.15	.08	100.14	908.53	100.37	.02	.54	.04	100.97	994.64

* Hg Rim

TABLE 9: Hg Contamination Test

Sample Number	O	Au	Hg	Ag	Cu	Total	Fineness
	Original	81.01	2.36	16.45	0	99.82	831.21
Au 11-2-7	Repolish	80.38	1.83	15.91	.03	98.15	834.77
	-10 Removed *						
	Original						
Au 11-2-8	Repolish	86.17	1.54	10.6	0	98.31	890.46
	-10 Removed	87.44	1.19	10.78	.09	99.49	890.24
	Original	78.79	10.52	8	.03	97.34	907.82
Au 11-2-10	Repolish	78.97	9.28	6	.02	94.27	929.38
	-10 Removed						
	Original	72.73	.2	26.96	.03	99.92	729.56
Au 11-2-11	Repolish	72.47	.11	27.57	0	100.15	724.41
	-10 Removed	74.21	.15	25.05	0	99.41	747.63
	Original	79.45	.79	20.71	0	100.94	793.23
Au 11-2-12	Repolished	76.88	.79	20.8	0	98.47	787.06
	-10 Removed						

* After Au 11-2-10 has been removed.

TABLE 10: Rim Distribution

Sample Number	Au50	Au51	Au52	Au11	Au01	Au43	Au75
% of Total Number of Particles Which are Rimmed	40.4	37.5	58.0	28.8	41.7	9.9	33.3
% of Rimmed Particles which are > 20% Rimmed	34.2	72.2	58.6	21.0	74.3	20	42.3
% of Total Number of Particles Which are > 20% Rimmed	13.8	27.1	34.0	6.1	30.9	2.0	14.1
Total Number of Particles in Mount	94	48	150	66	84	101	78
Rimmed Particles	38	18	87	19	35	10	26
> 20% Rimmed Particles	13	13	51	4	26	2	11

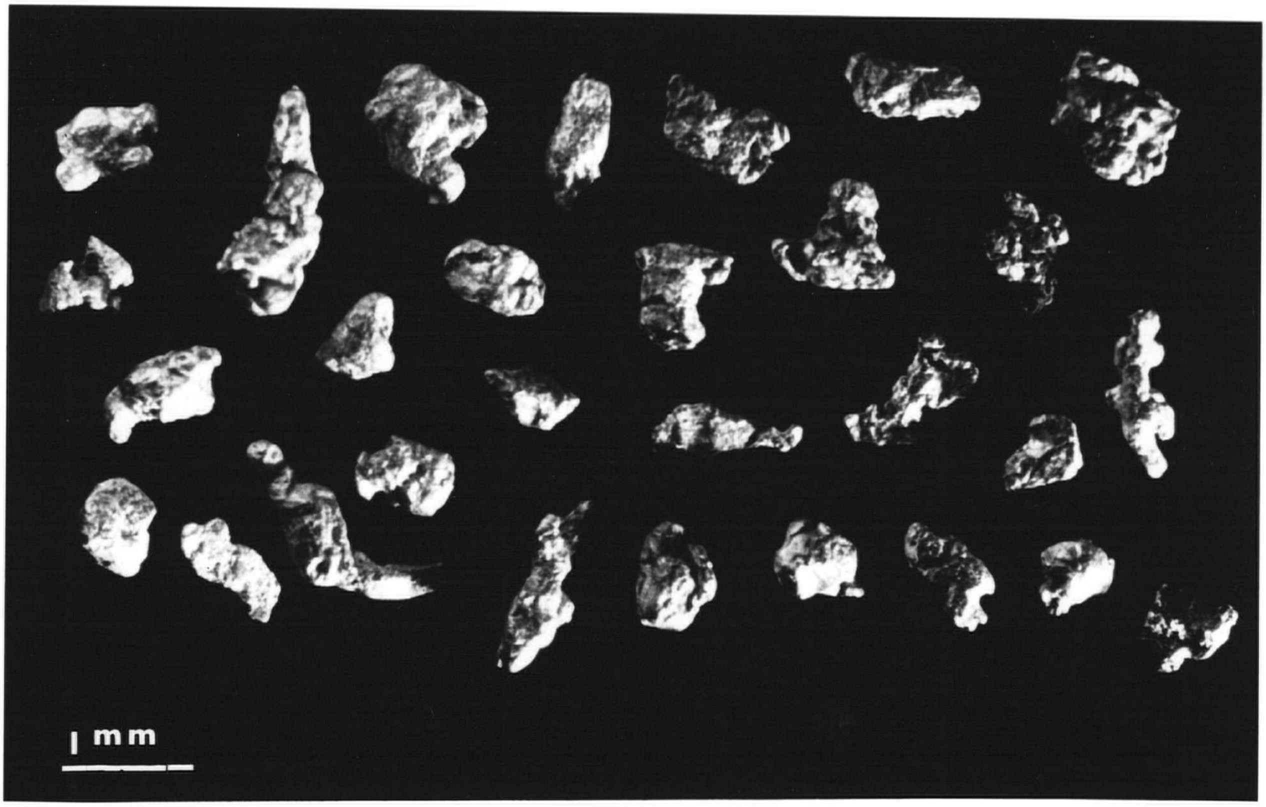
TABLE 11: Lode Gold

	Au	Hg	Ag	Cu	Total	Fineness
Bralorne						
Au 21	86.22	.1	13.78	.03	100.23	862.2
Au 22	96.29	.07	3.38	1.08	100.85	966.09
Au 25	82.87	.25	16.2	.04	99.47	836.48
Cariboo						
Au 17	94.39	0	4.38	.05	99.85	955.6

PLATE 1

Plate 1a : AU48-2 is an example of angular, unflattened grains, (reflected light image).

1b : AU52-2 is an example of smooth, flattened grains, (reflected light image).


1 mm


1 mm

PLATE 2

Plate 2a : AU52-3-6 shows the smooth contact between core and rim, (backscattered electron image).

2b : AU52-2-9 shows the smooth contact between core and rim, (backscattered electron image).

2c : AU52-5-15 shows the smooth contact between core and rim, (backscattered electron image).

2d : AU52-1-18 shows high fineness gold along cracks, (backscattered electron image).

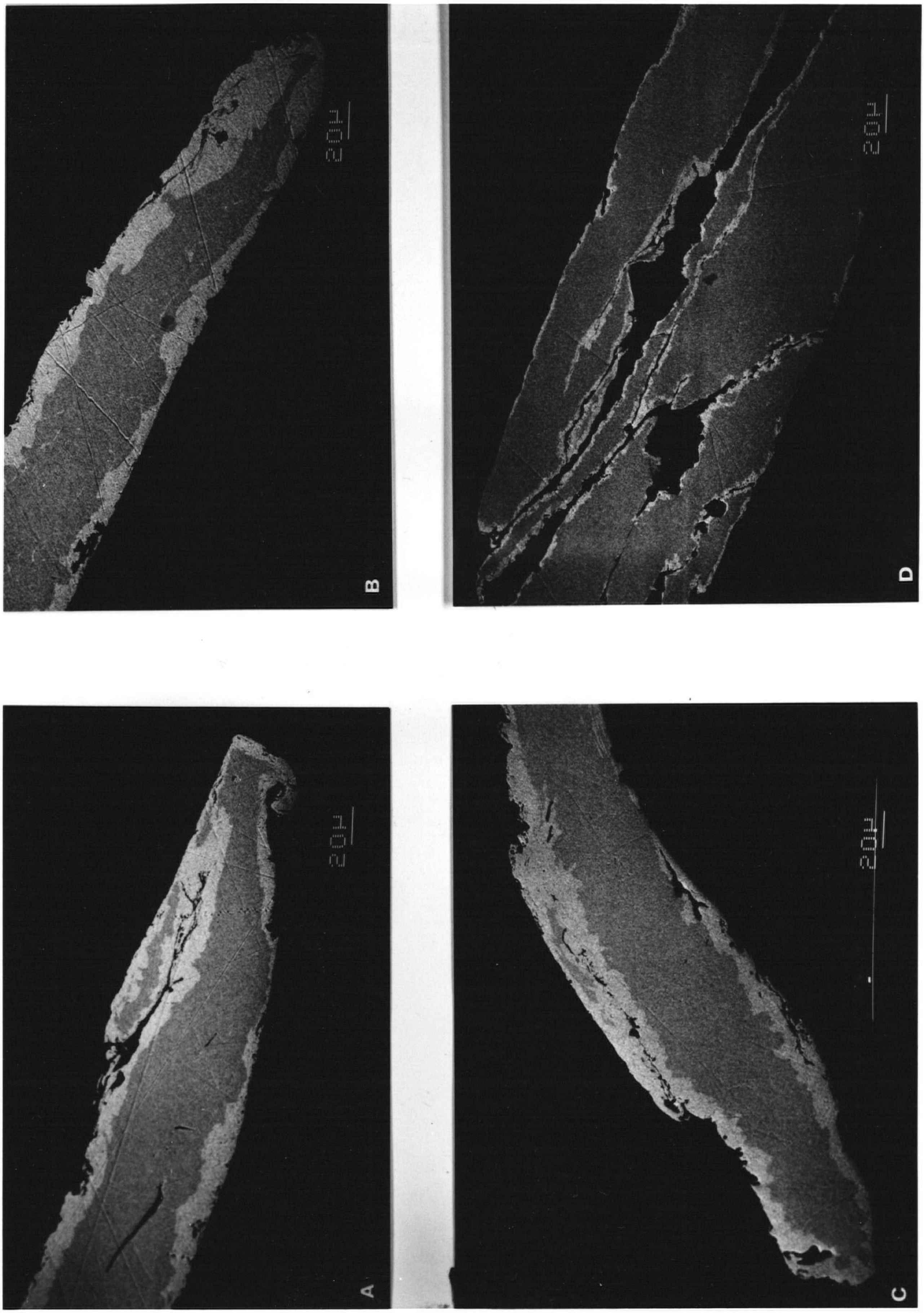

B
20μ
D
20μ
A
20μ
C
20μ

PLATE 3

Plate 3a : AU52-1-21 shows high fineness gold along cracks, (backscattered electron image).

3b : AU52-4-26 shows the uniform thinness of the rim on straight sections and thickening along external bends, (backscattered electron image).

3c : AU52-3-12 shows islands of original gold separated by rim gold, (backscattered electron image).

3d : AU52-4-13 shows islands of original gold separated by rim gold, (backscattered electron image).

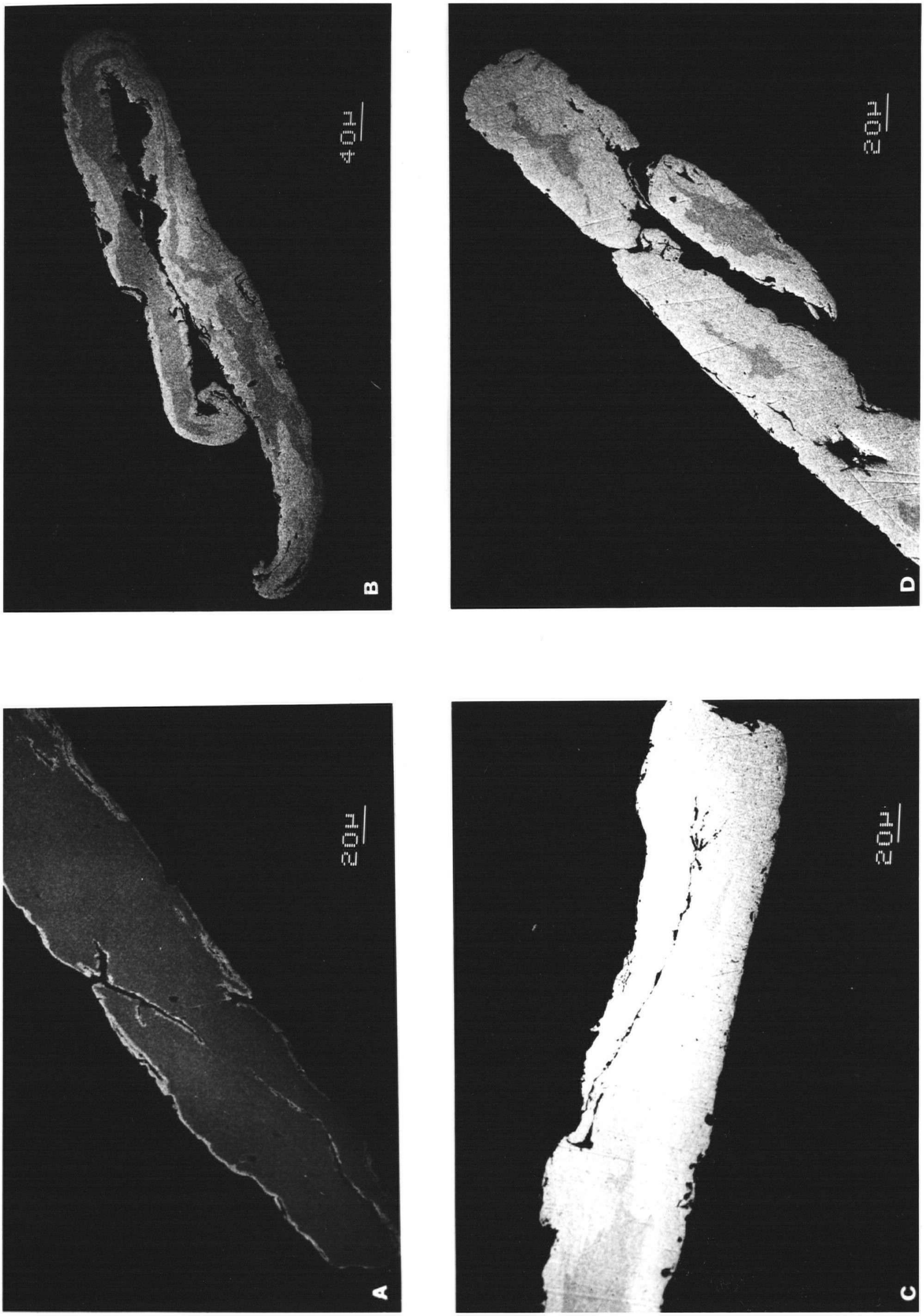
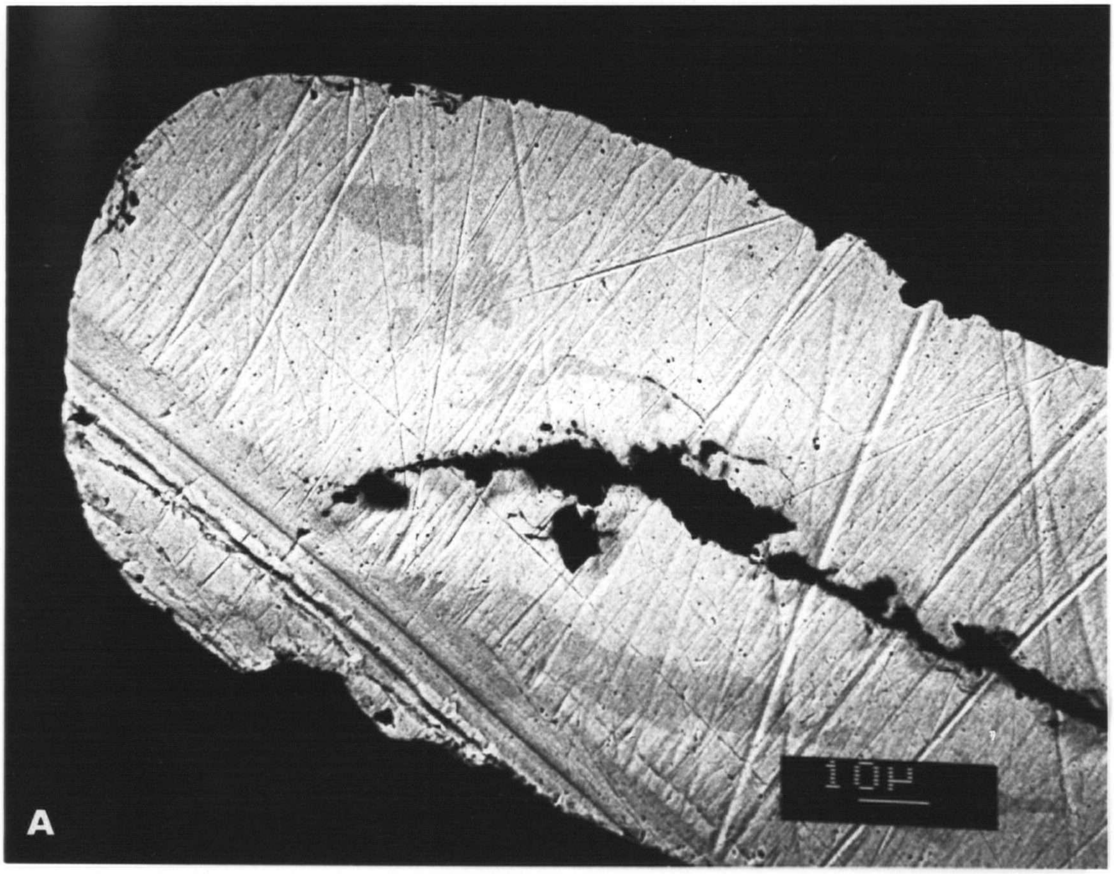
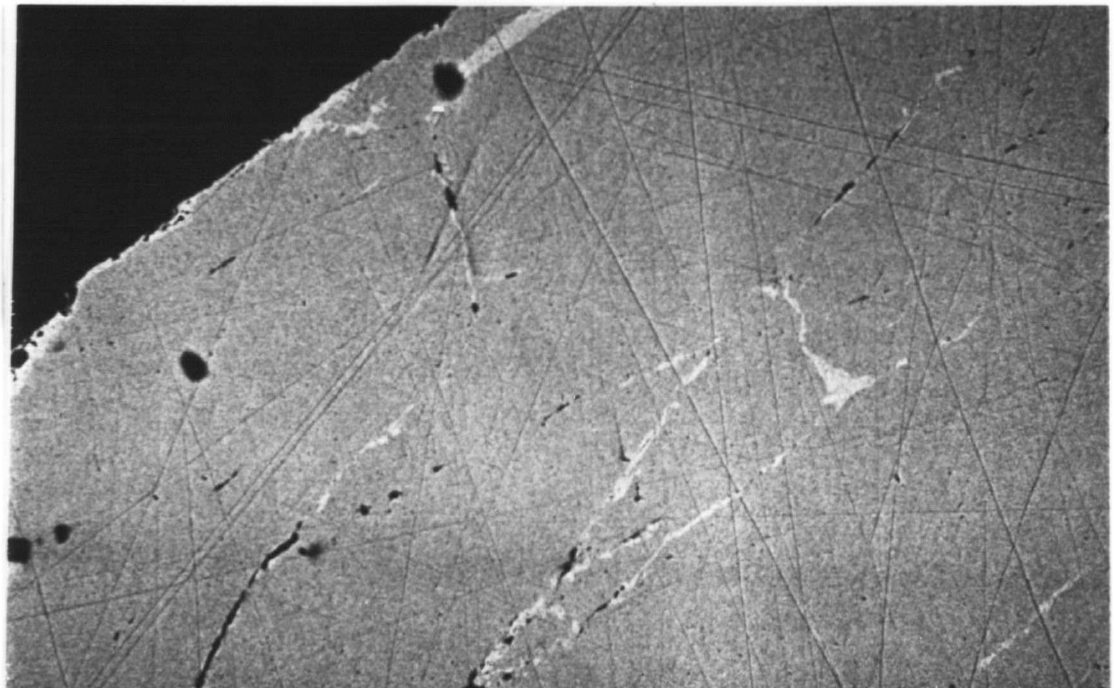

B
40μ
D
20μ
A
20μ
C
20μ

PLATE 4

Plate 4a : AU52-2-20 shows islands of original gold separated by rim gold, (backscattered electron image).

4b : AU52-4-15 shows lenses of rim gold within a gold particle, (backscattered electron image).


10μ
A


10μ
B

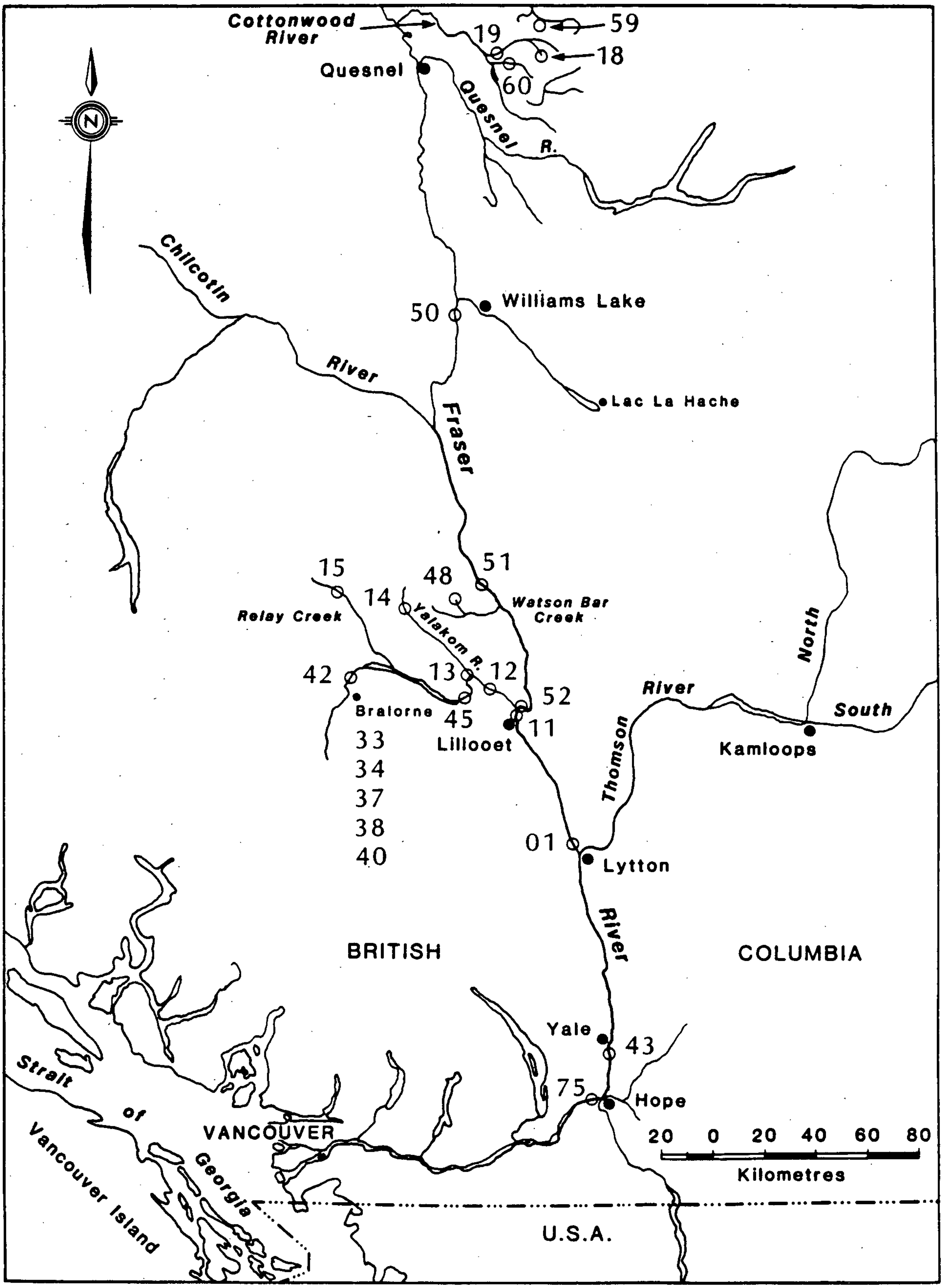


Figure 1: Sample Location

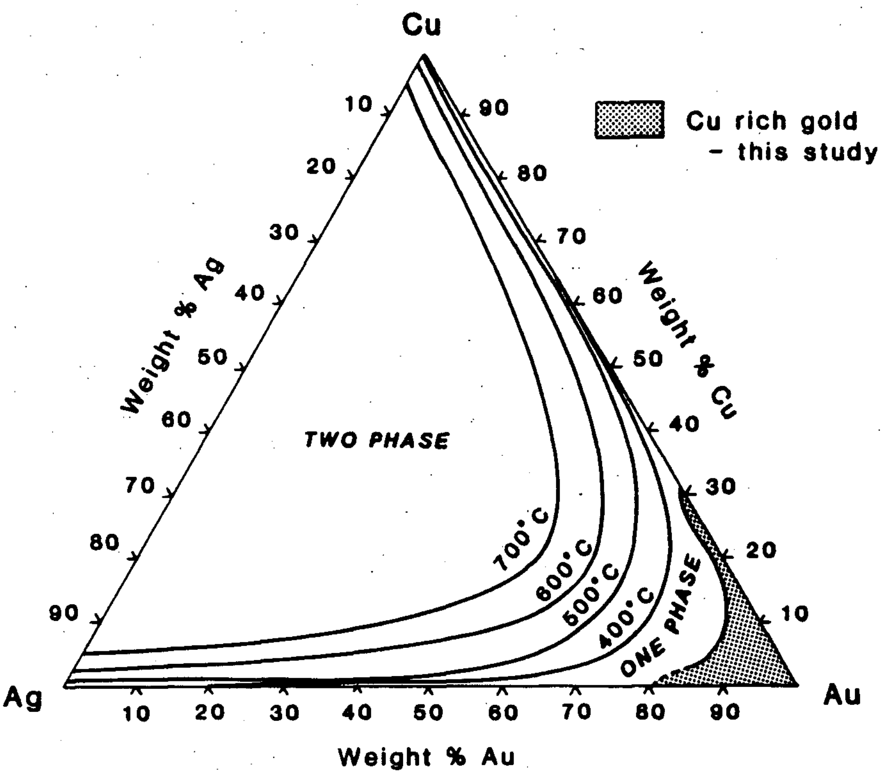


Figure 2a: Experimentally Derived Solvus at Various Temperatures for the Cu-Ag-Au Ternary (after Chang et al. 1977).

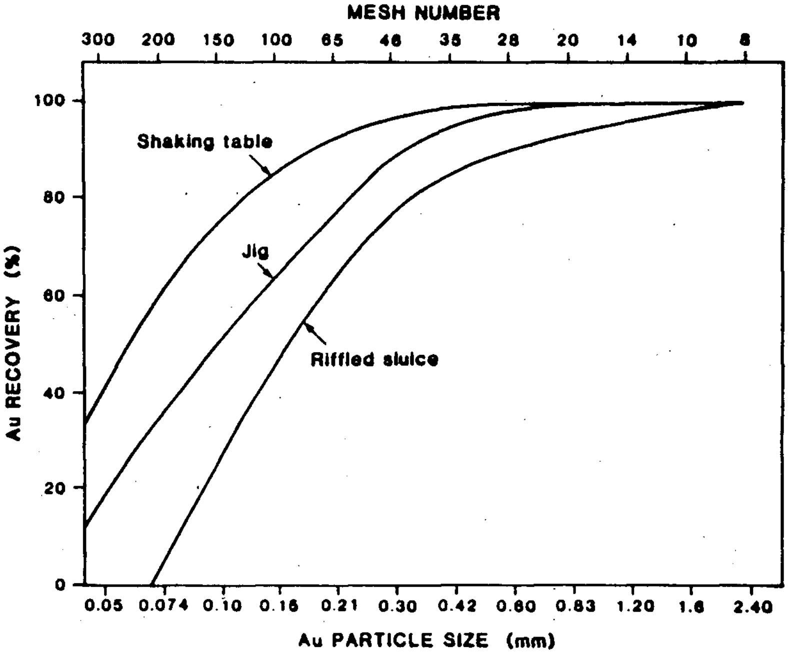
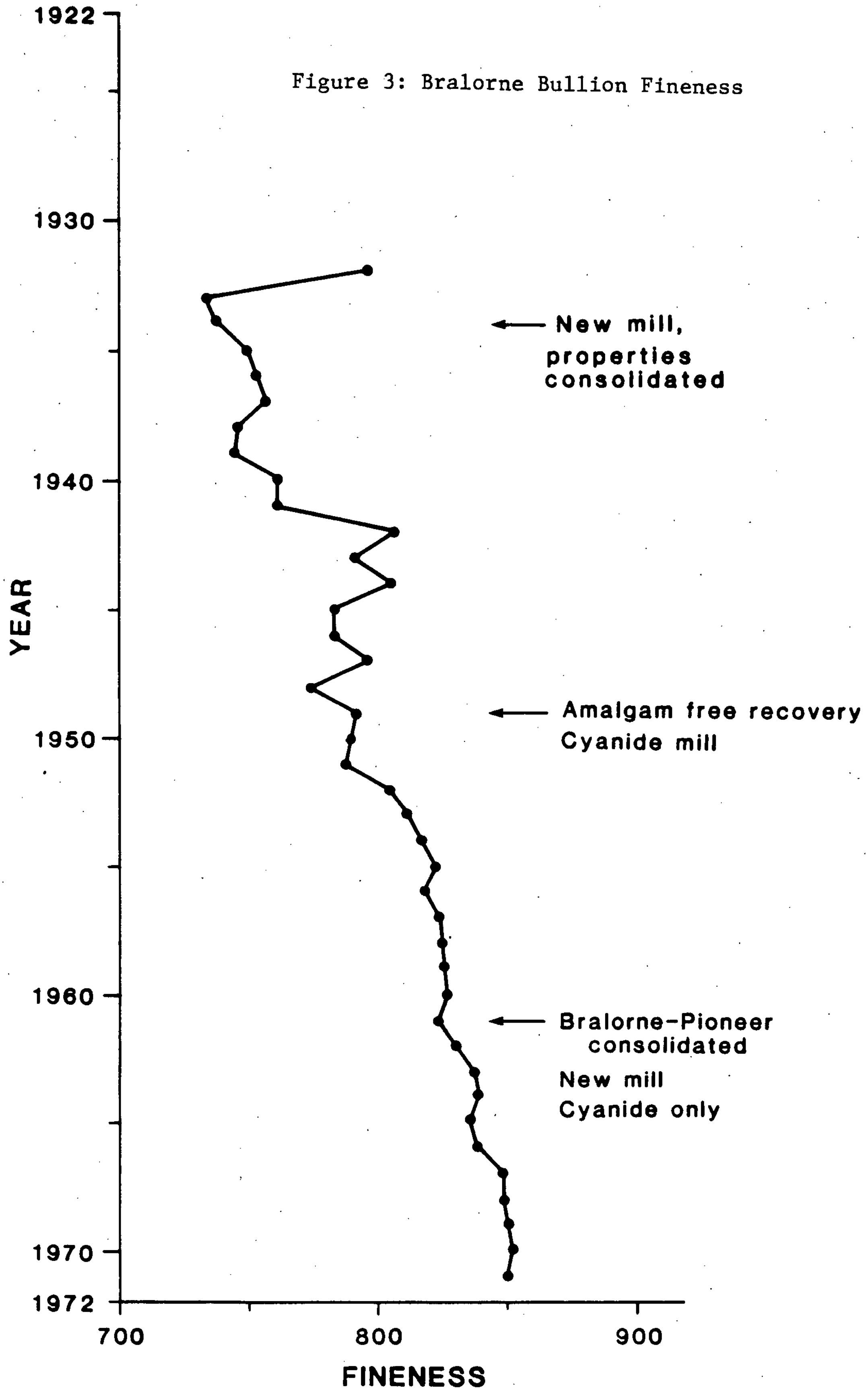


Figure 2b: Recovery of Different Size Au Particles by Gravity Devices (after Wang and Poling, 1983).

Figure 3: Bralorne Bullion Fineness



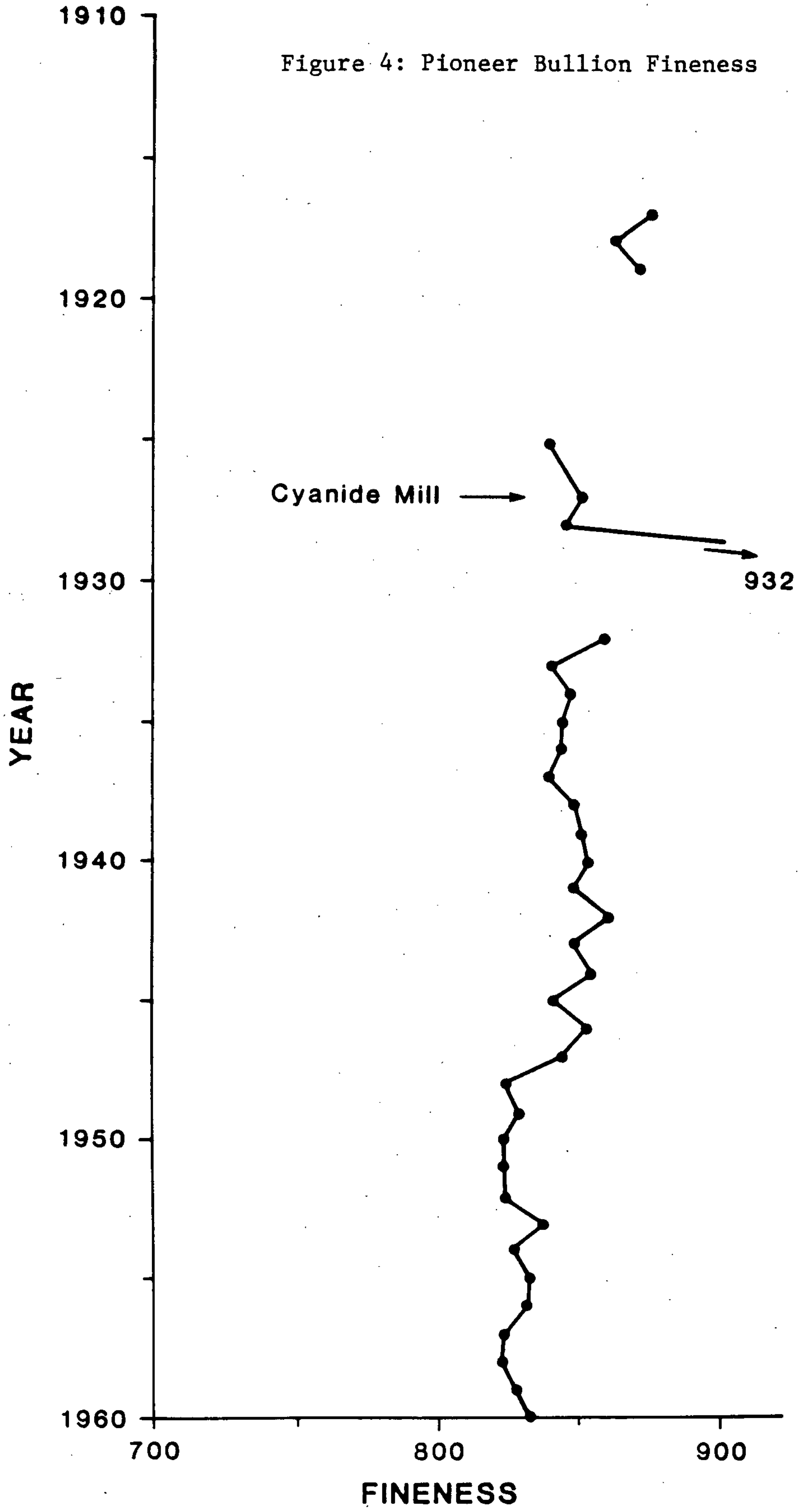


Figure 4: Pioneer Bullion Fineness
Cyanide Mill
932
YEAR
1910
1920
1930
1940
1950
1960
700
800
900
FINENESS

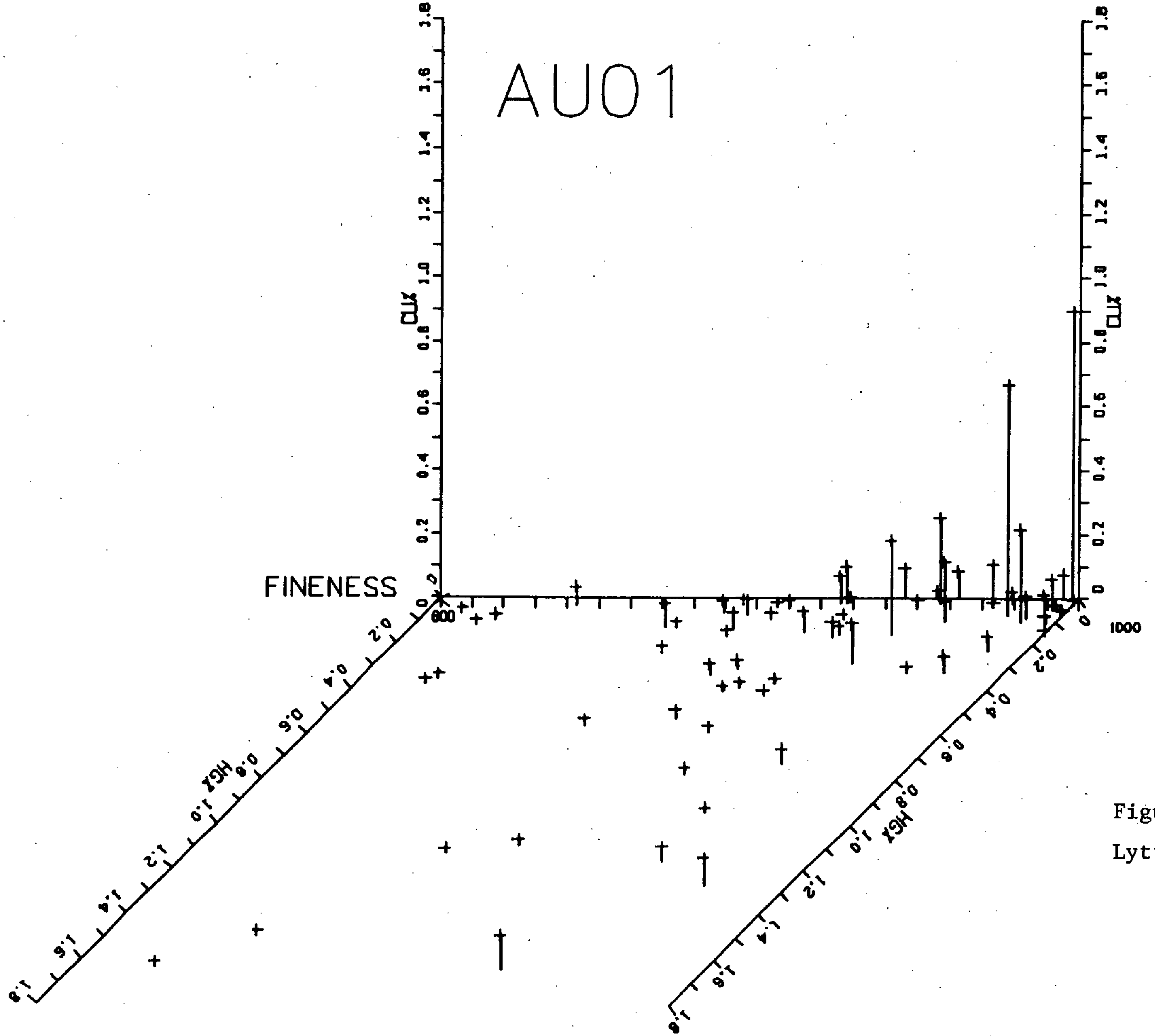


Figure 5a:
Lytton

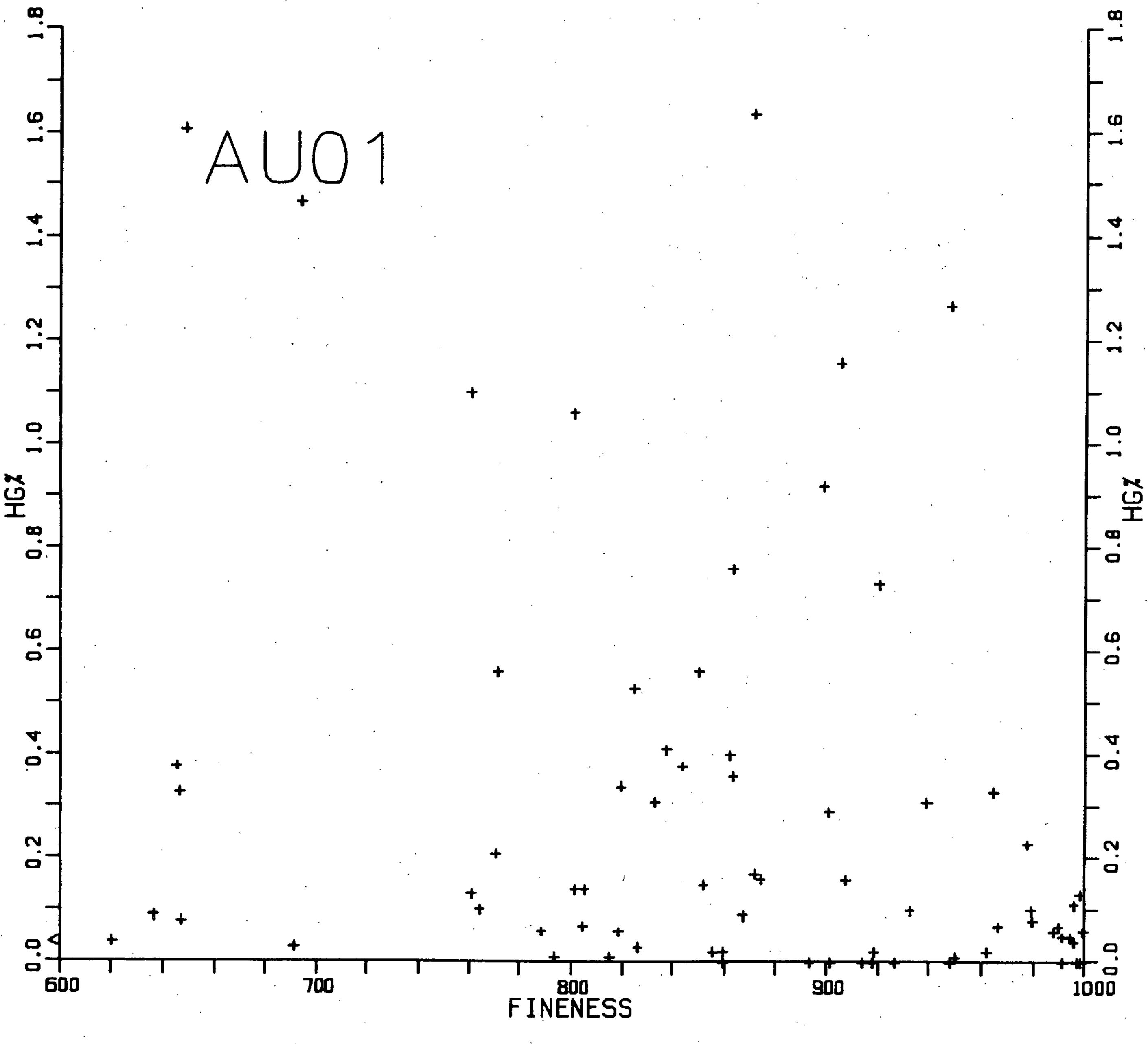


Figure 5b:
Lytton

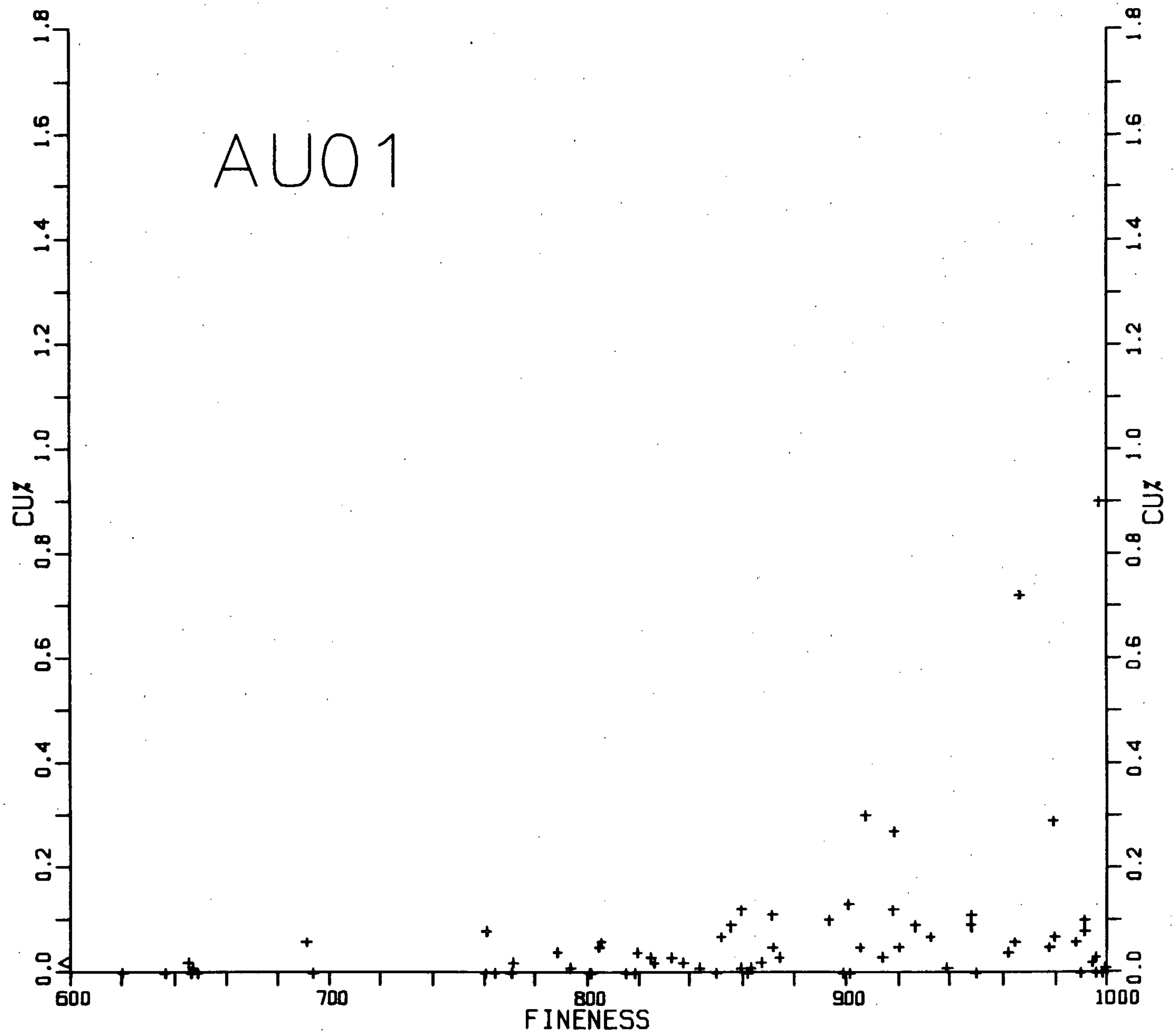


Figure 5c:
Lytton

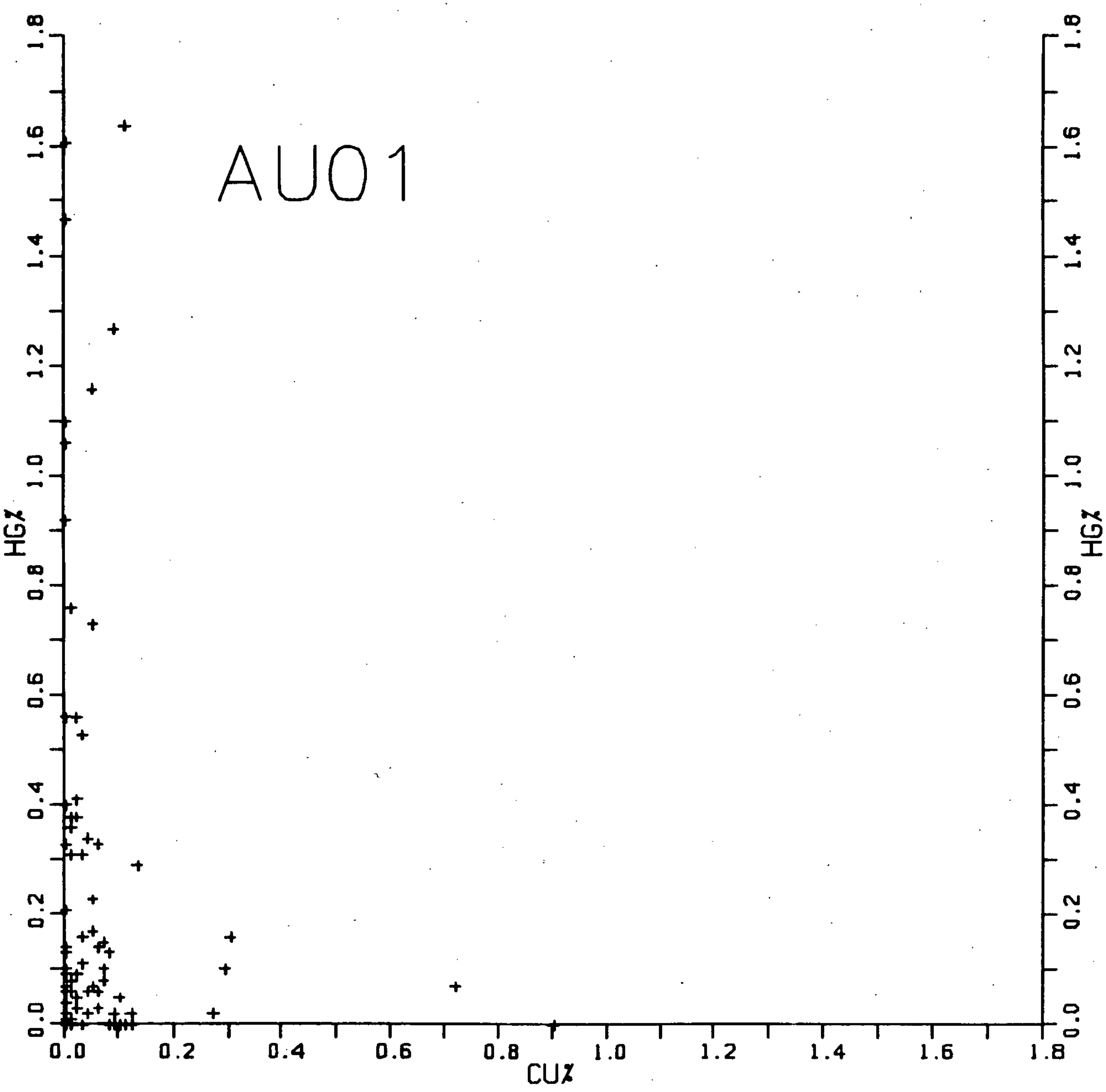


Figure 5d:
Lytton

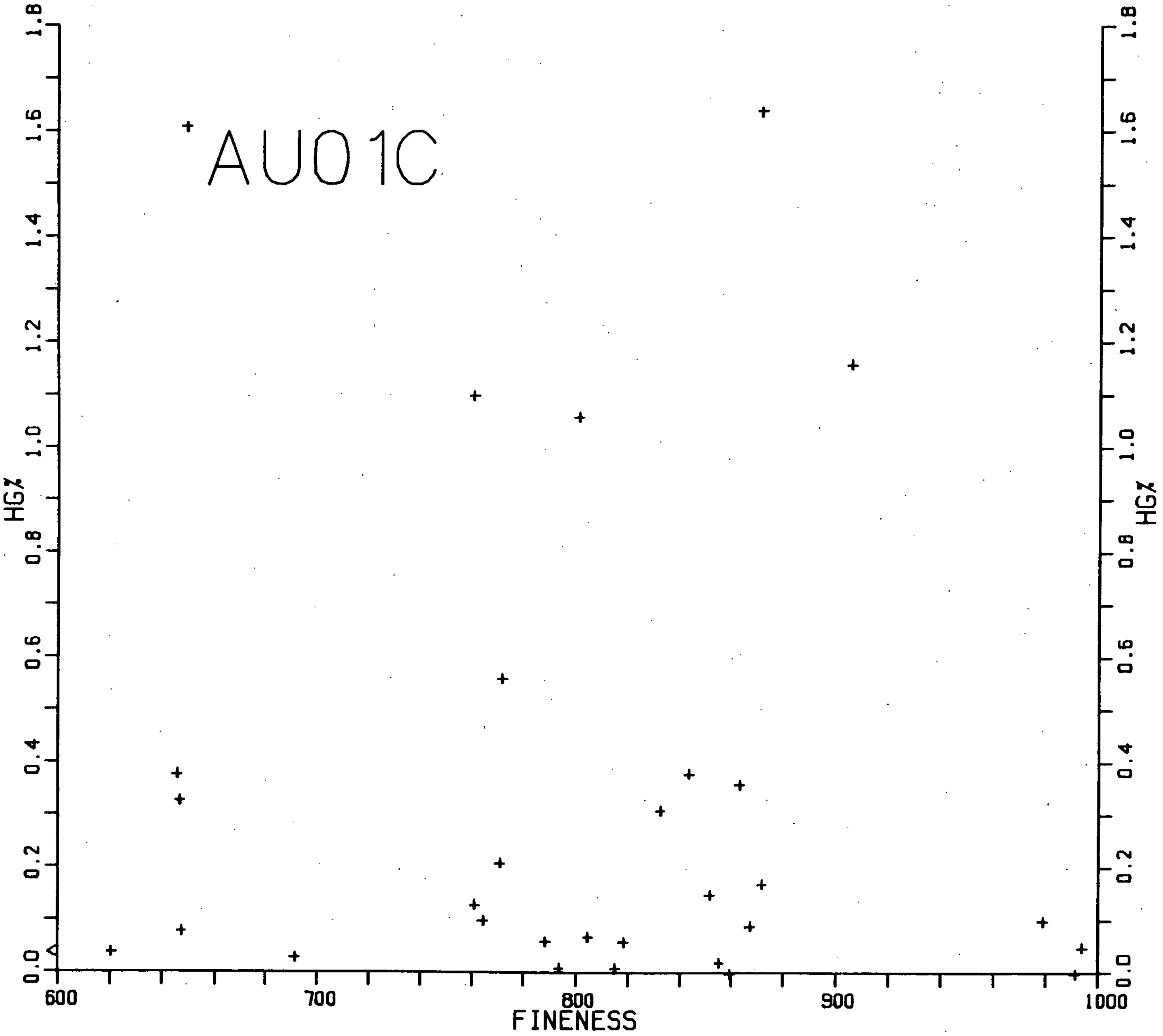


Figure 5e:

Lytton (Rimmed)

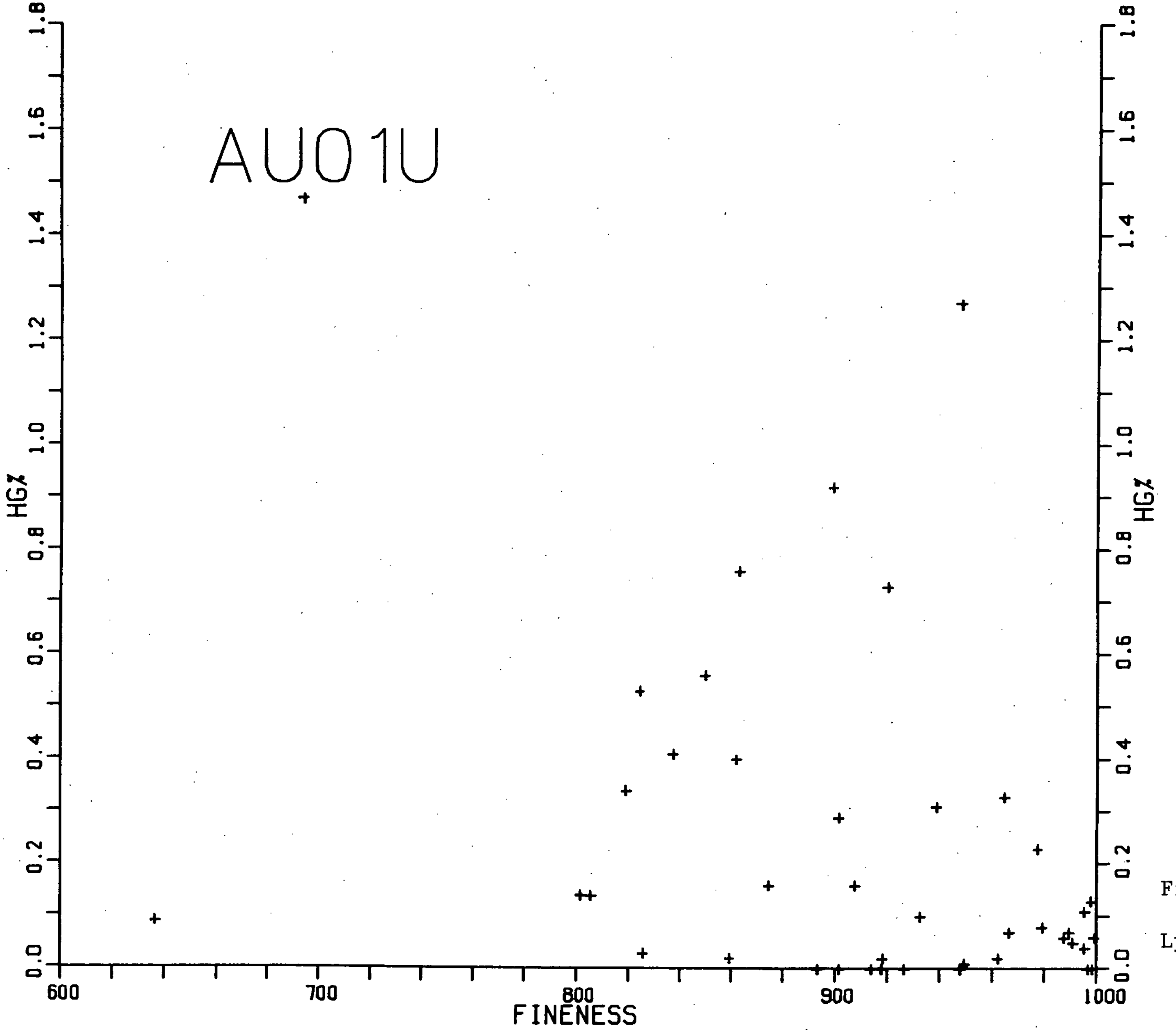


Figure 5f:

Lytton (Unrimmed)

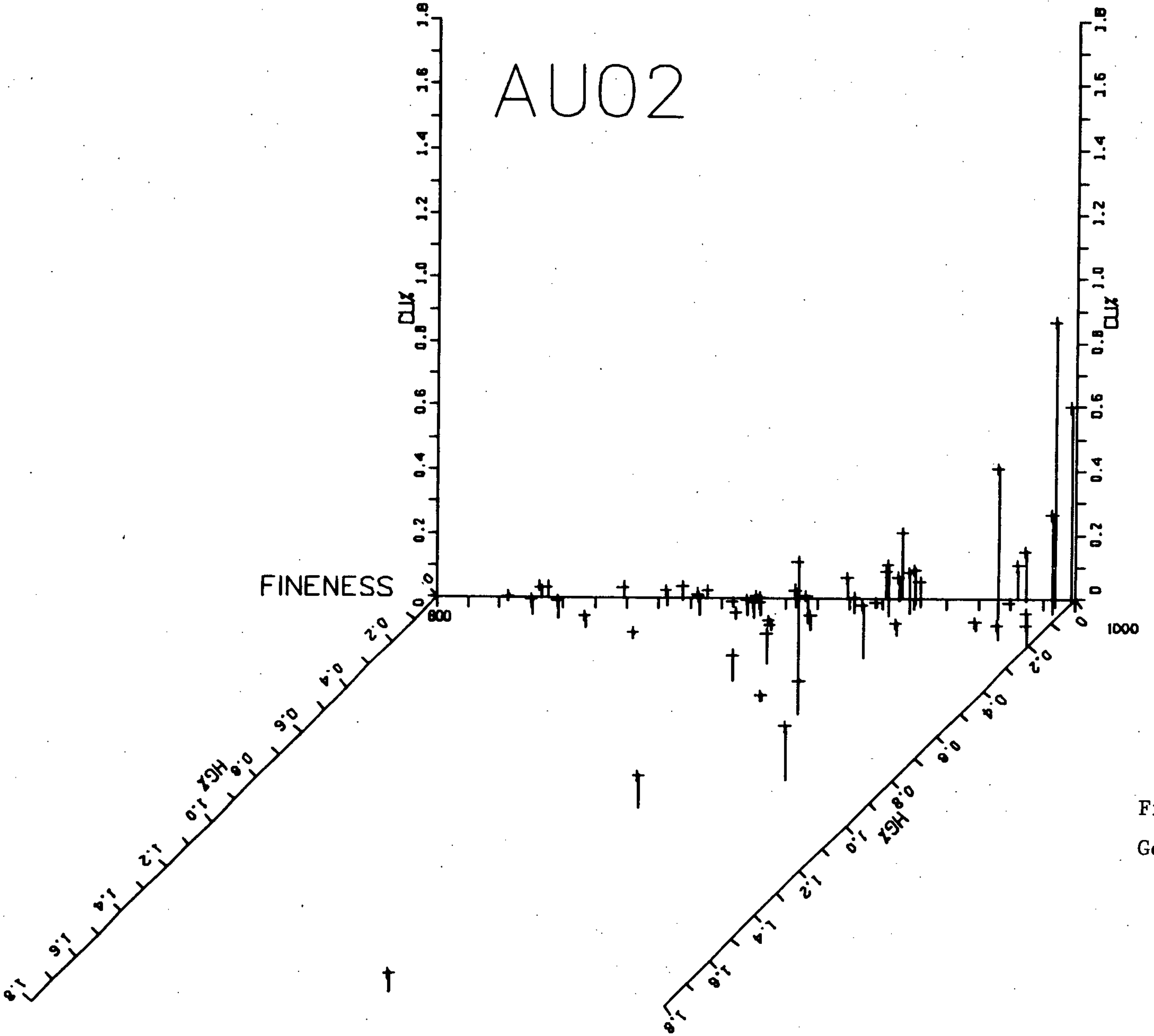


Figure 6a:
Gold Pan

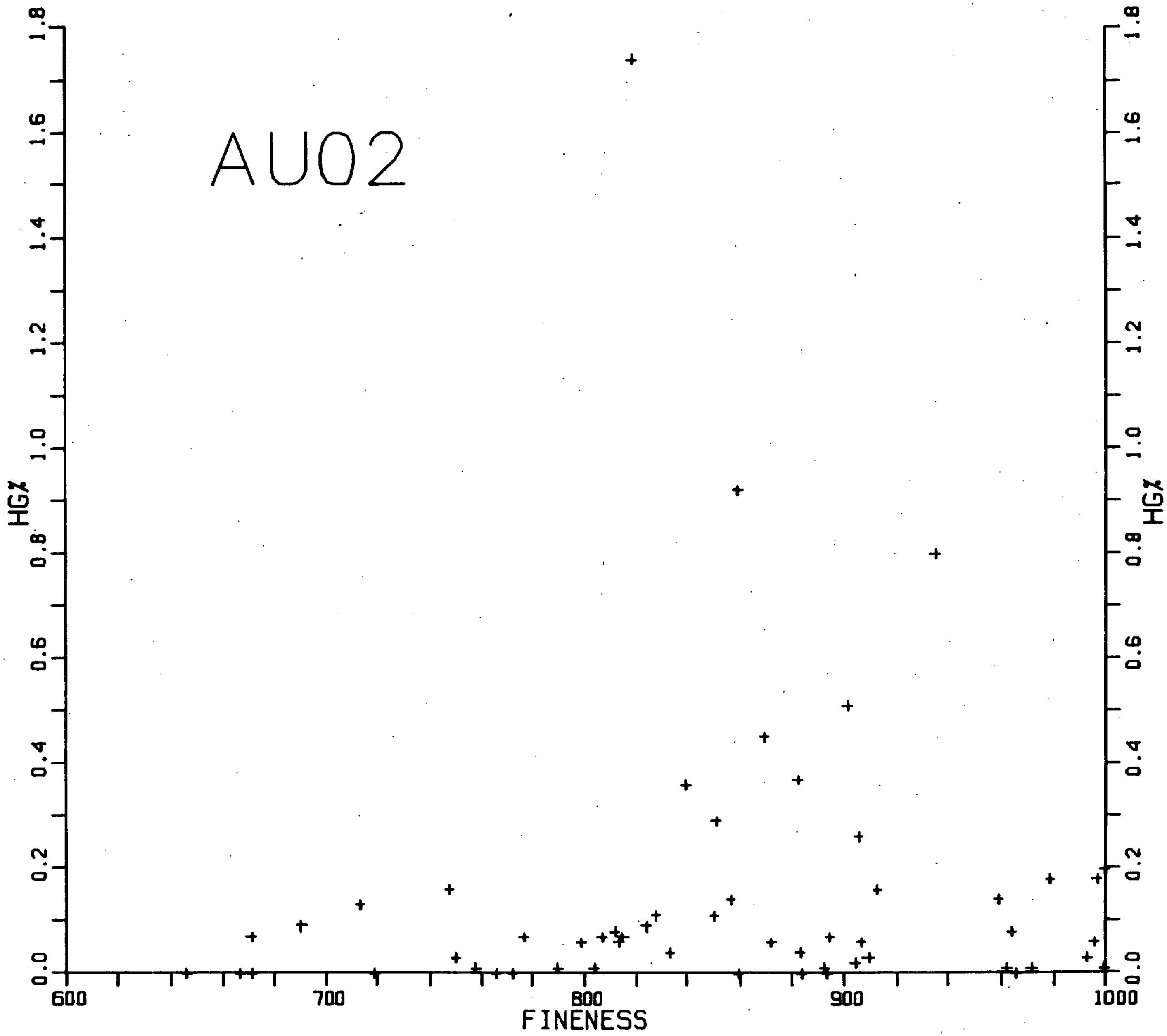


Figure 6b:
Gold Pan

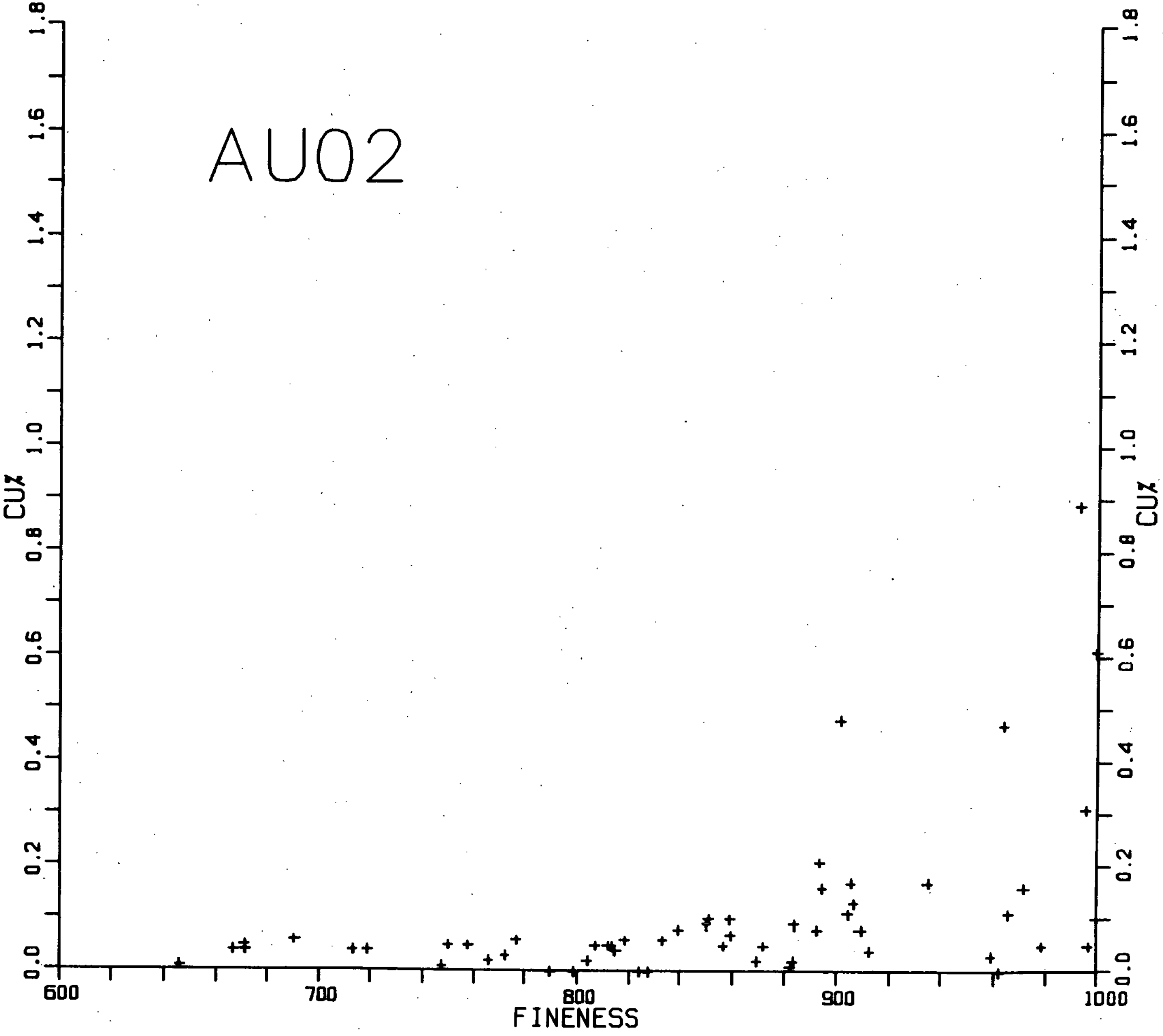


Figure 6c:
Gold Pan

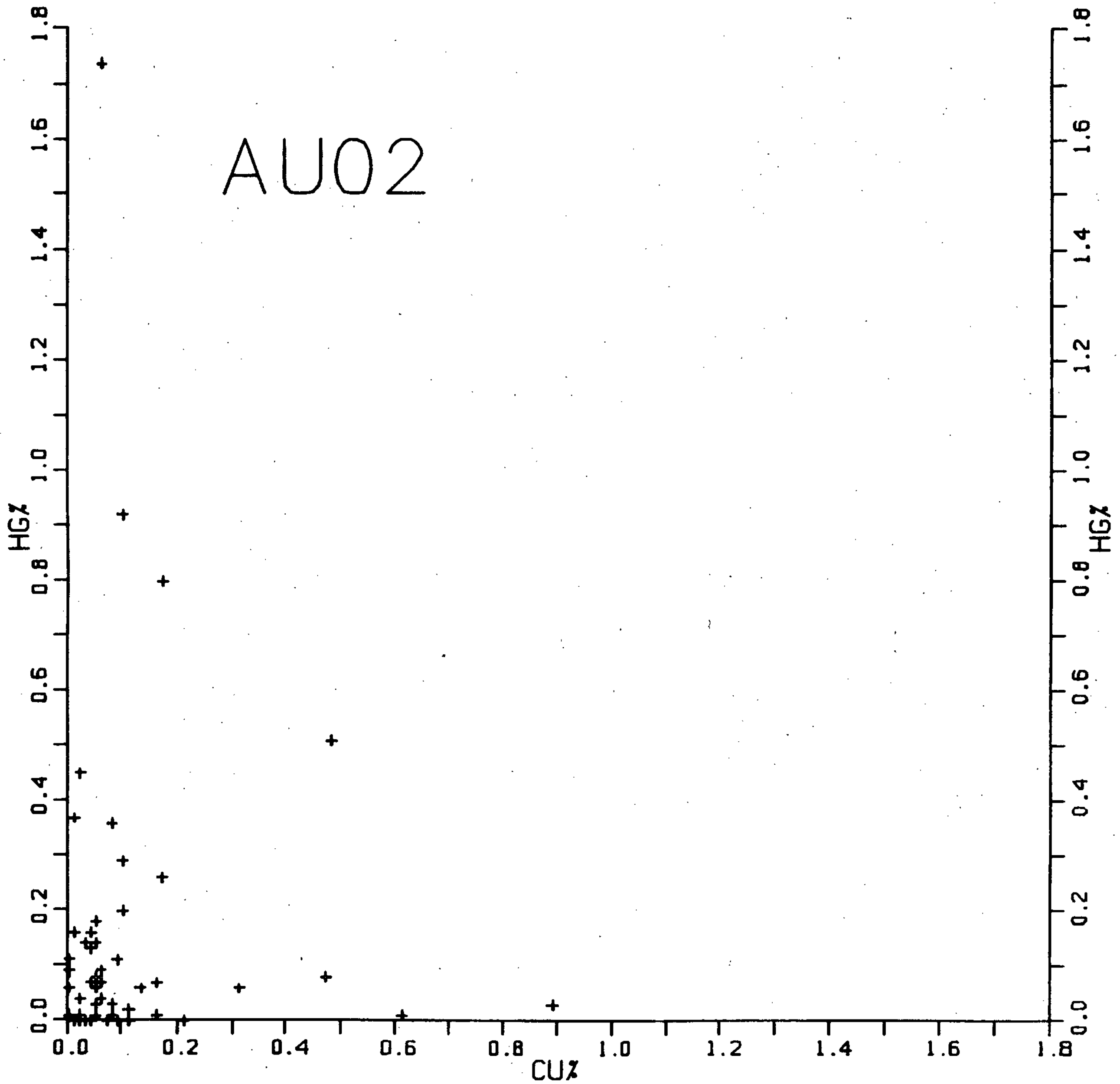


Figure 6c:
Gold Pan

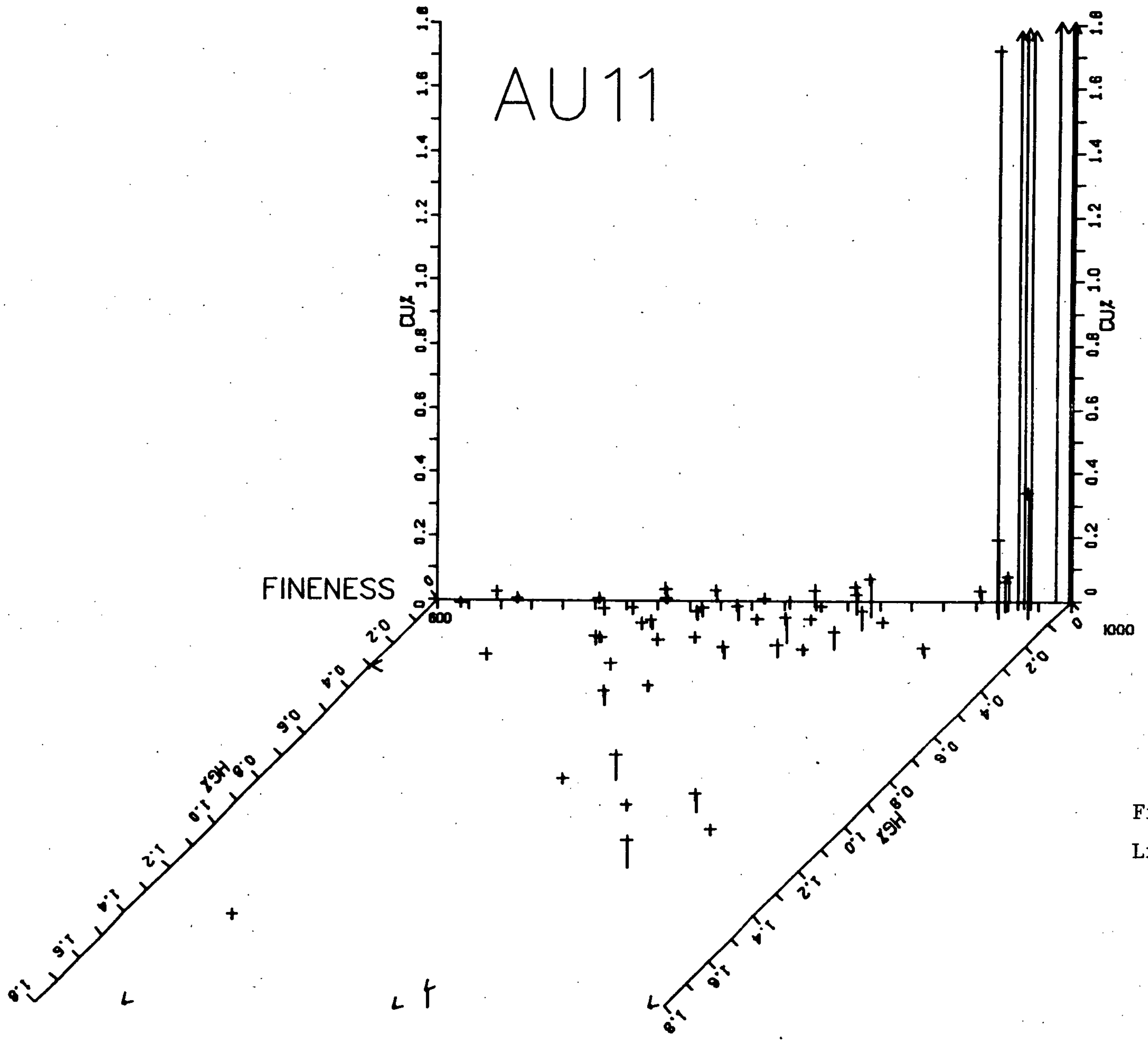


Figure 7a:
Lilloett

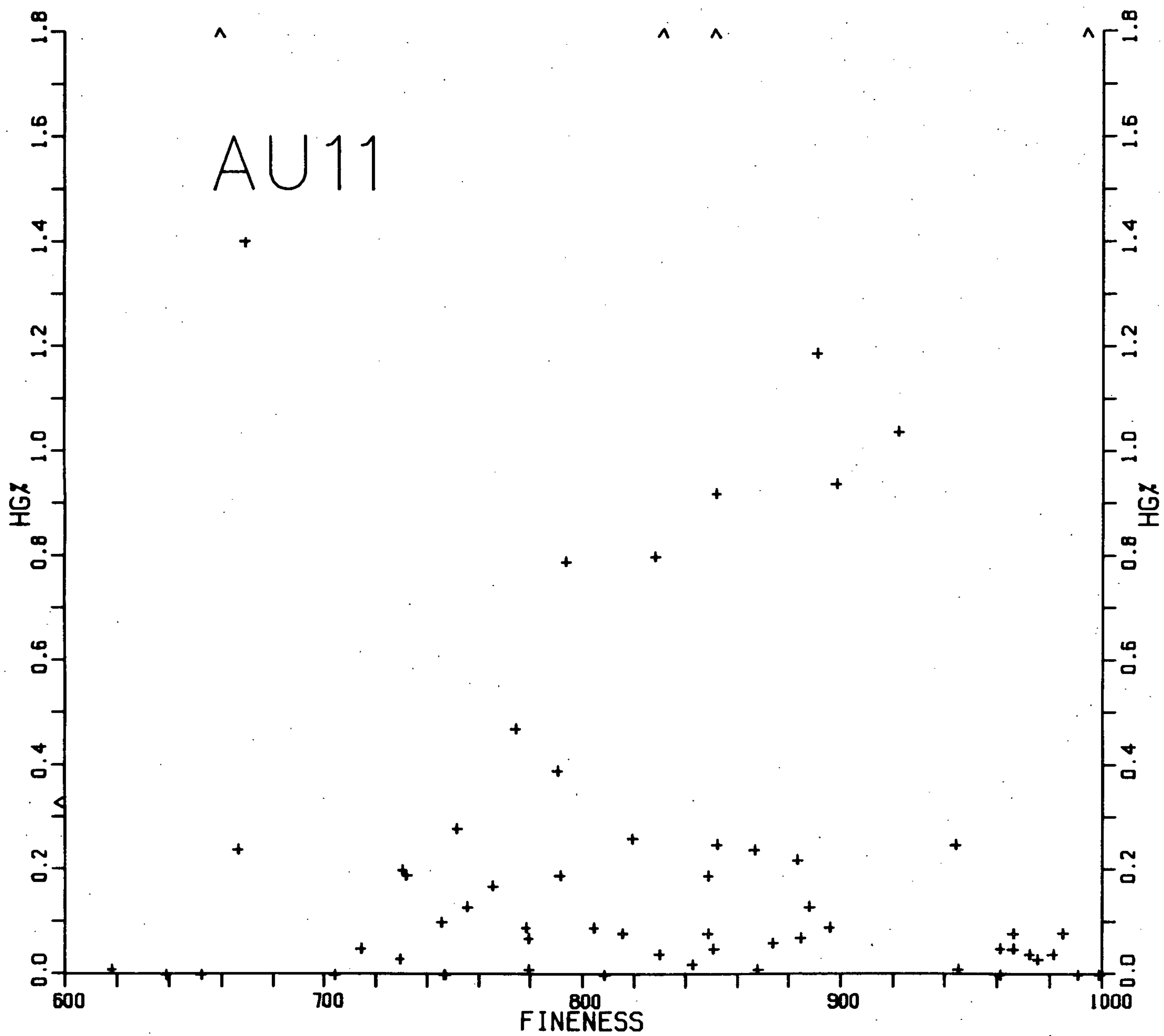


Figure 7b:
Lilloett

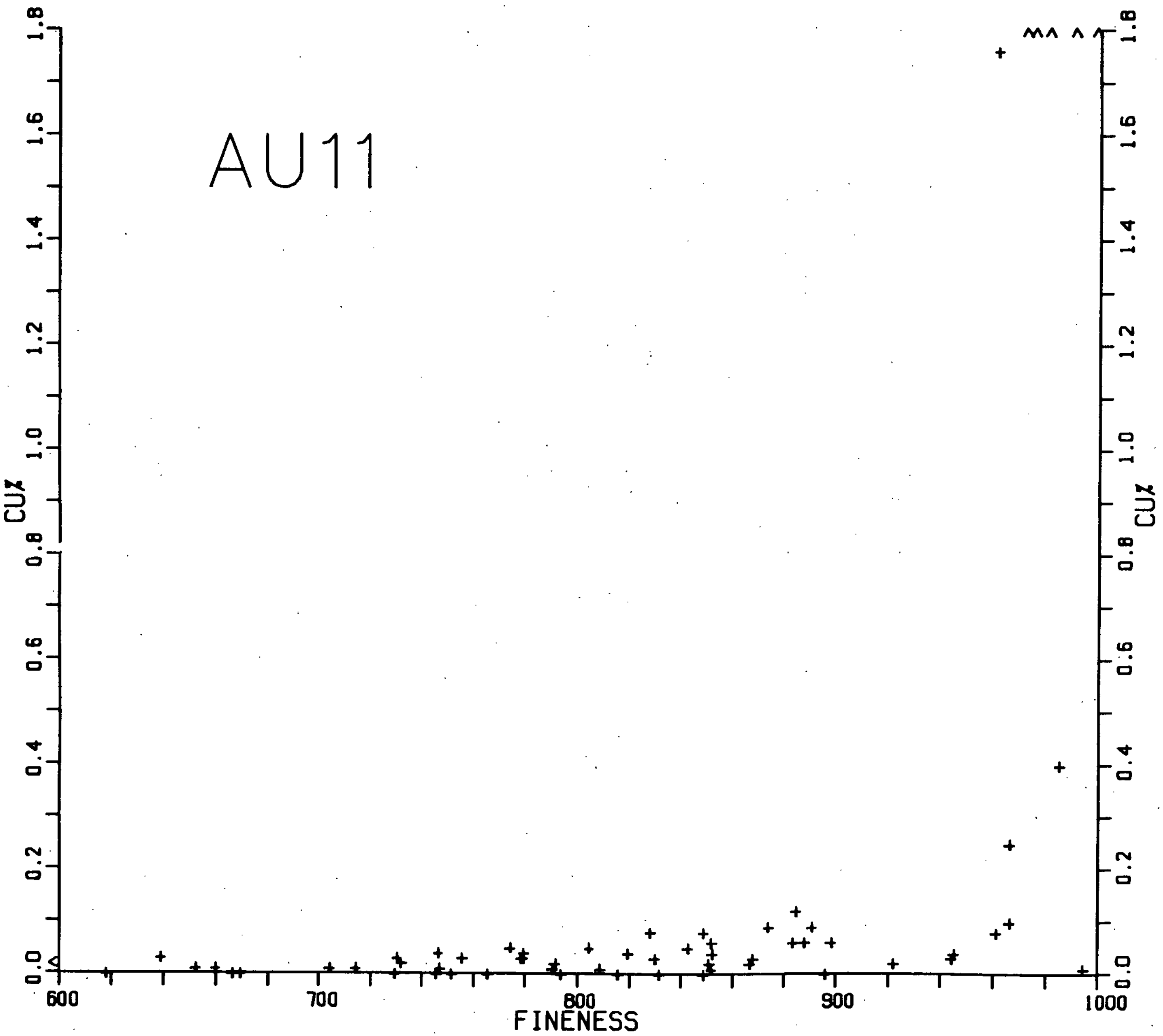


Figure 7c:
Lilloett

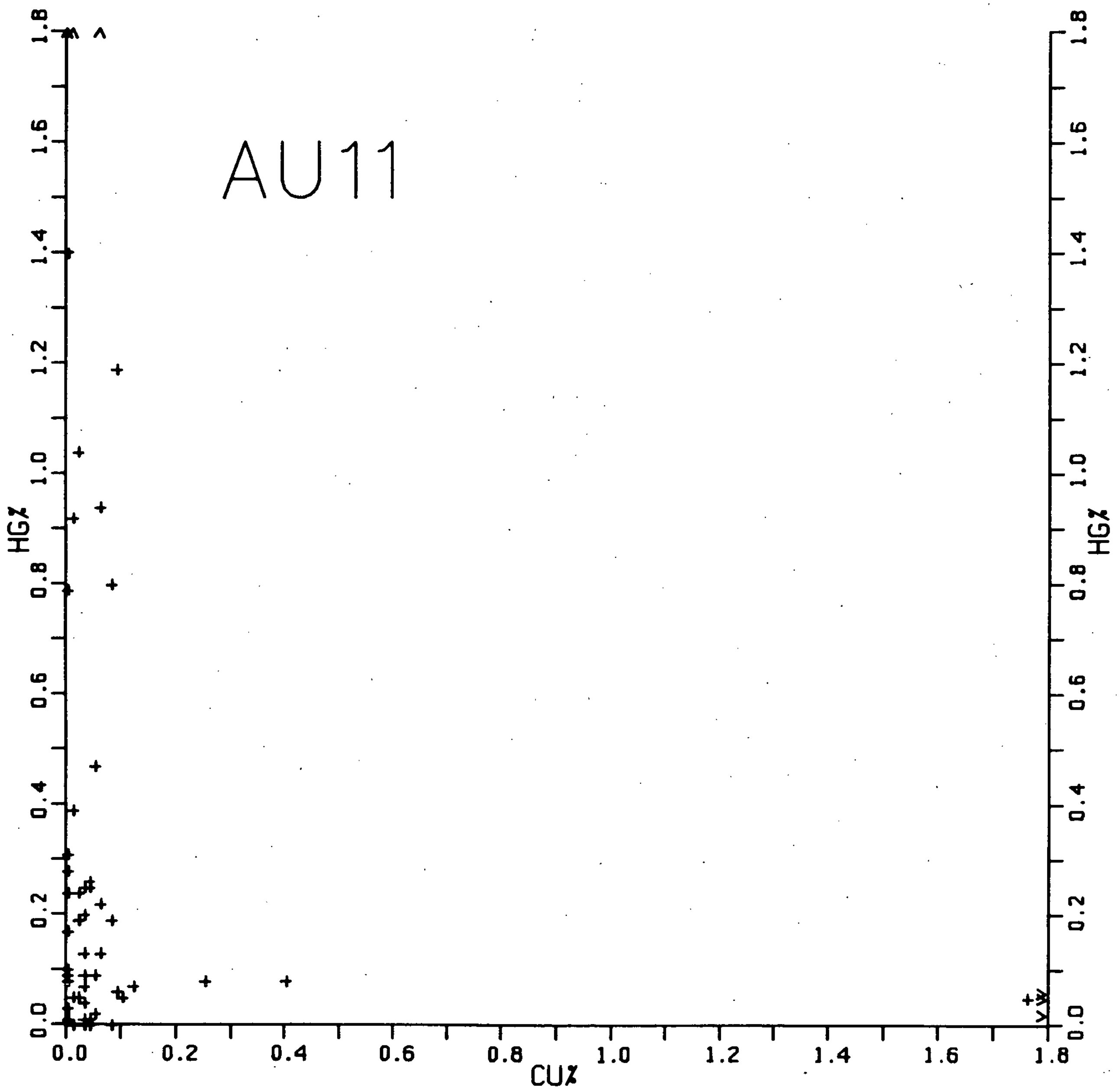


Figure 7d:
Lilloett

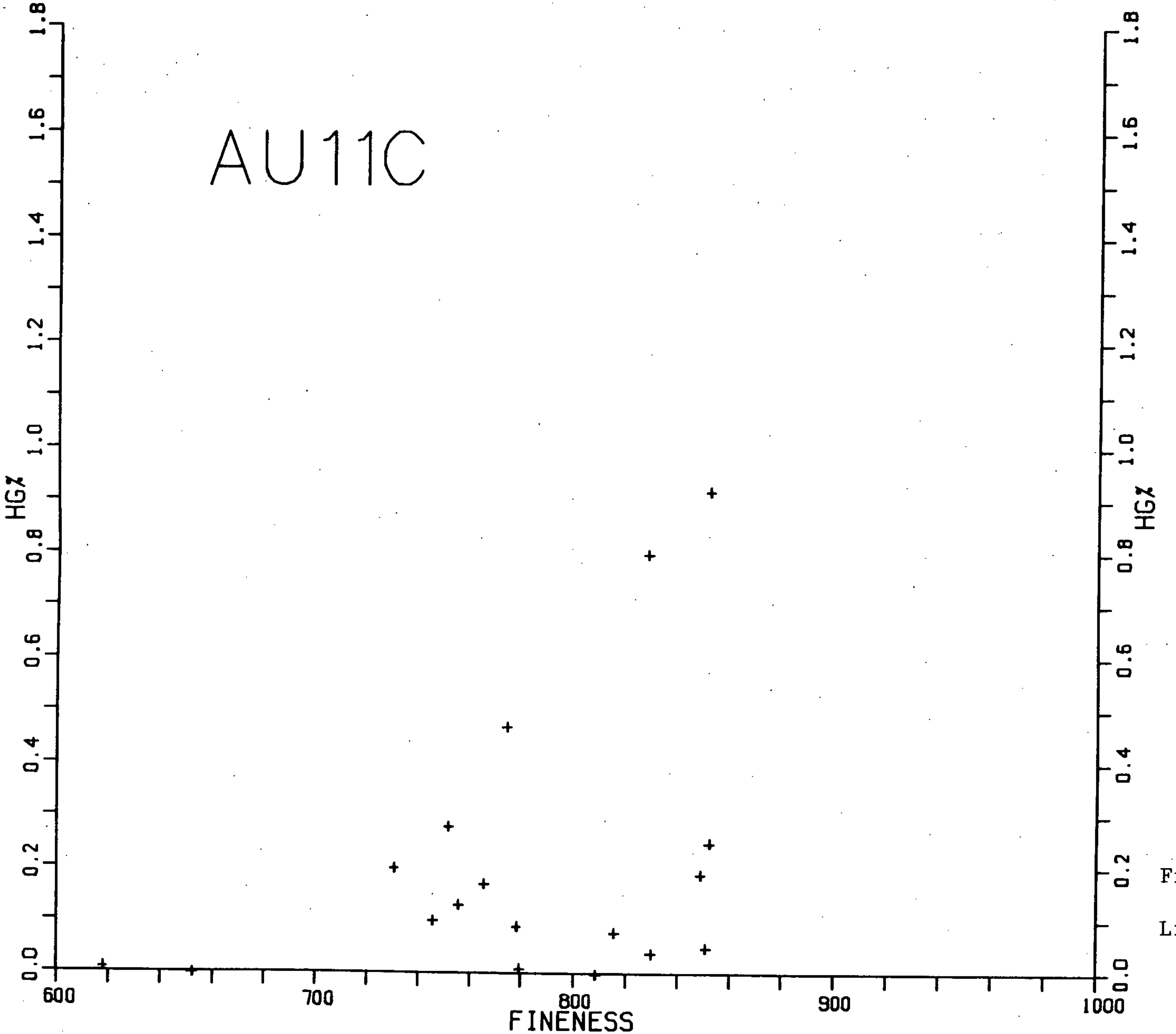


Figure 7e:

Lillooet (Rimmed)

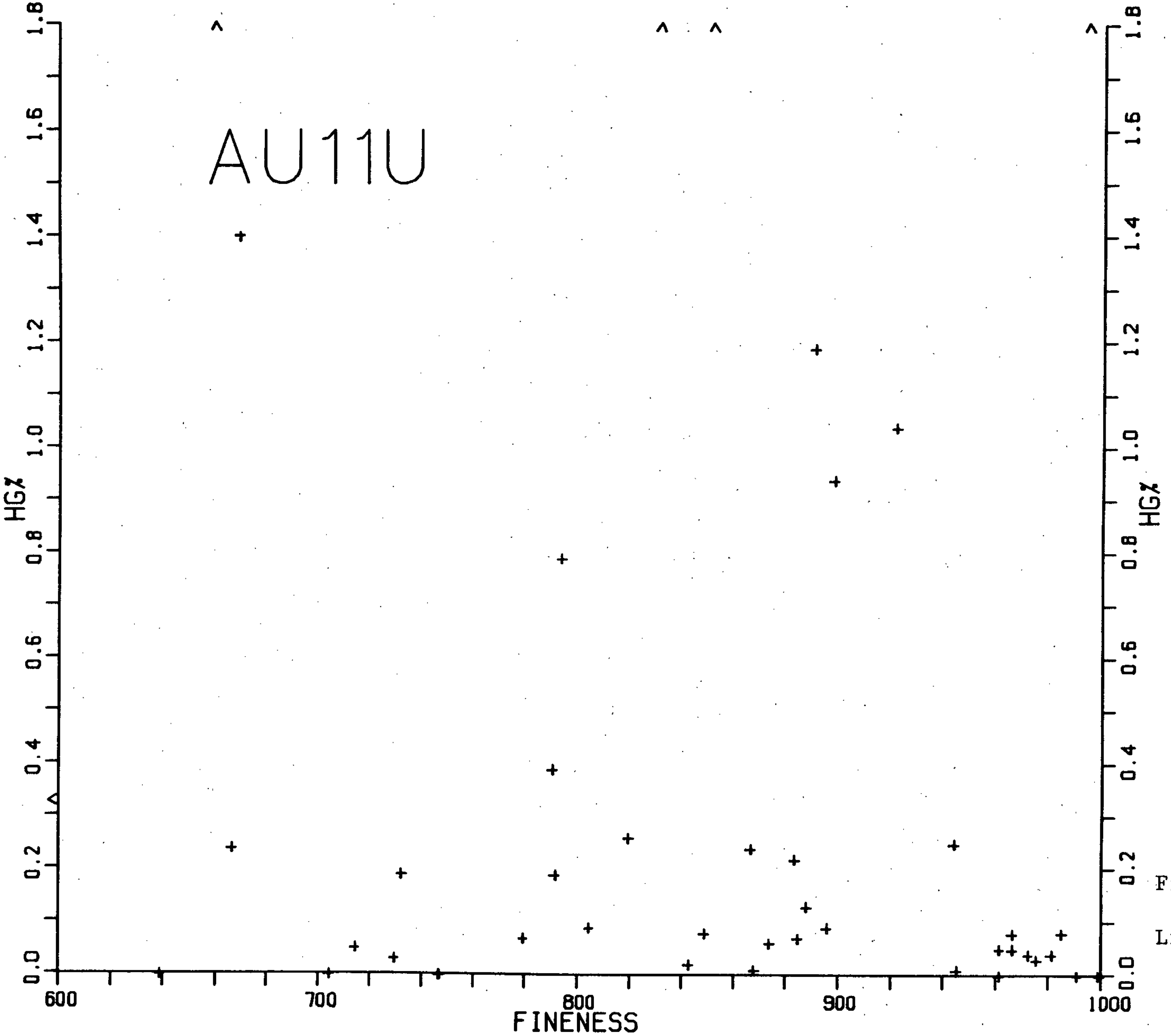


Figure 7f:

Lilloet (Unrimmed)

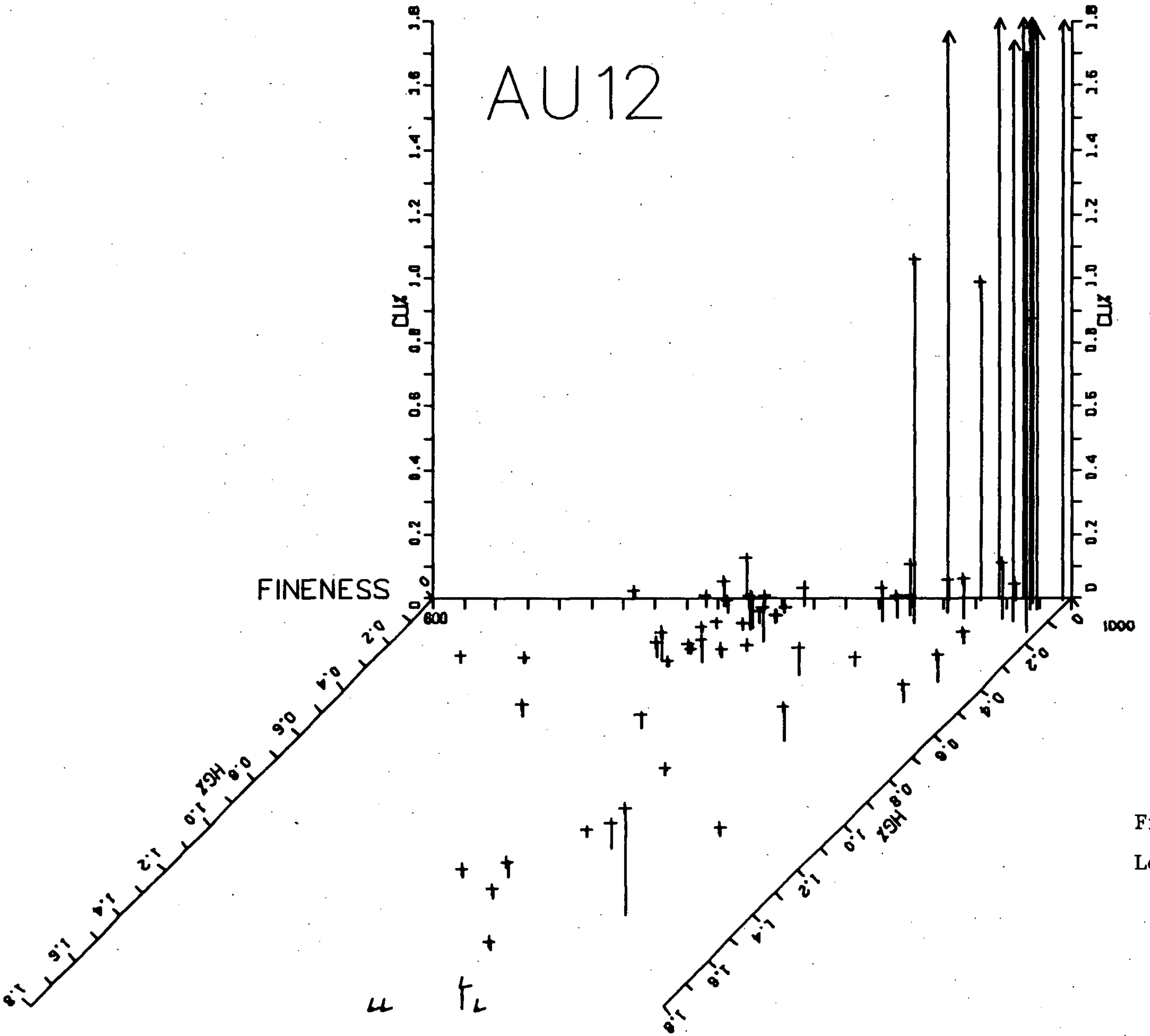


Figure 8a:
Lower Bridge

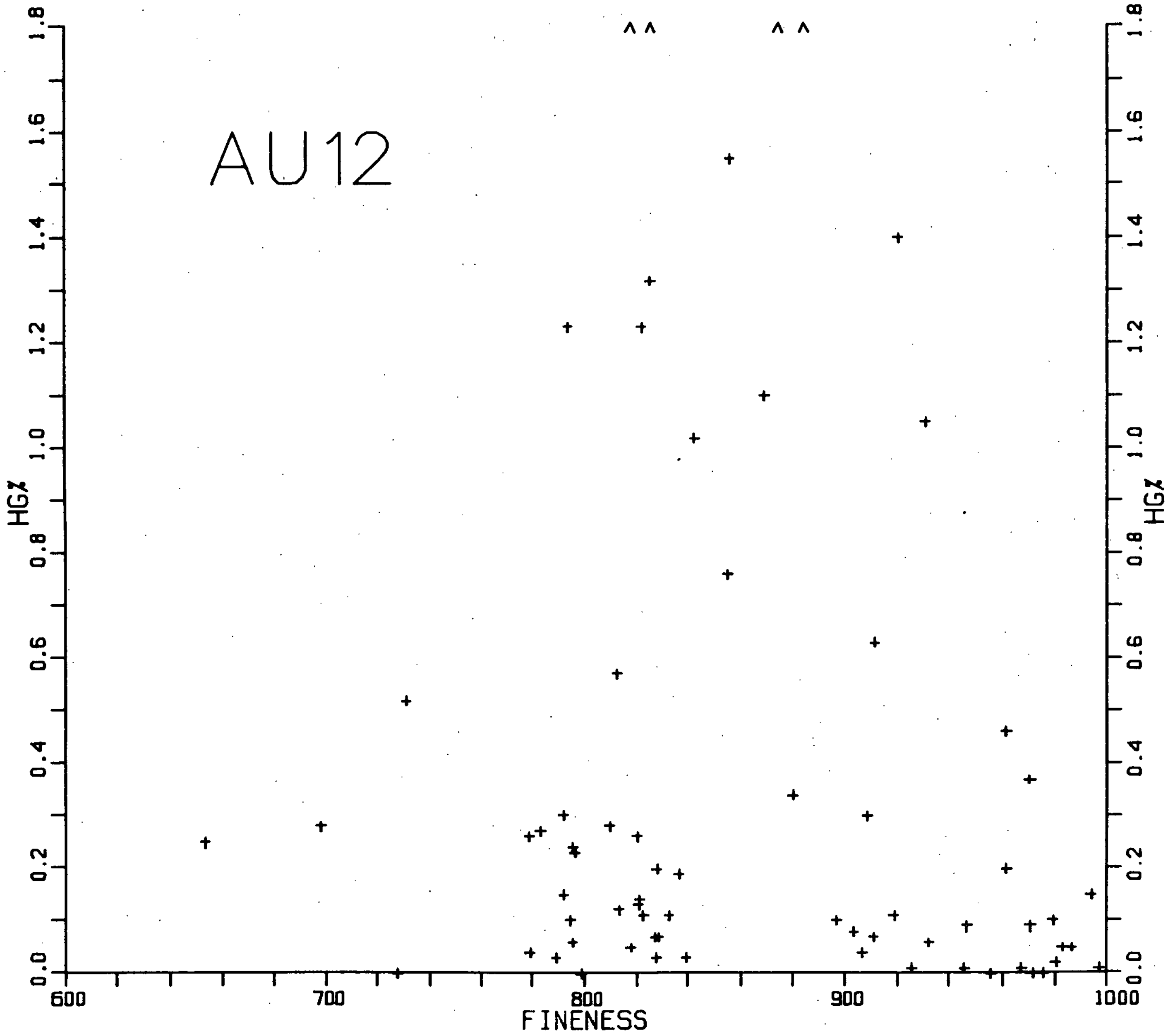


Figure 8b:
Lower Bridge

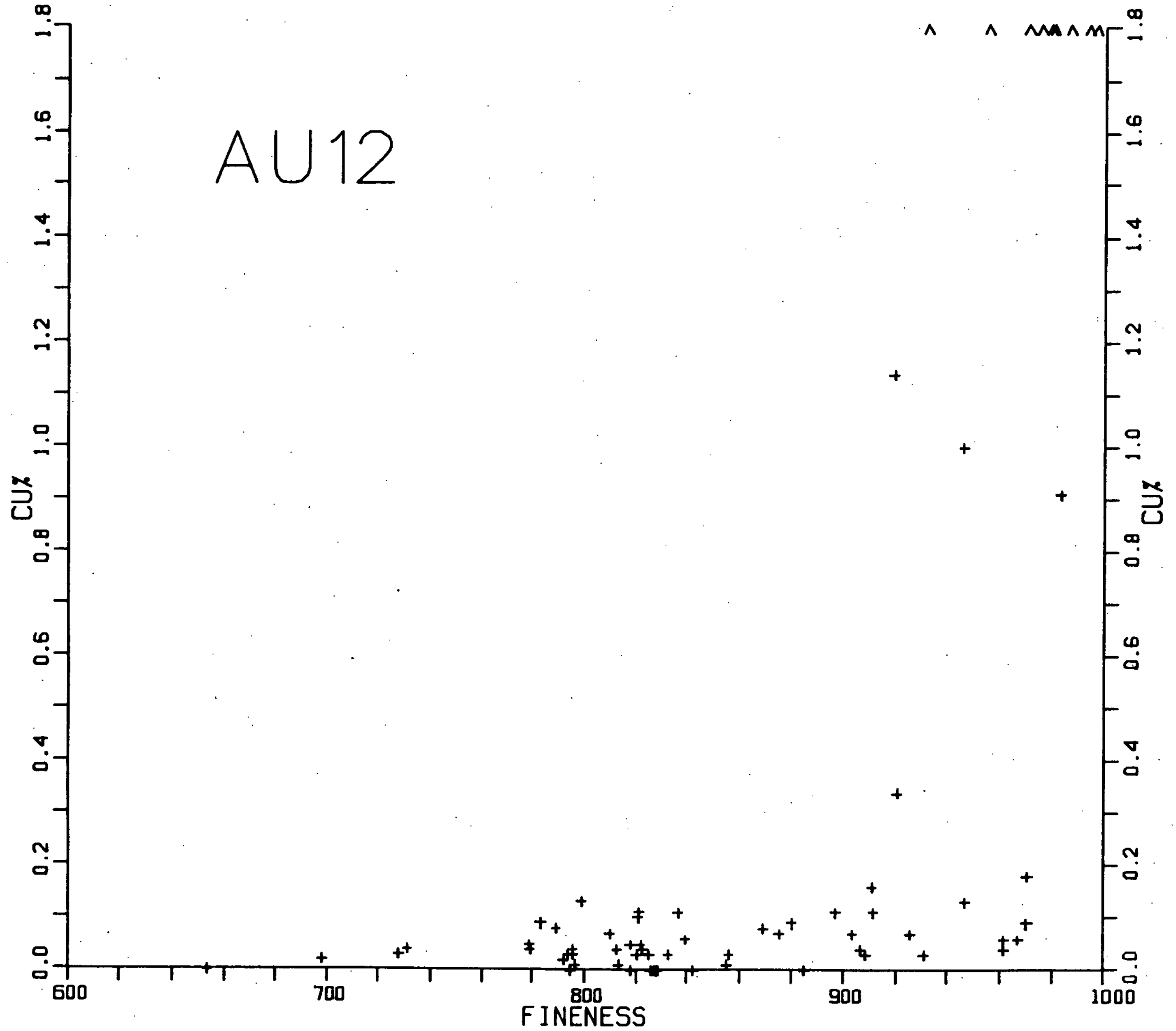


Figure 8c:
Lower Bridge

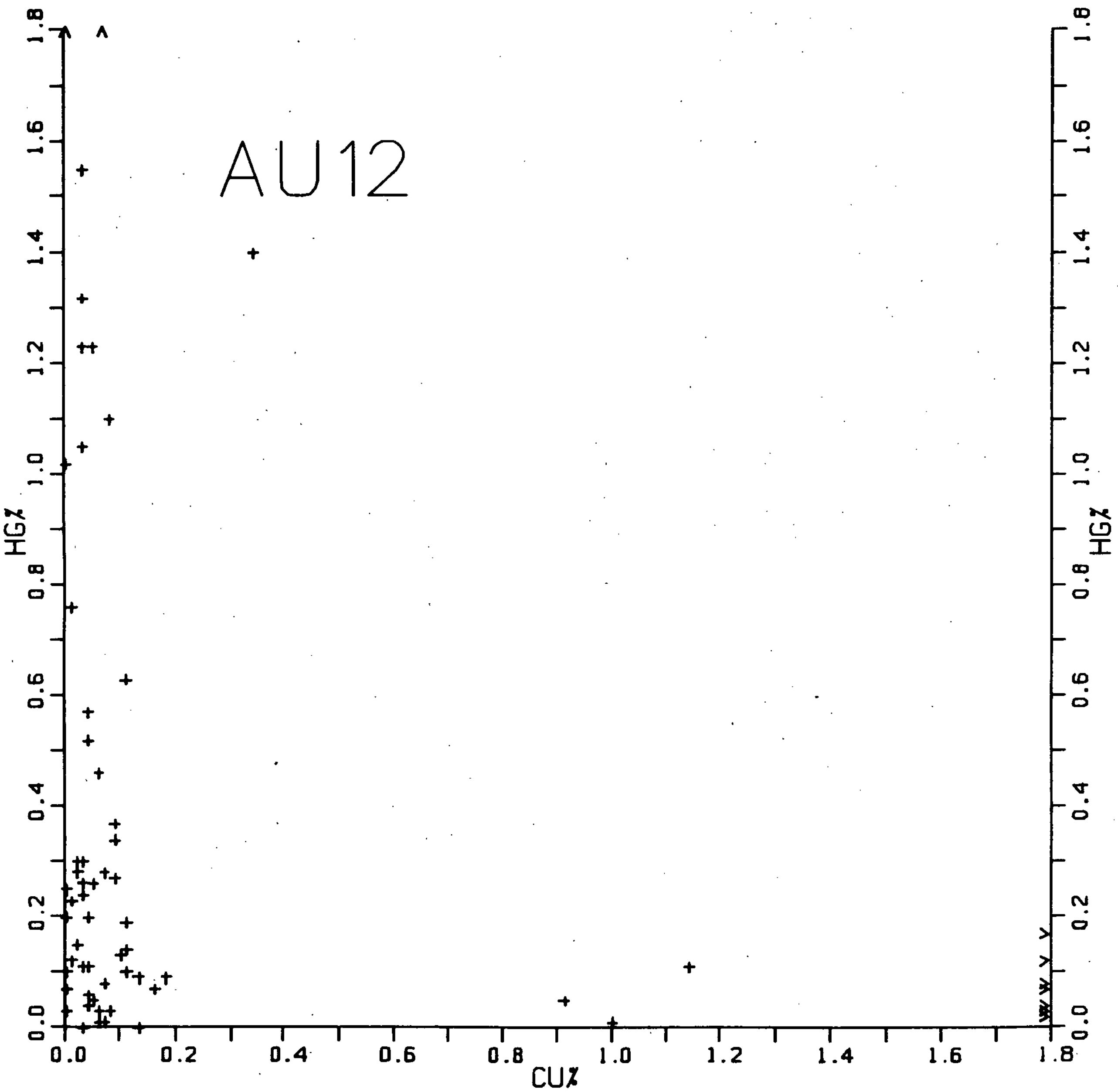


Figure 8d:
Lower Bridge

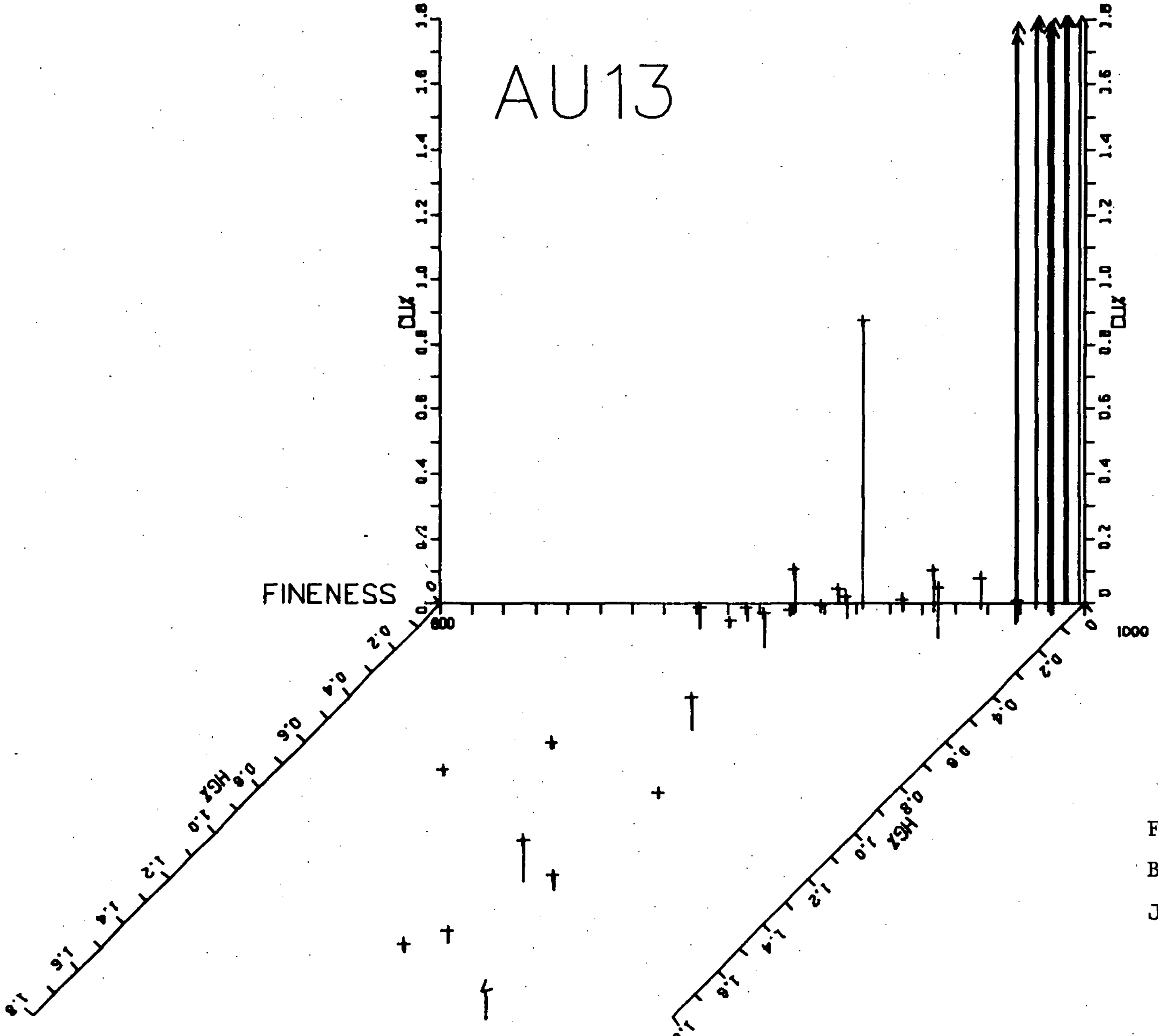


Figure 9a:
Bridge-Yalakom
Junction

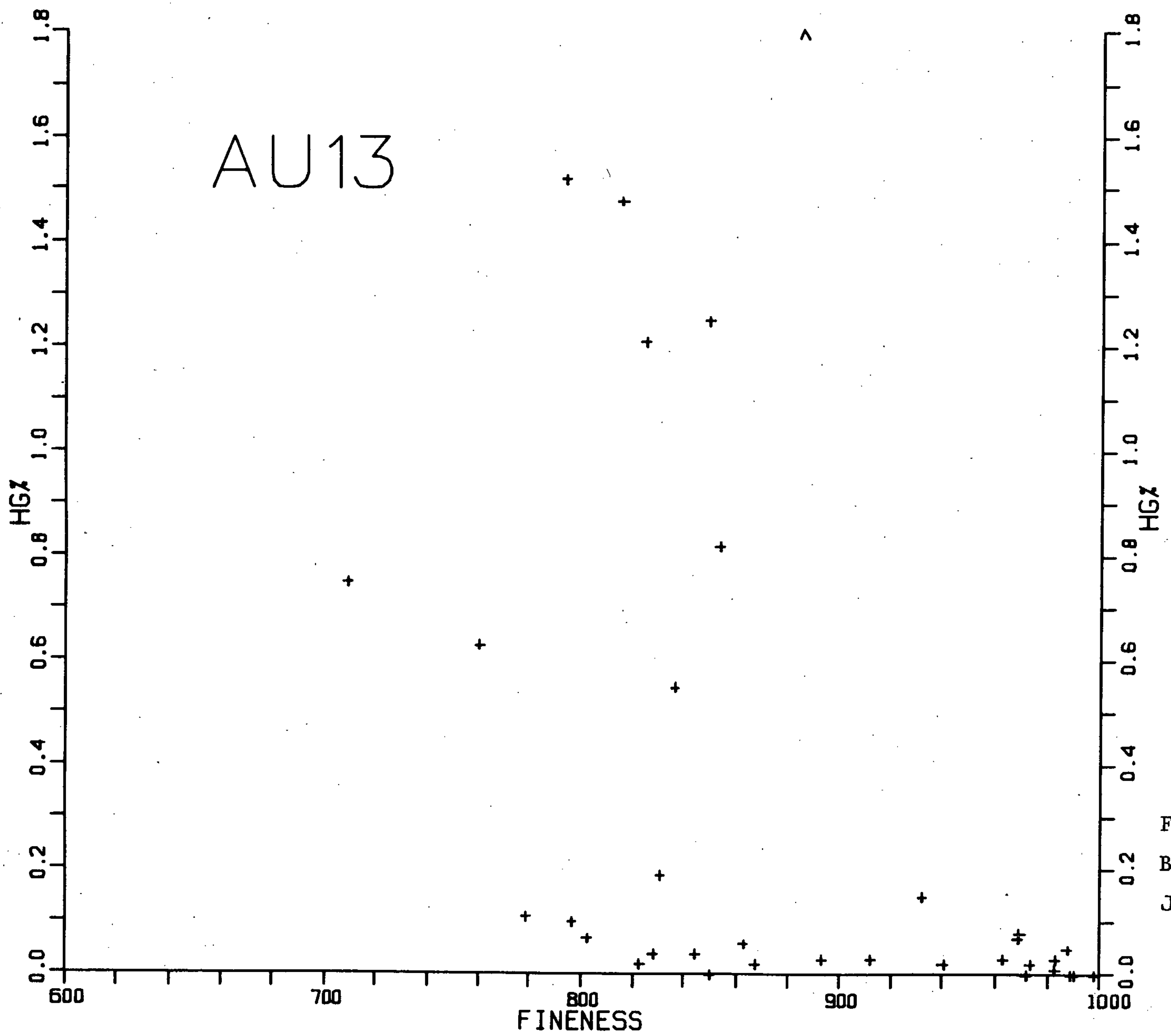


Figure 9b:
Bridge-Yalakom
Junction

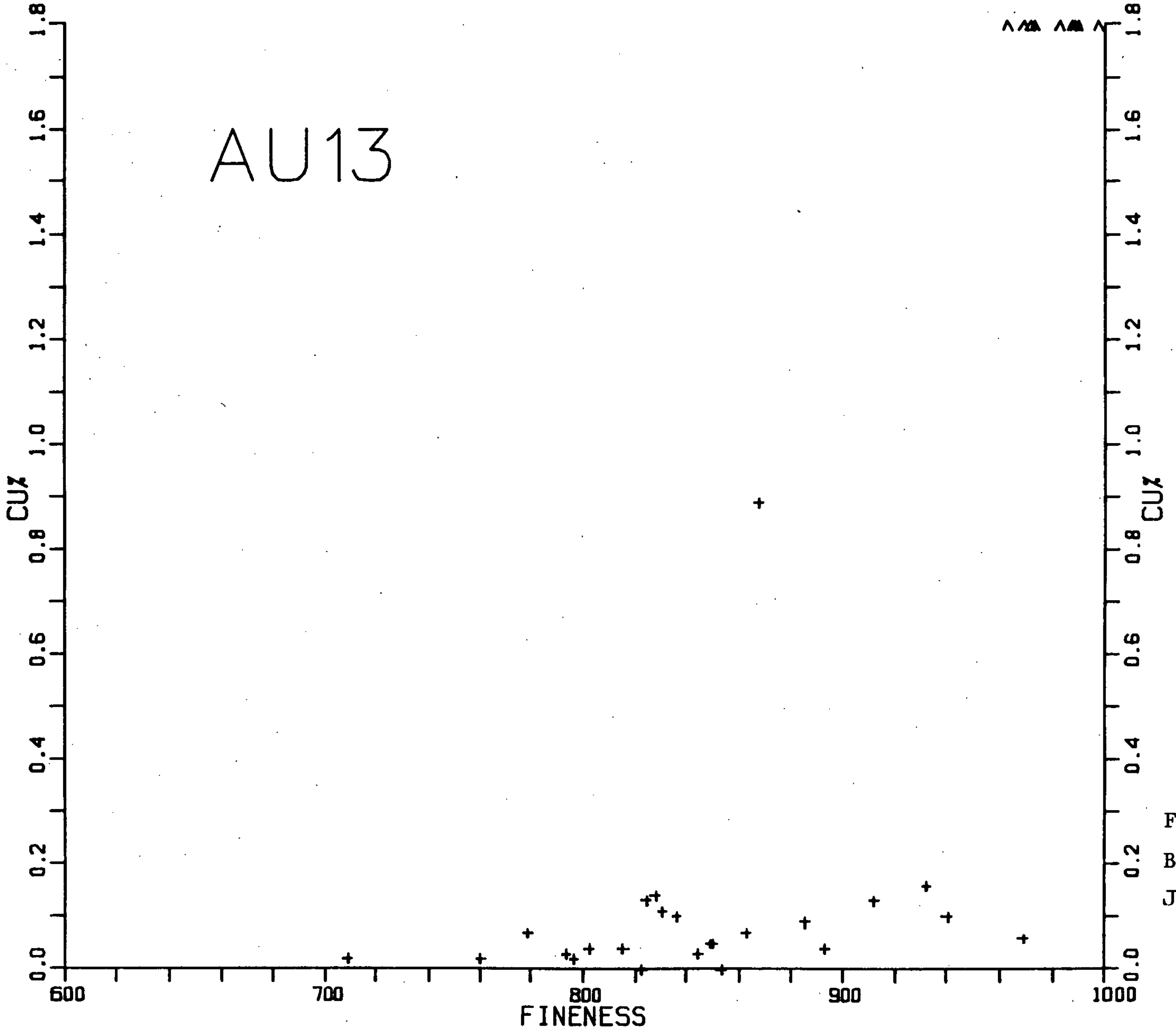


Figure 9c:
Bridge-Yalakom
Junction

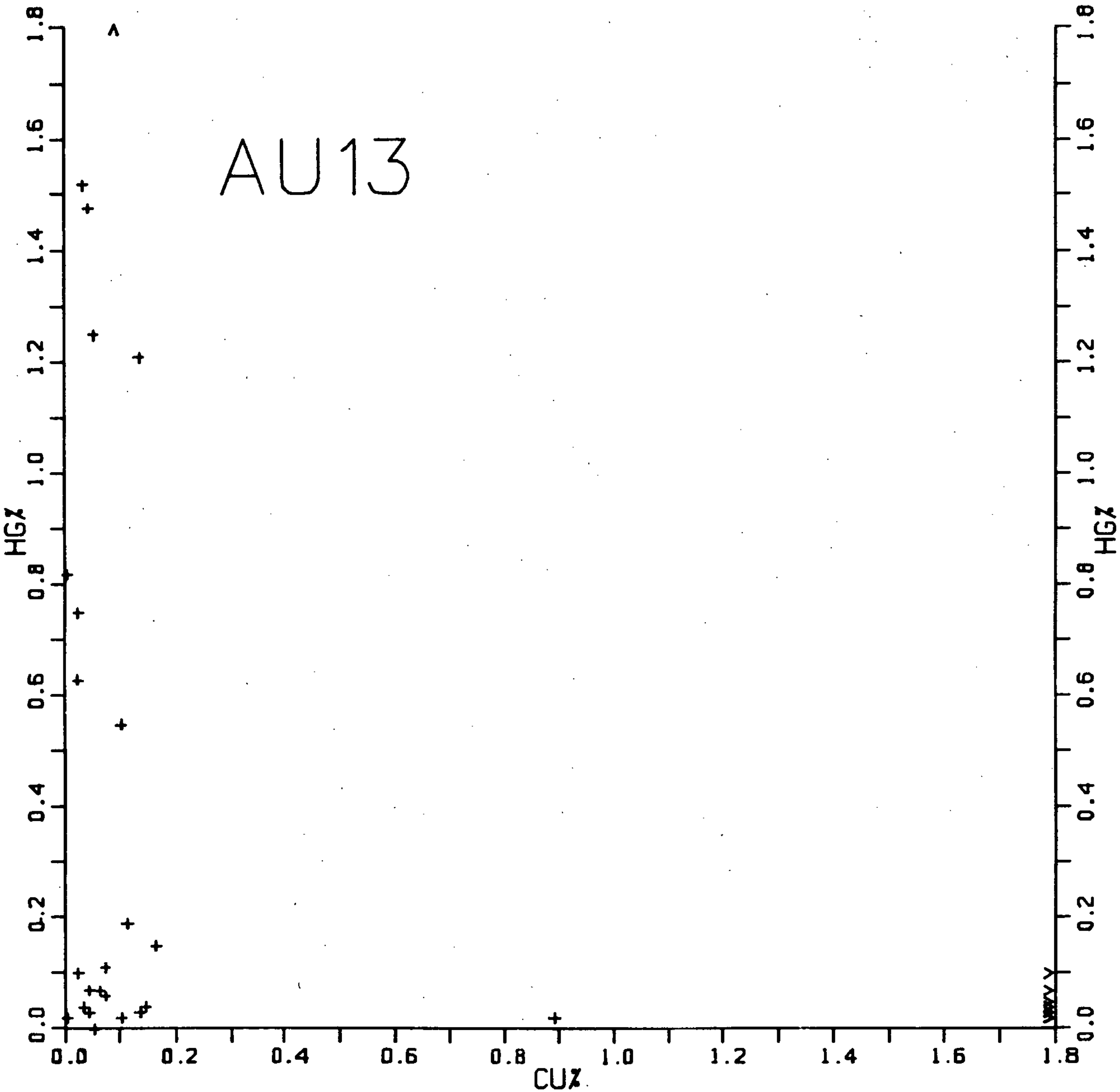


Figure 9d:
Bridge-Yalakom
Junction

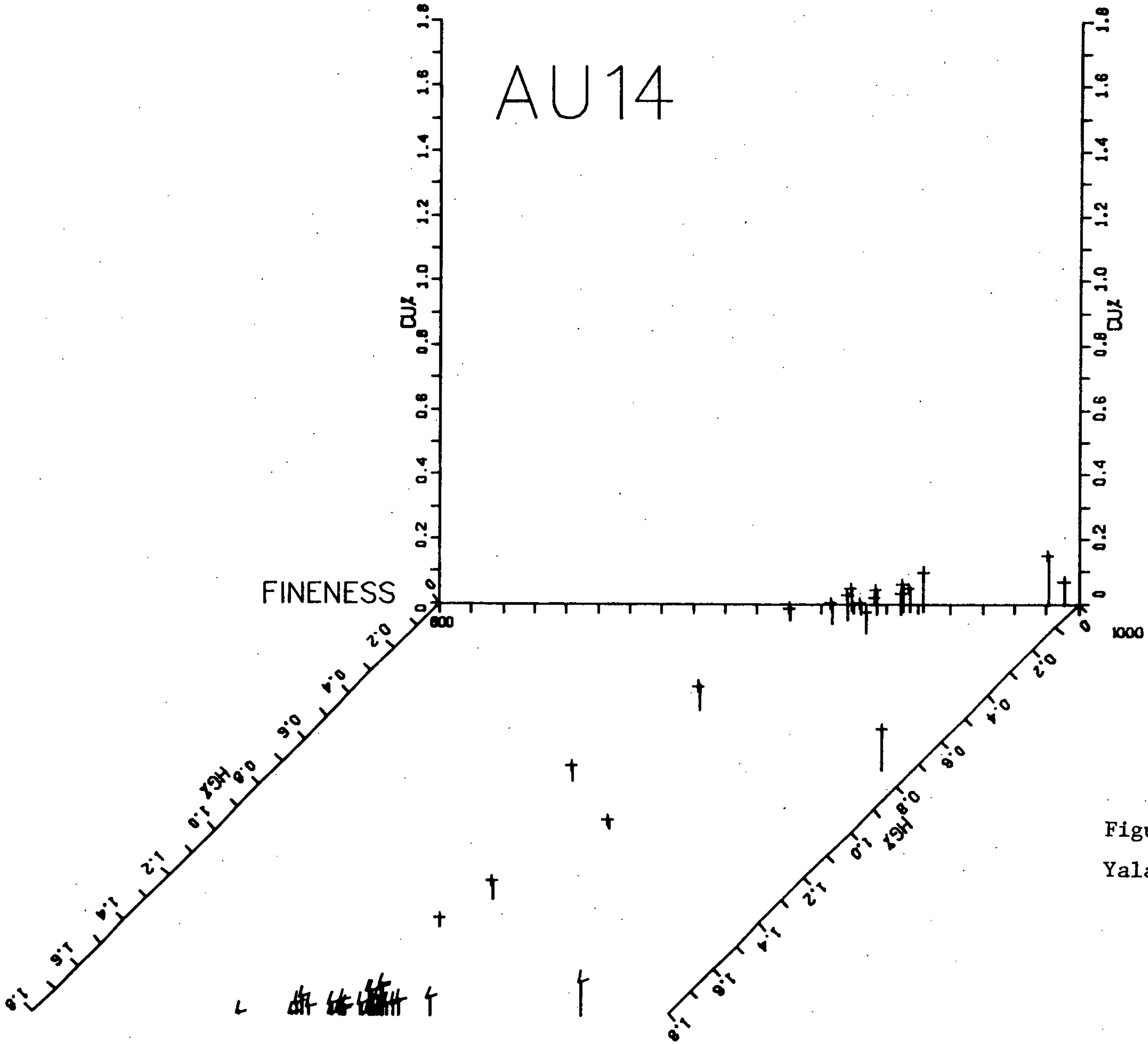


Figure 10a:
Yalakom

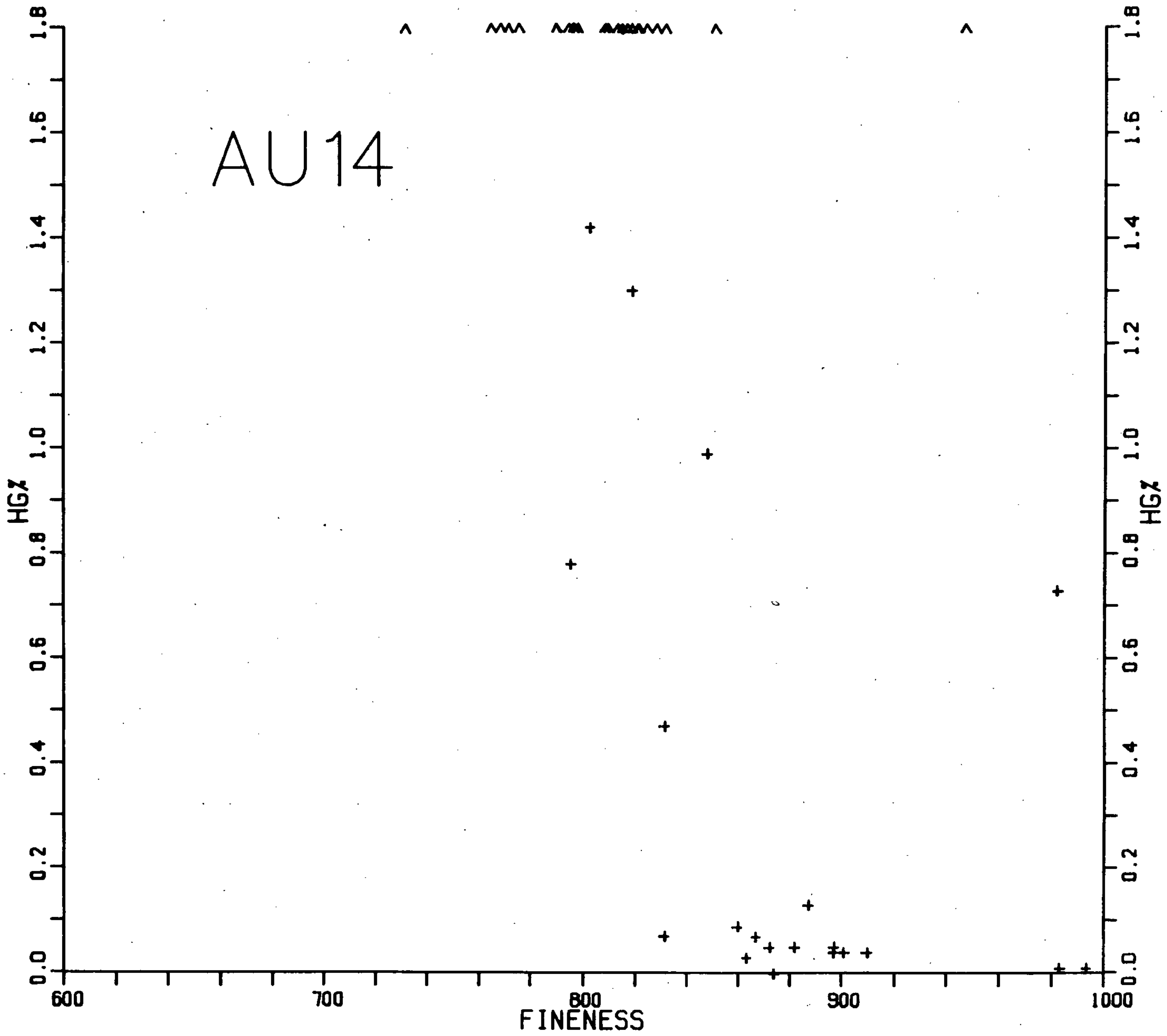


Figure 10b:
Yalakom

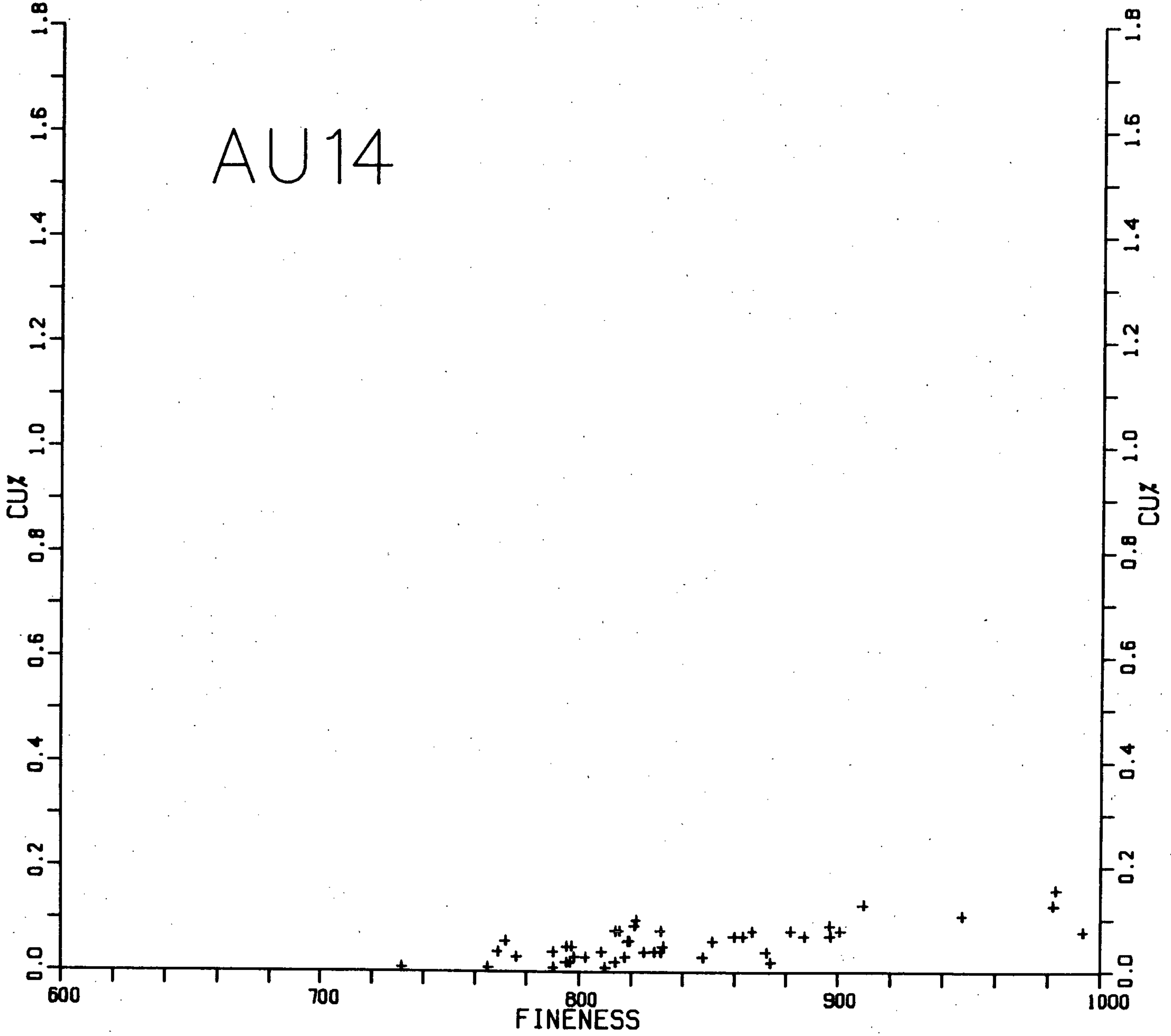


Figure 10c:
Yalakom

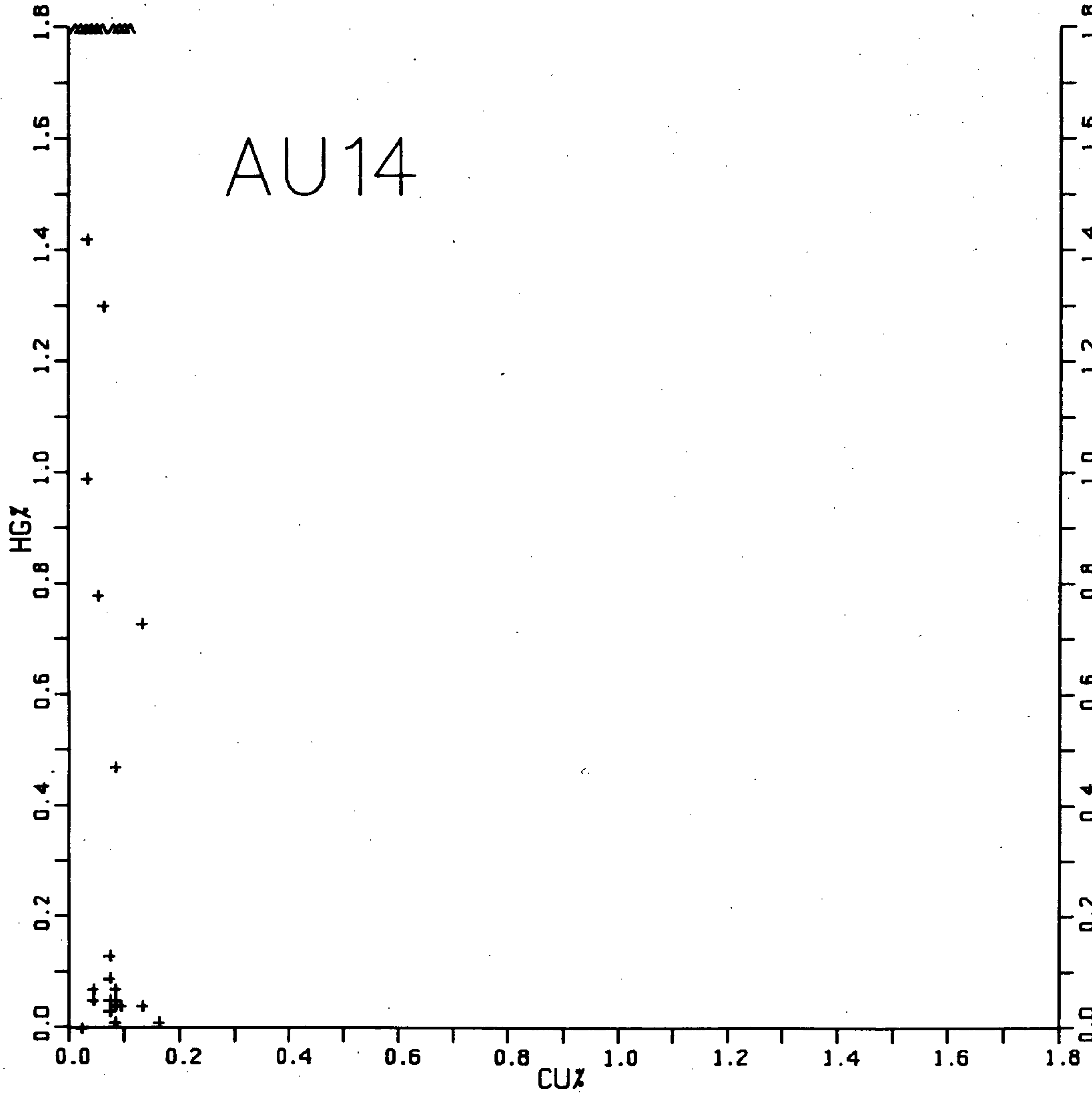


Figure 10d:
Yalakom

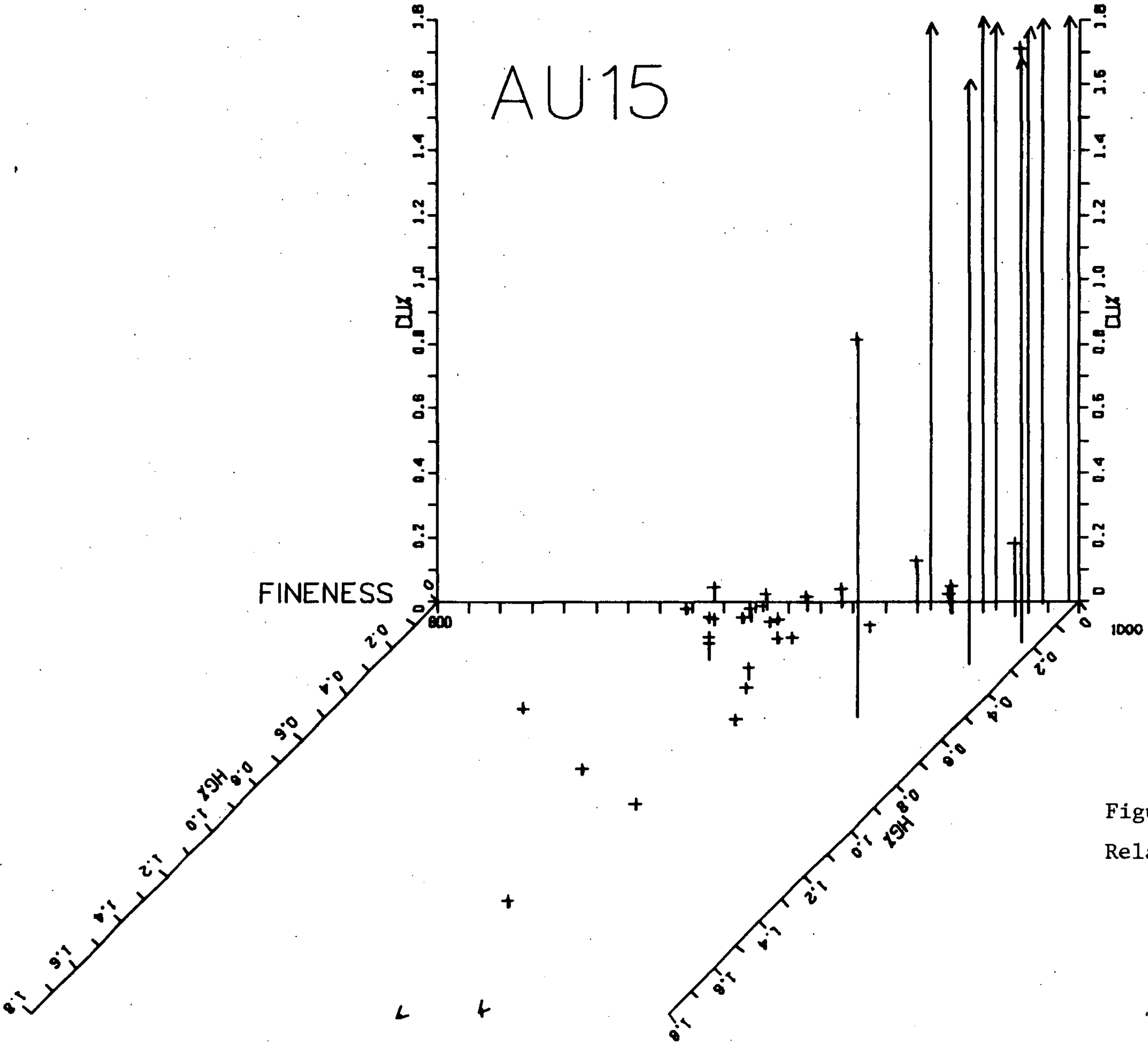


Figure 11a:
Relay

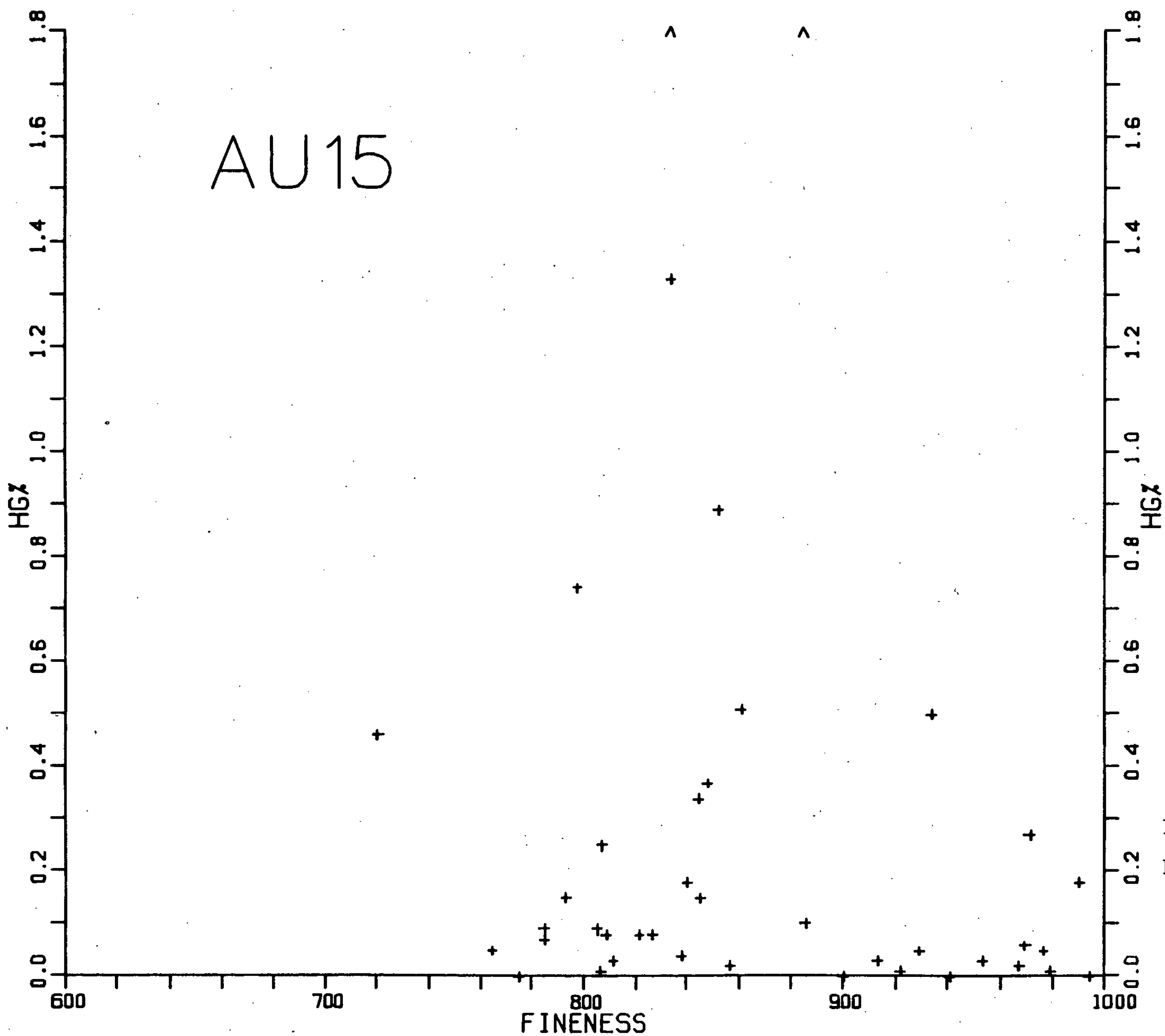


Figure 11b:
Relay

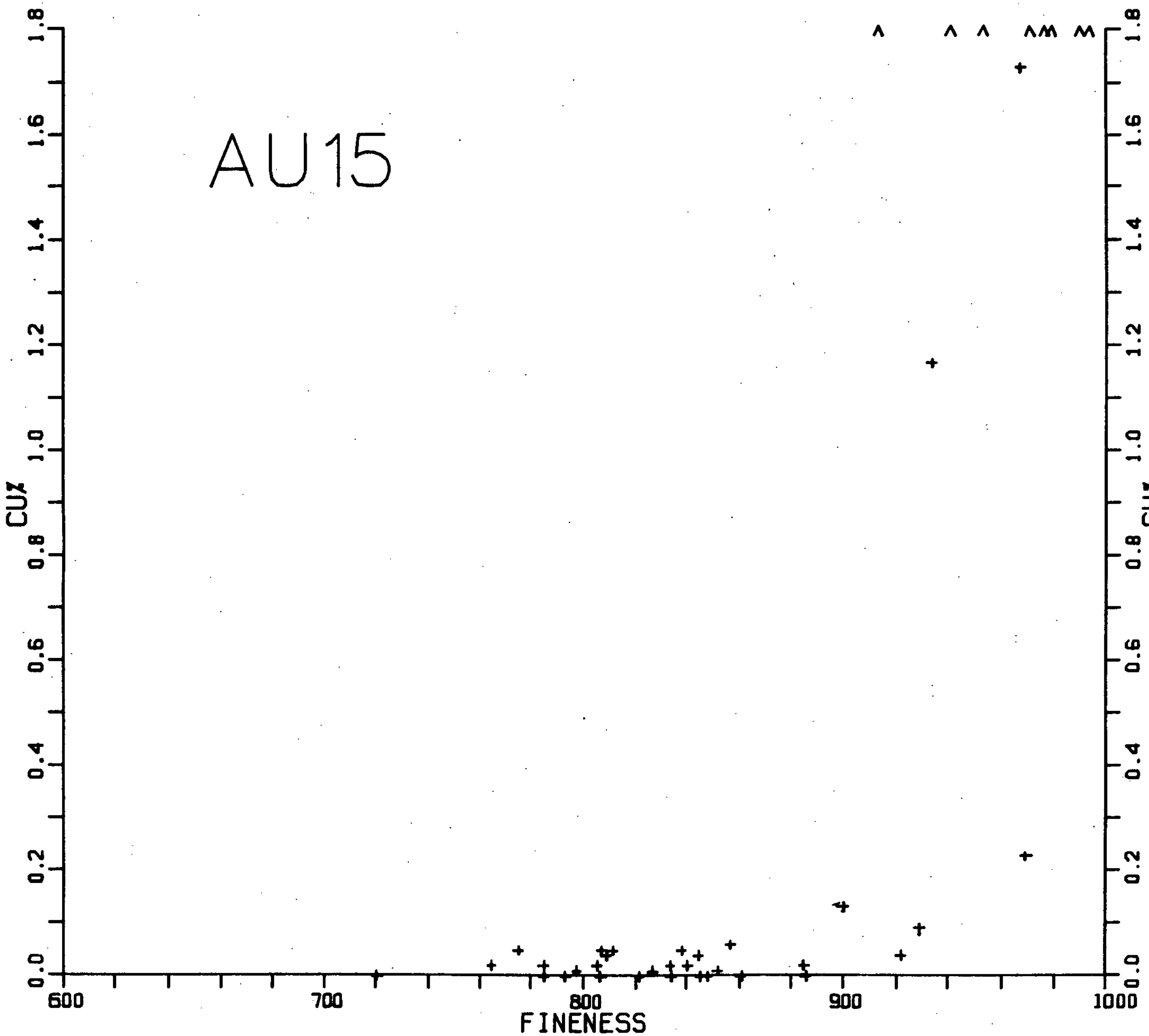


Figure 11c:
Relay

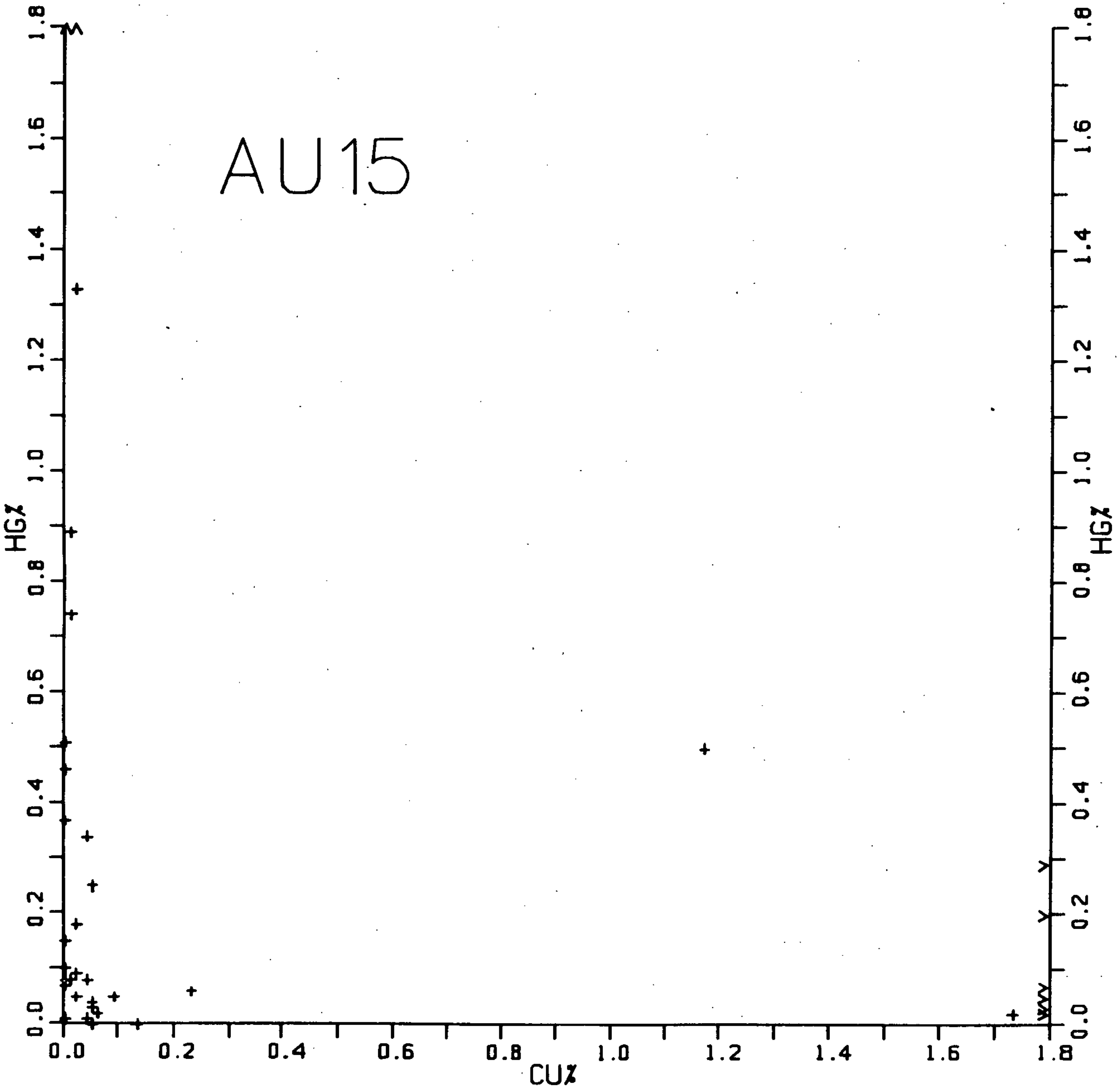


Figure 11d:
Relay

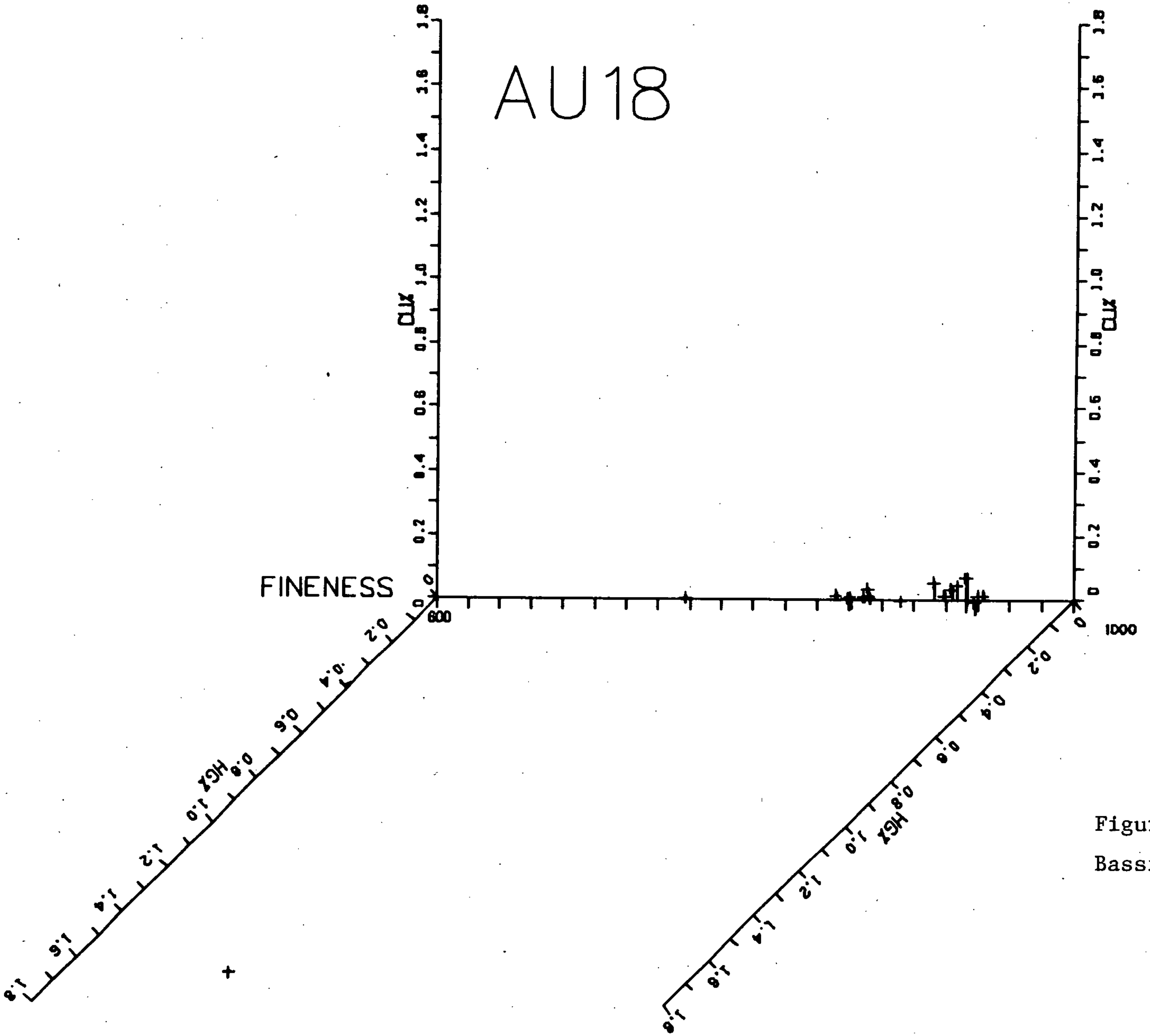


Figure 12a:
Bassford

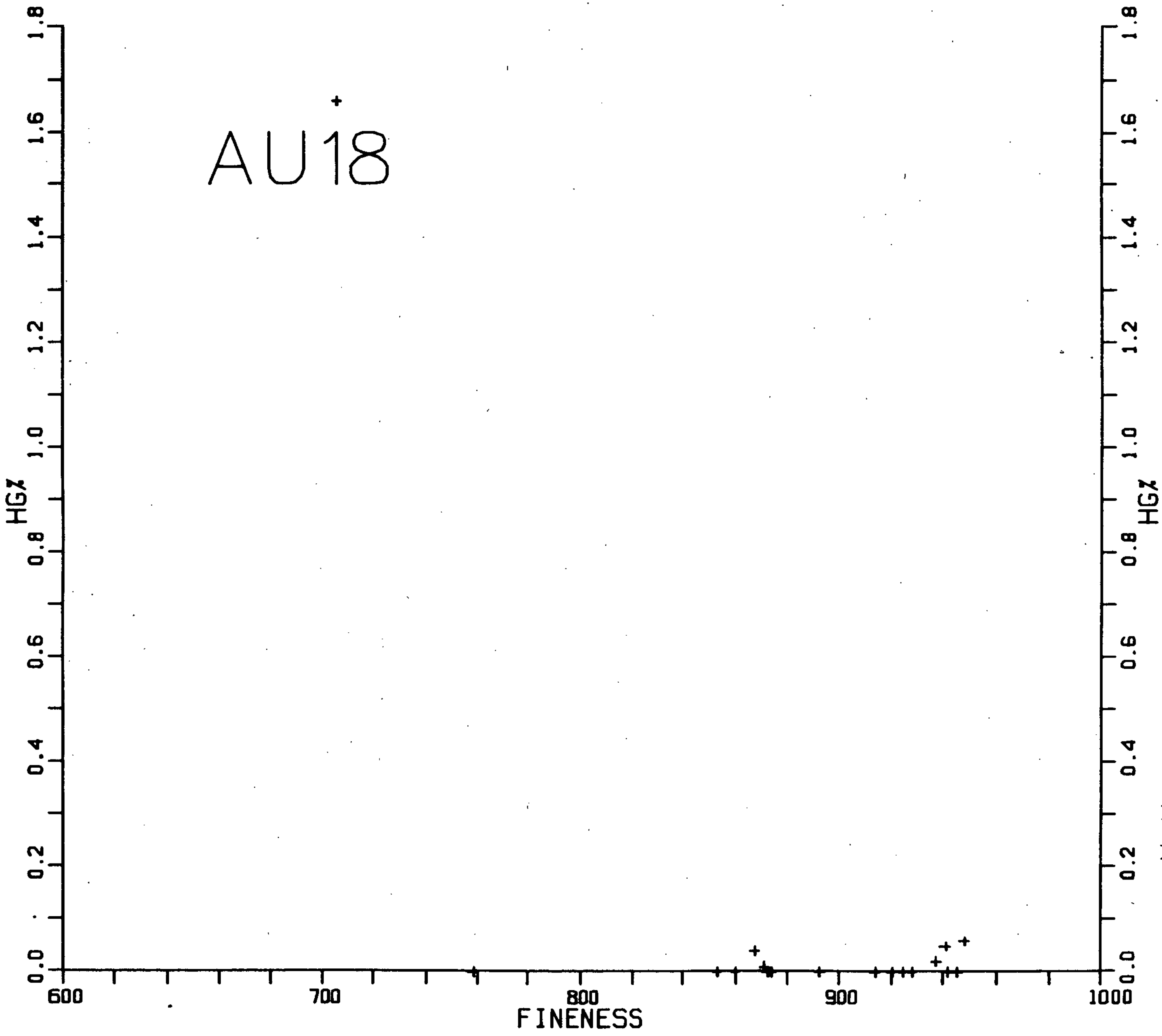


Figure 12b:
Bassford

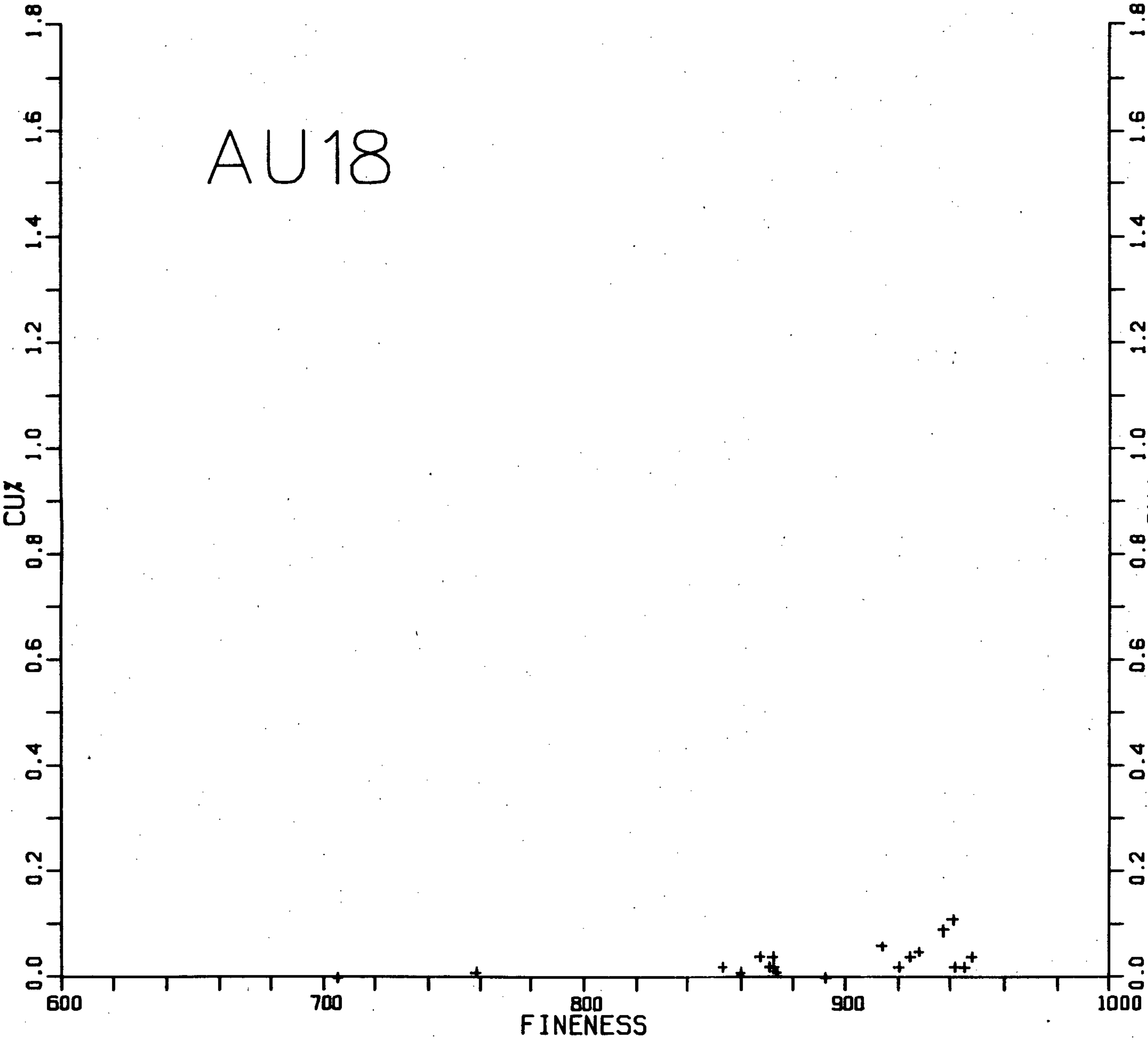


Figure 12c:
Bassford

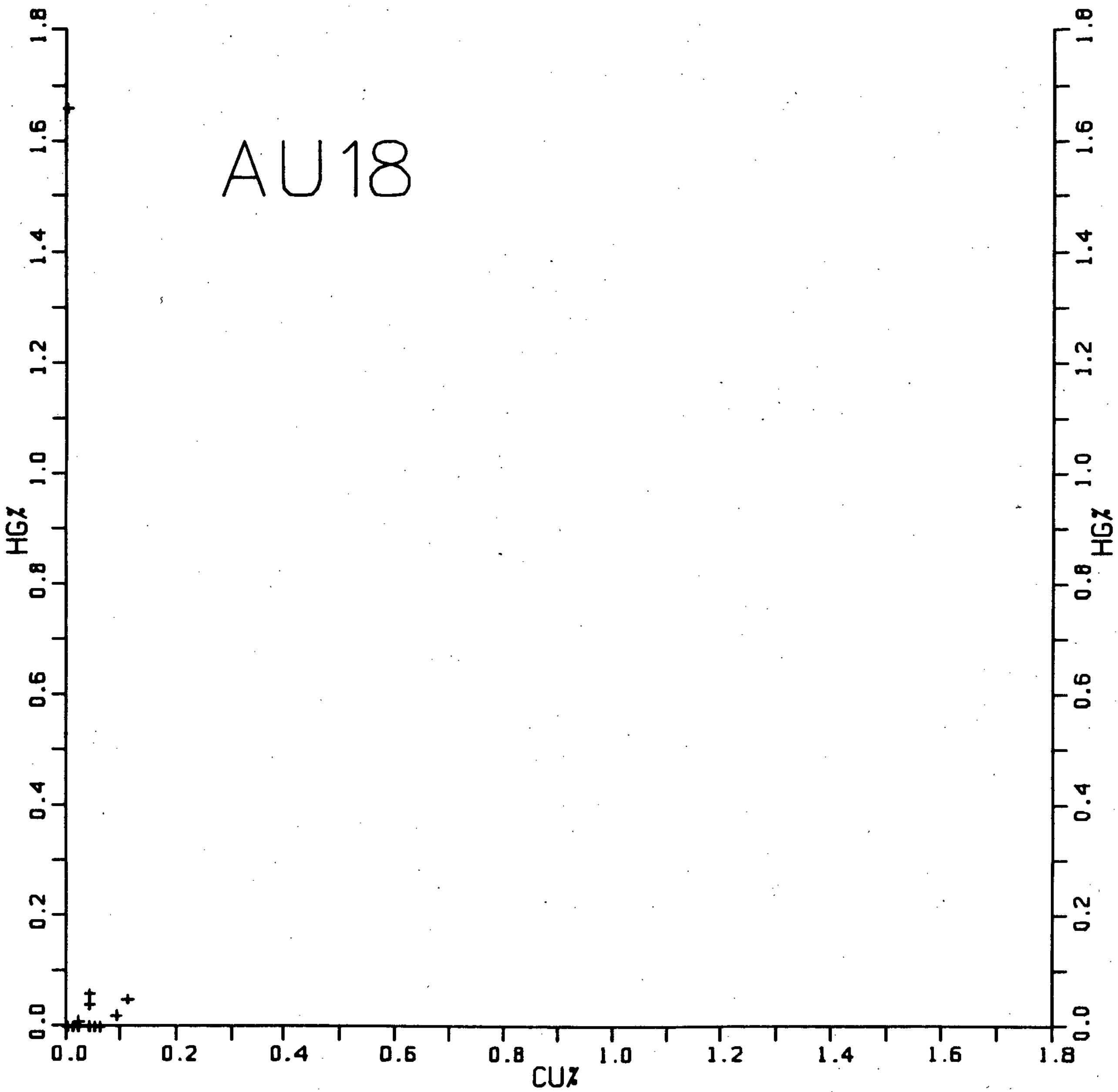


Figure 12d:
Bassford

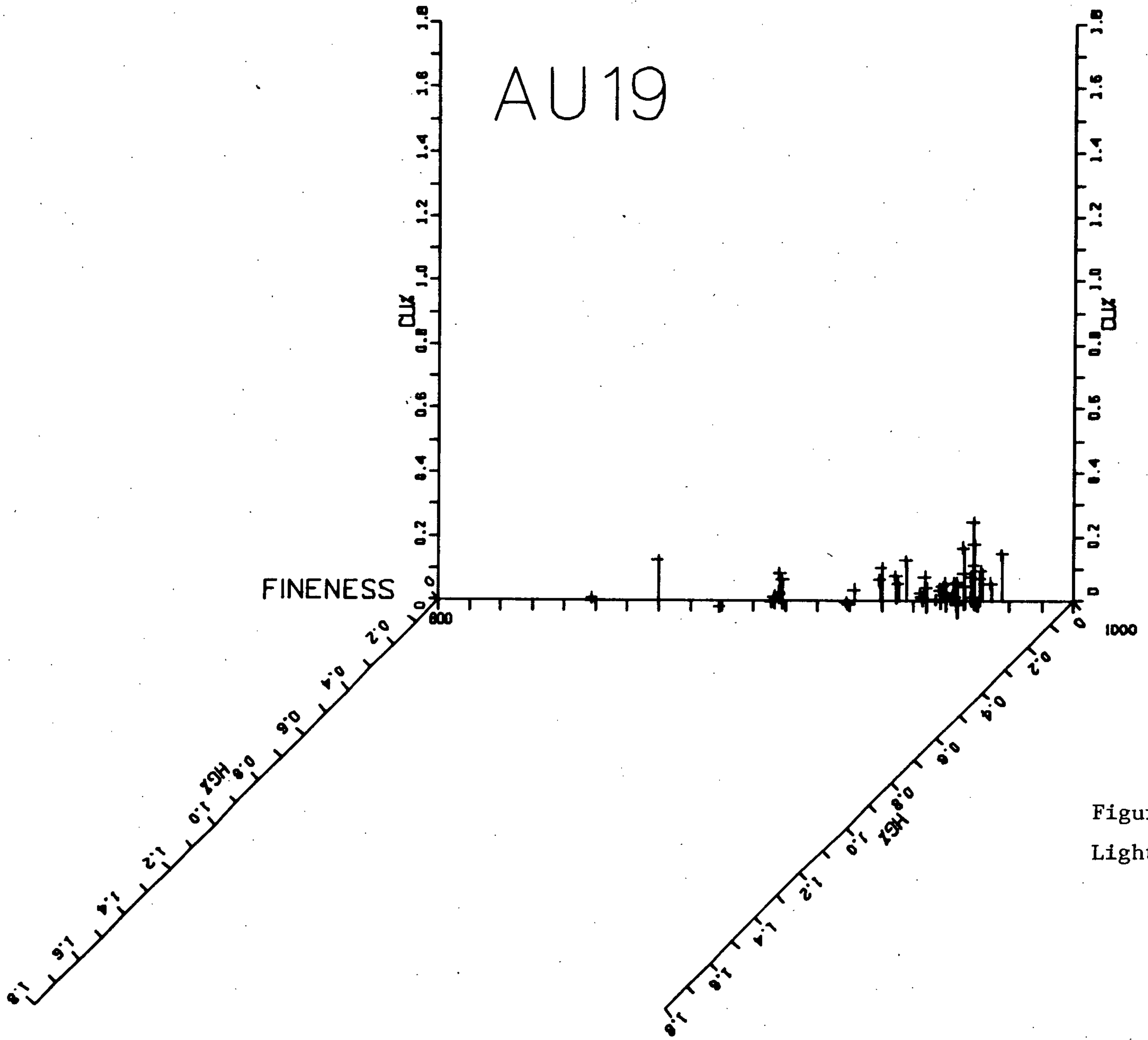


Figure 13a:
Lightening

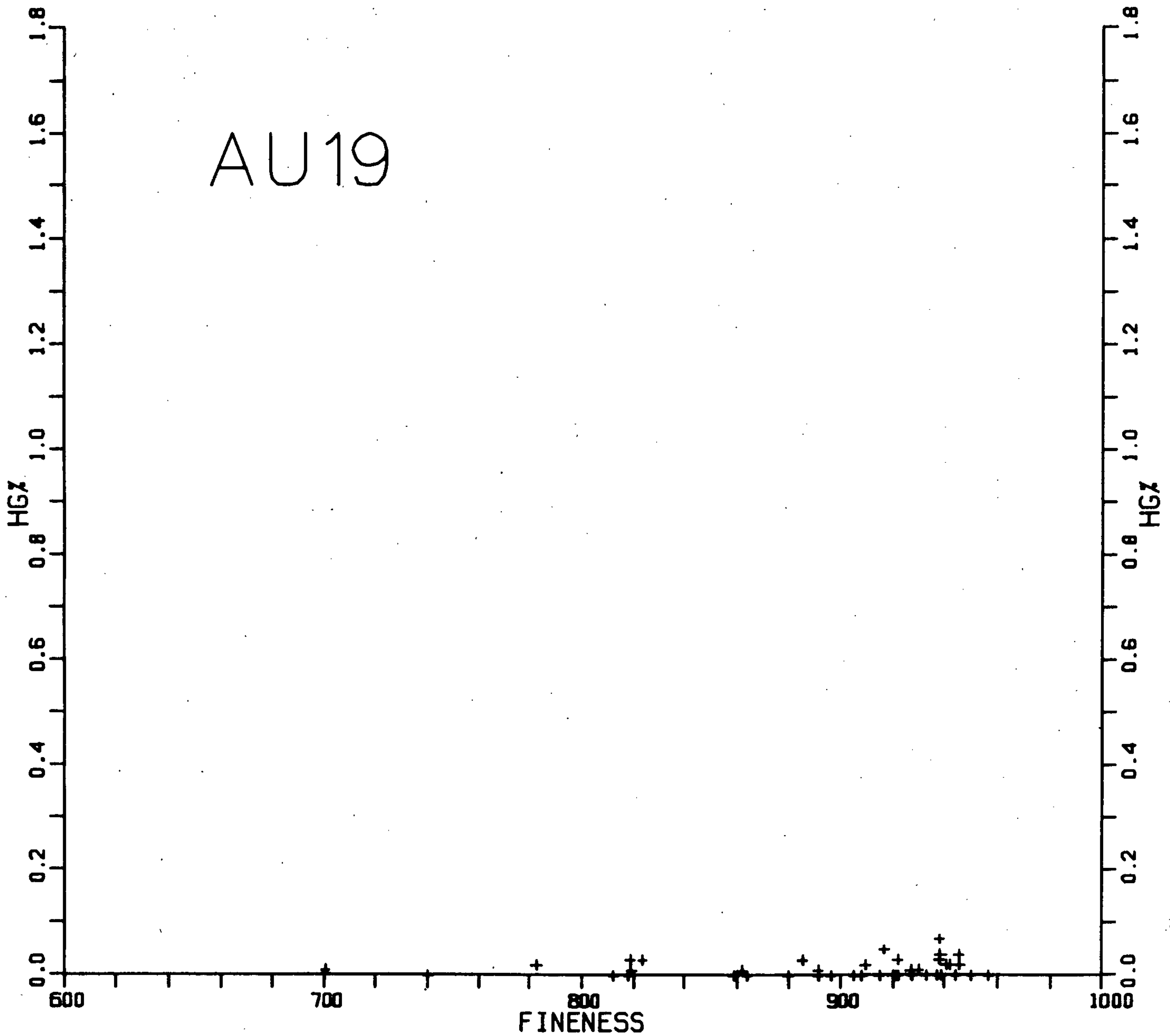


Figure 13b:
Lightening

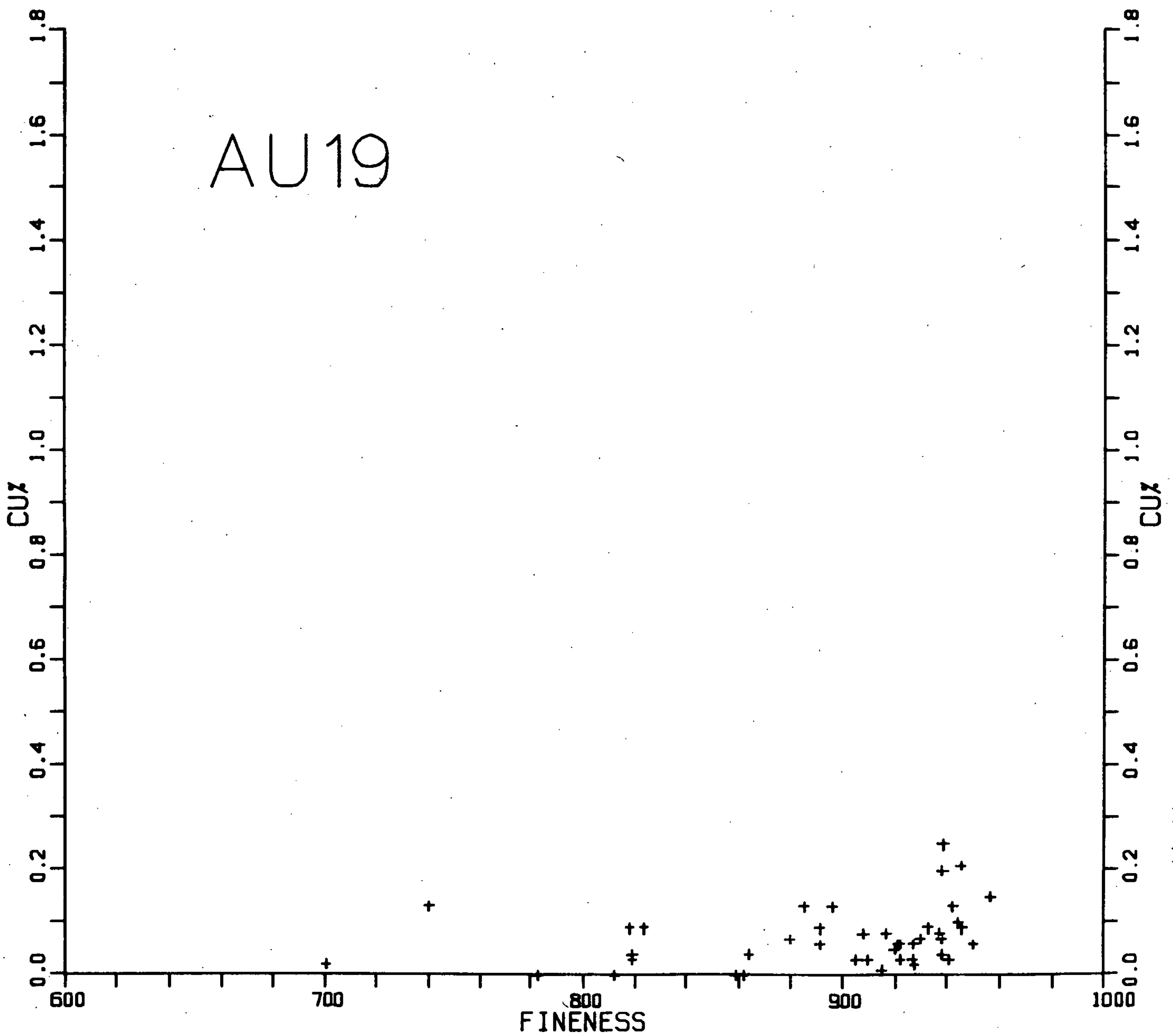


Figure 13c:
Lightening

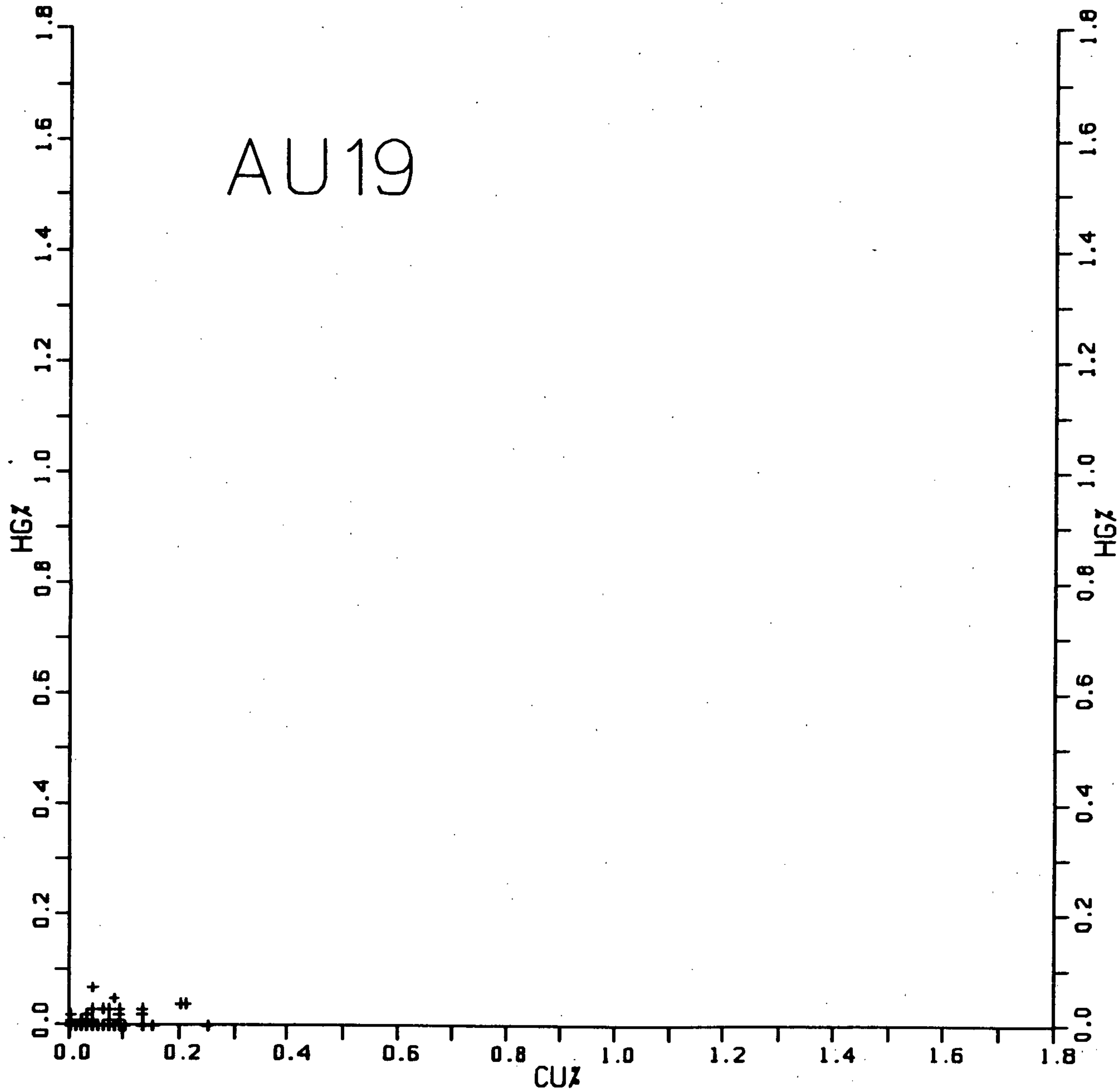


Figure 13d:
Lightening

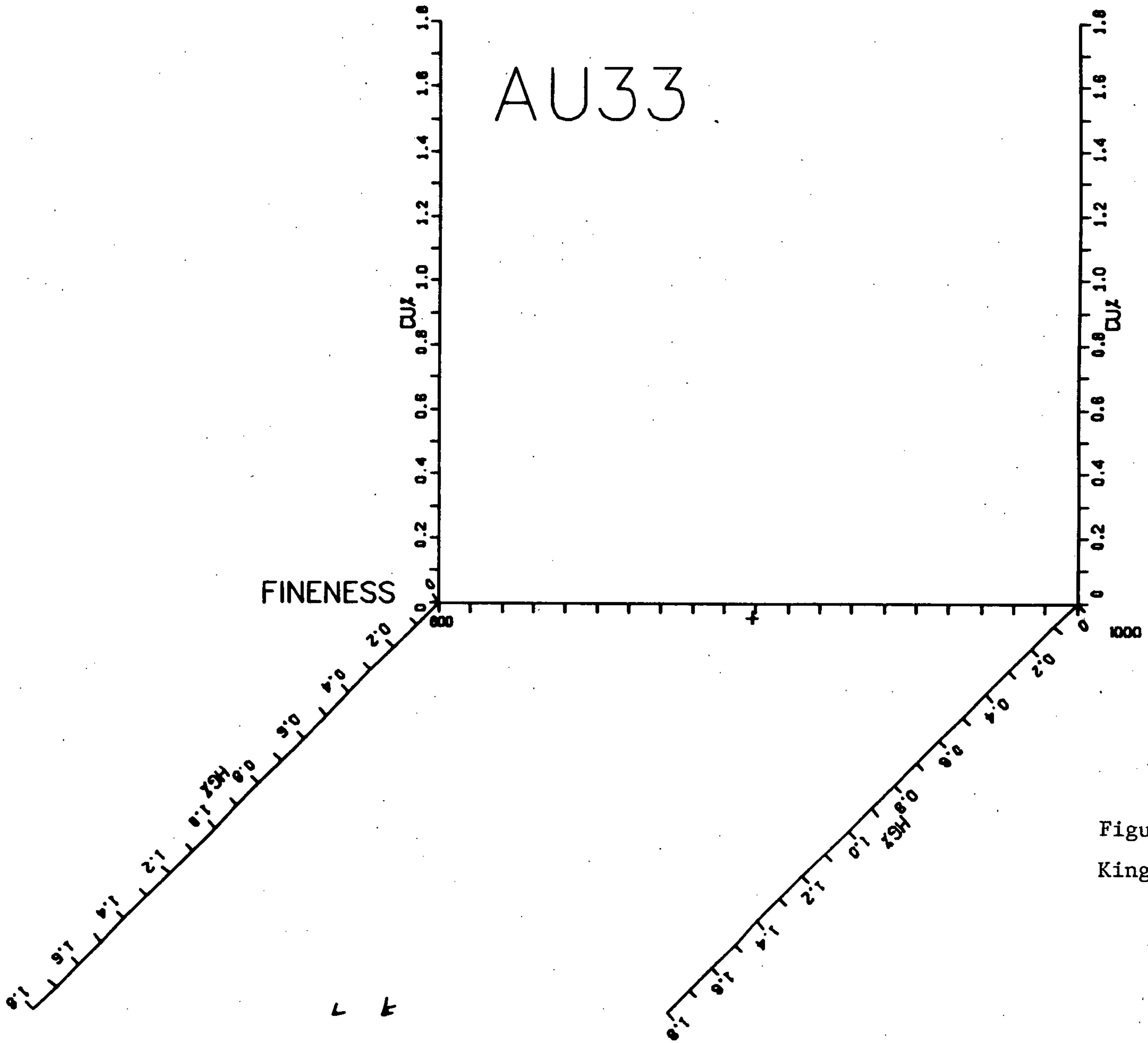


Figure 14a:
King Curve

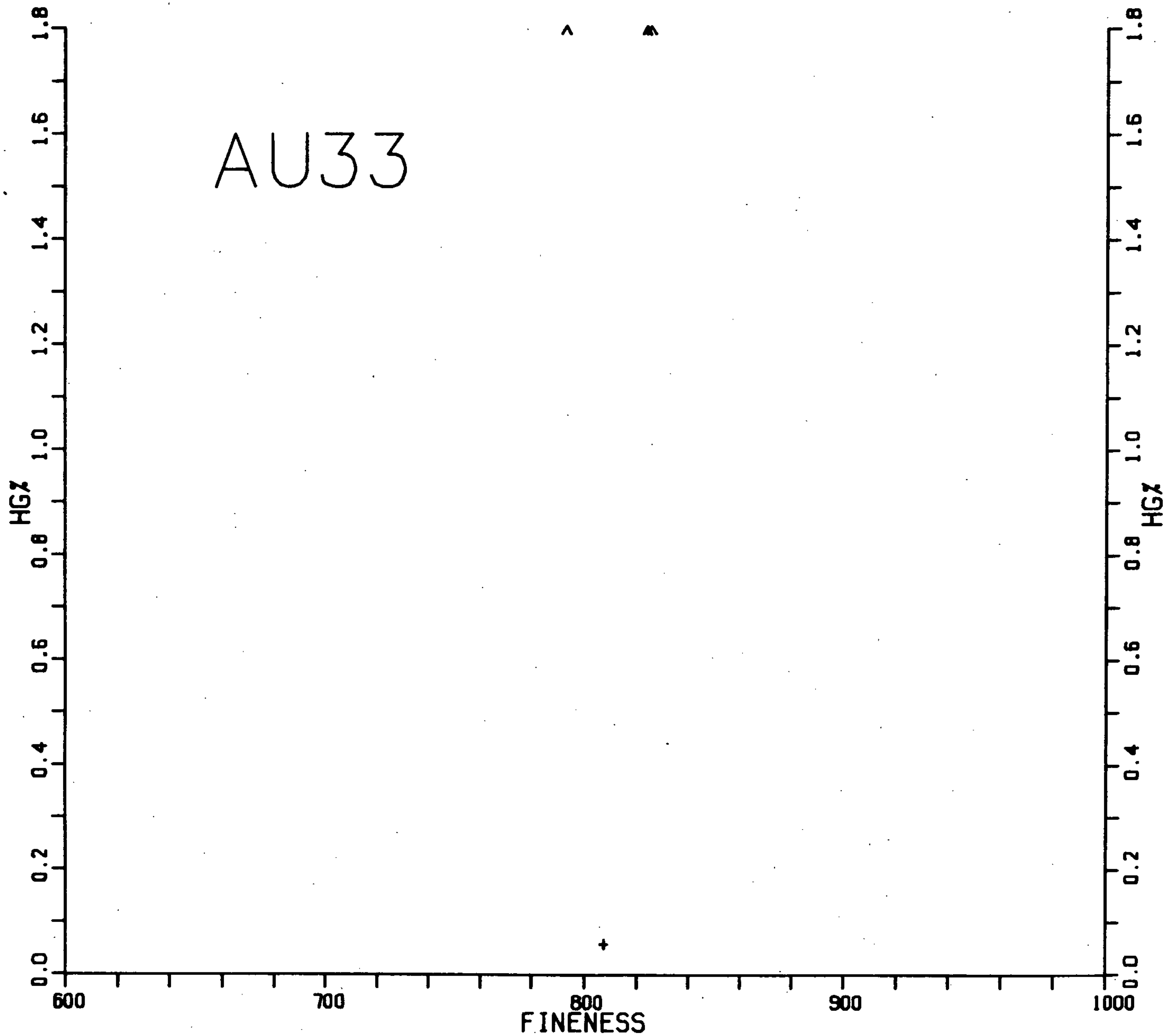


Figure 14b:
King Curve

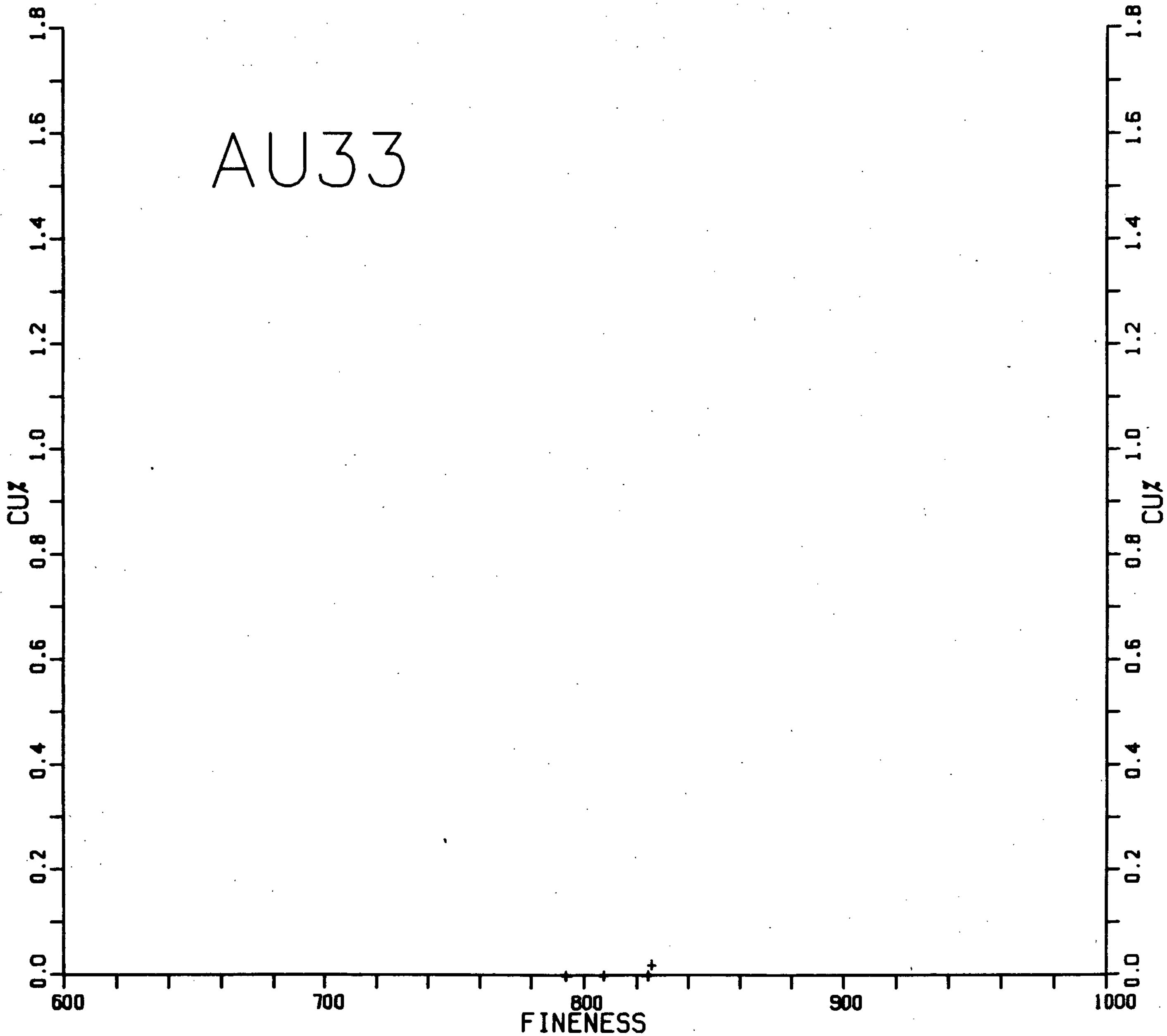


Figure 14c:
King Curve

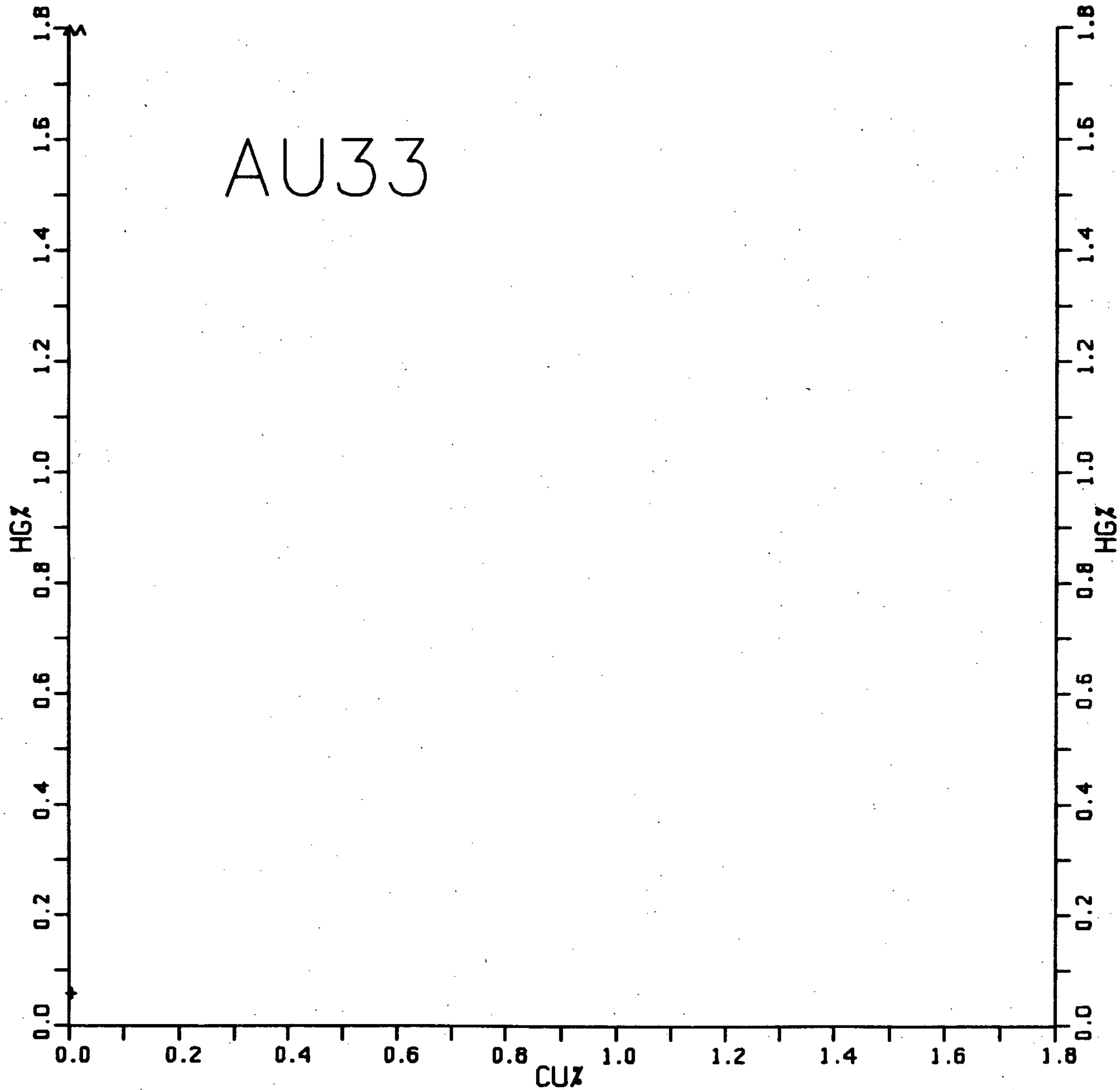


Figure 14d:
King Curve

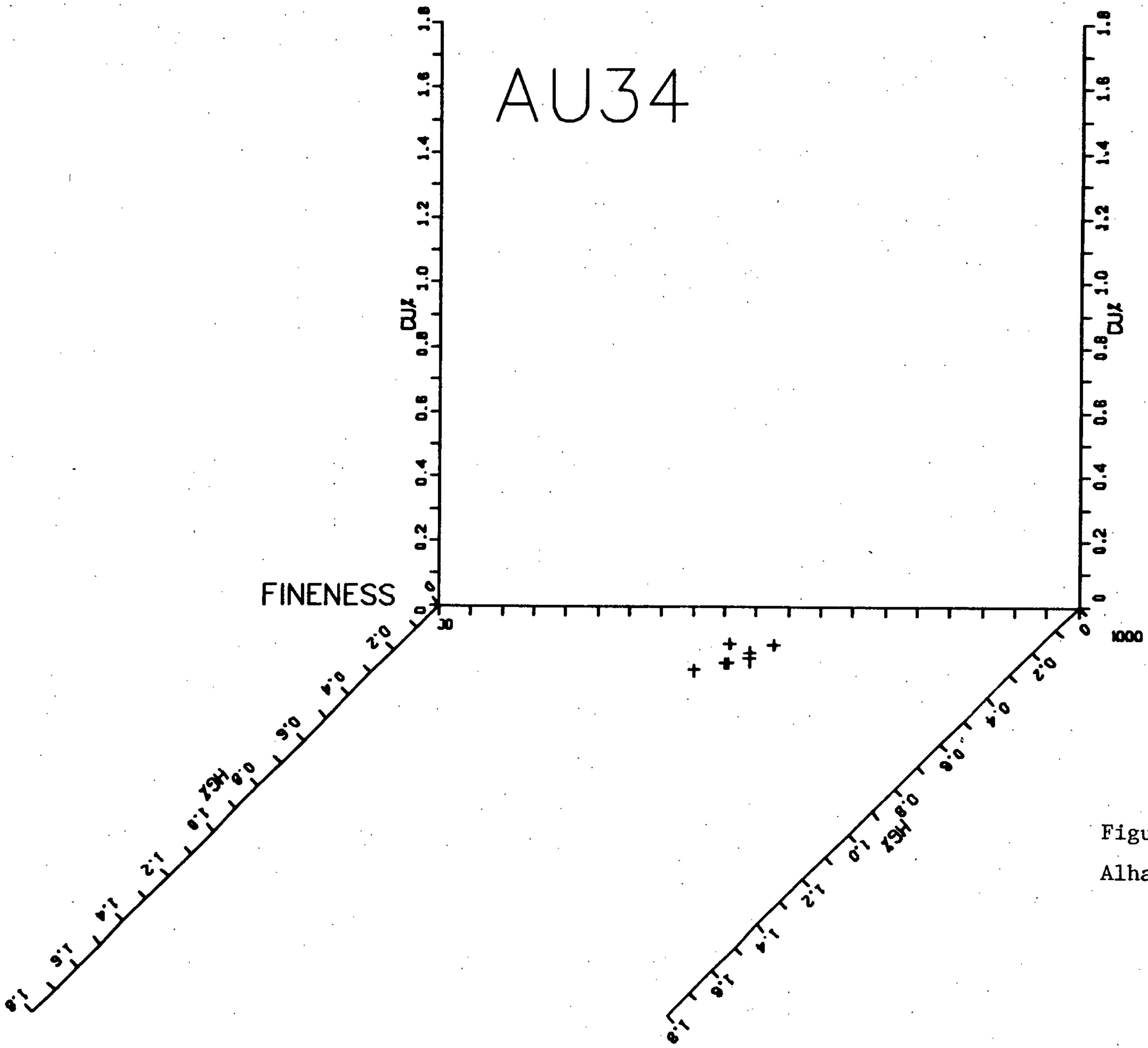


Figure 15a:
Alhambra

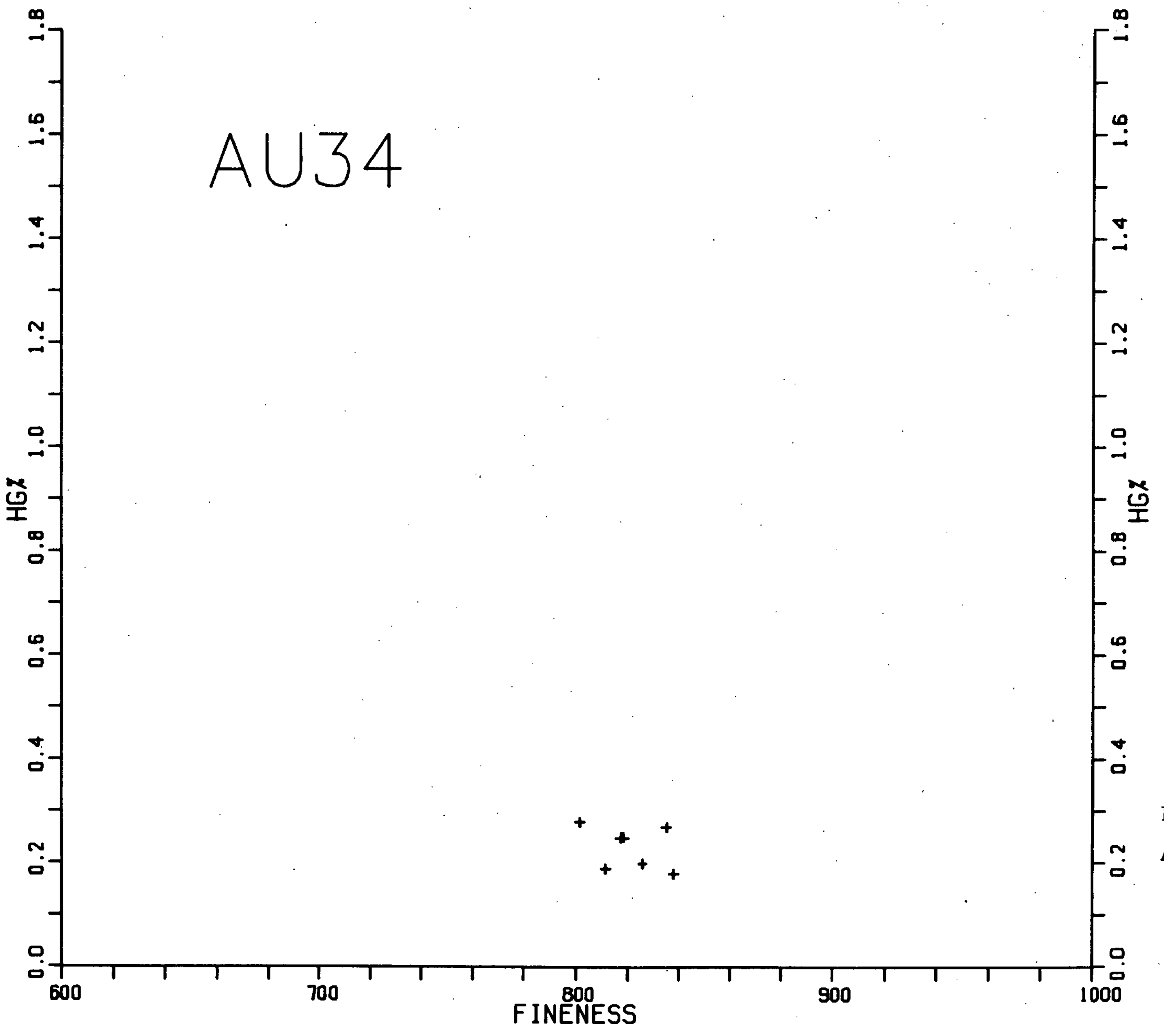


Figure 15b:
Alhambra

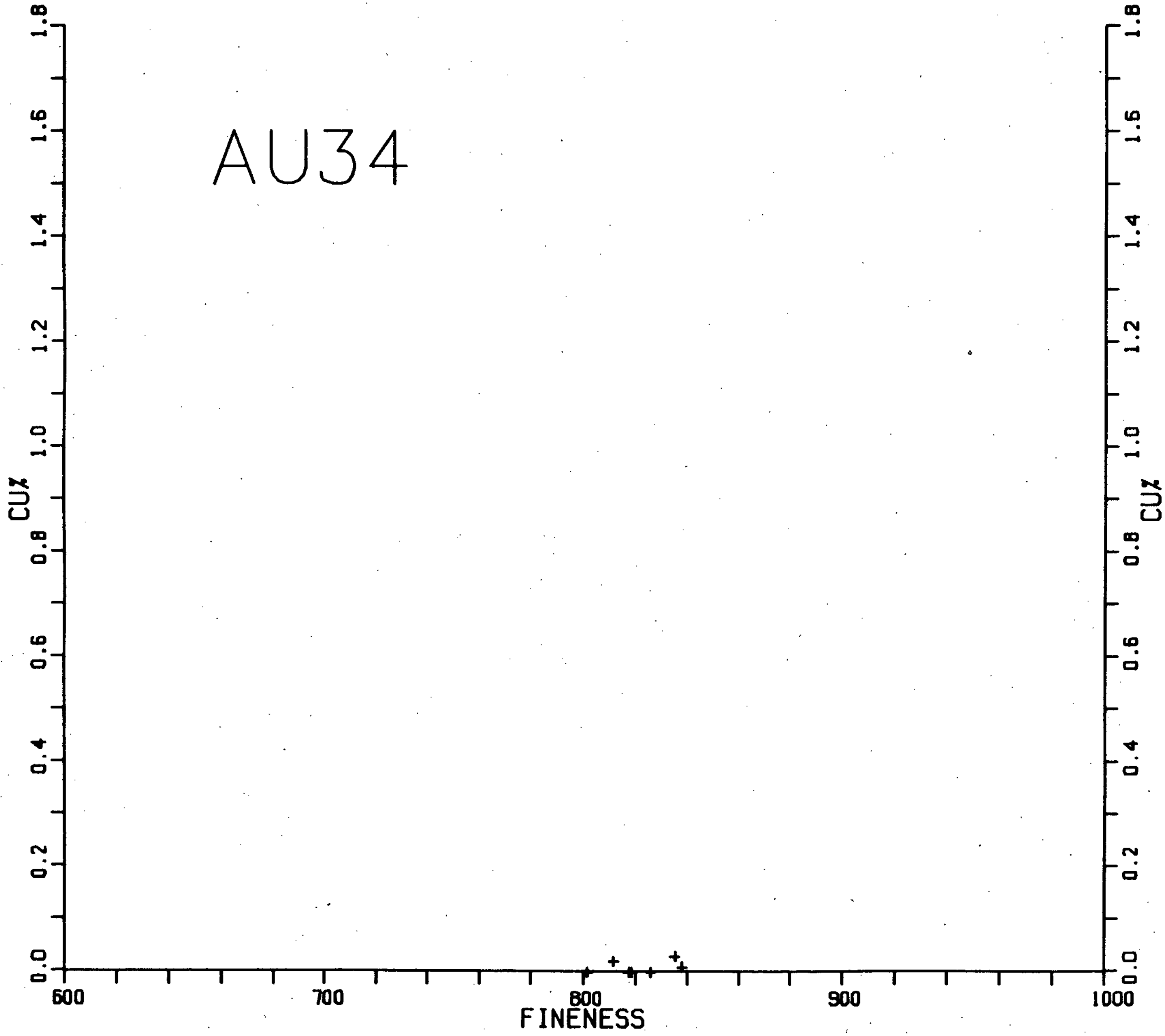


Figure 15c:
Alhambra

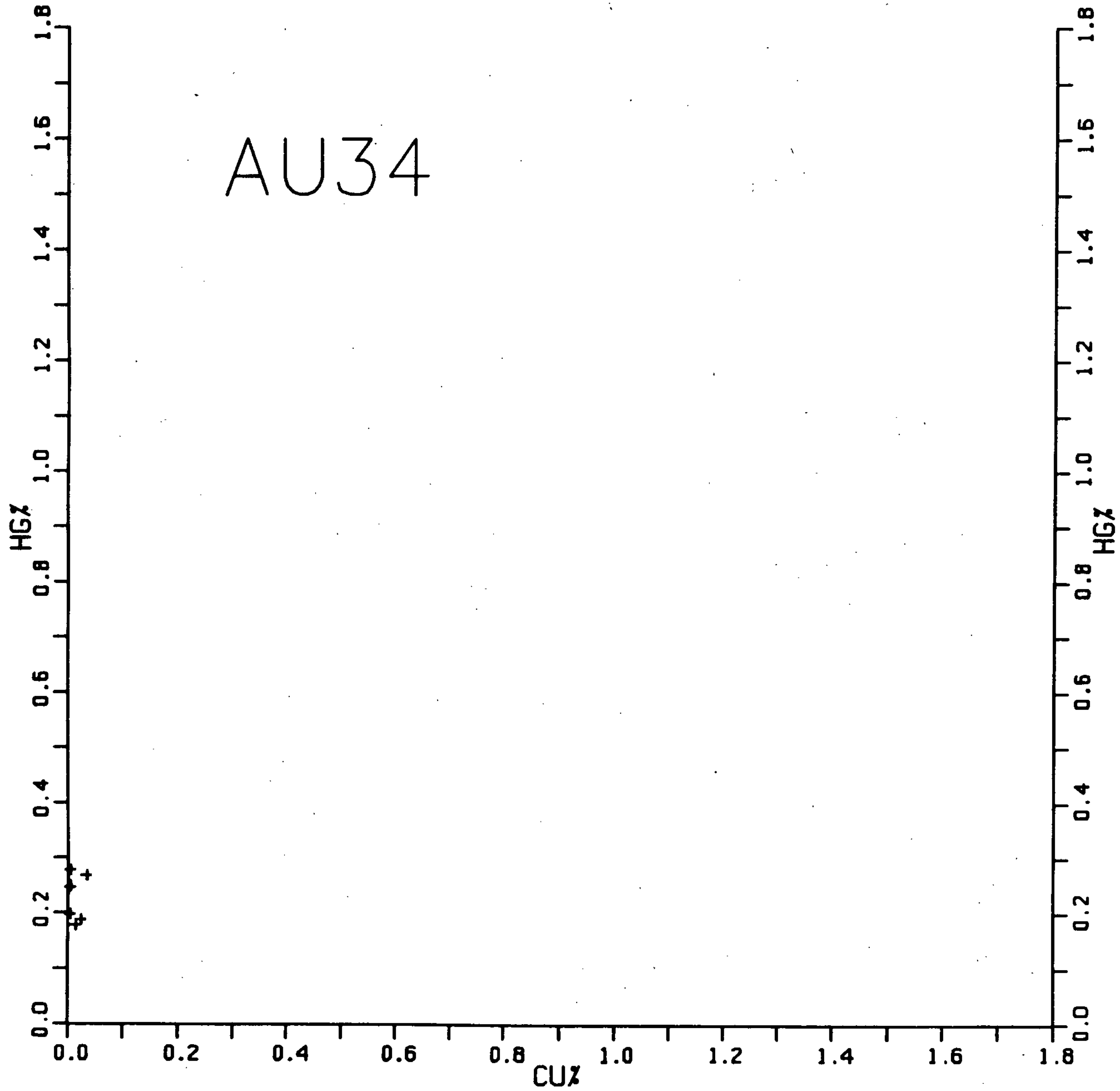


Figure 15d:
Alhambra

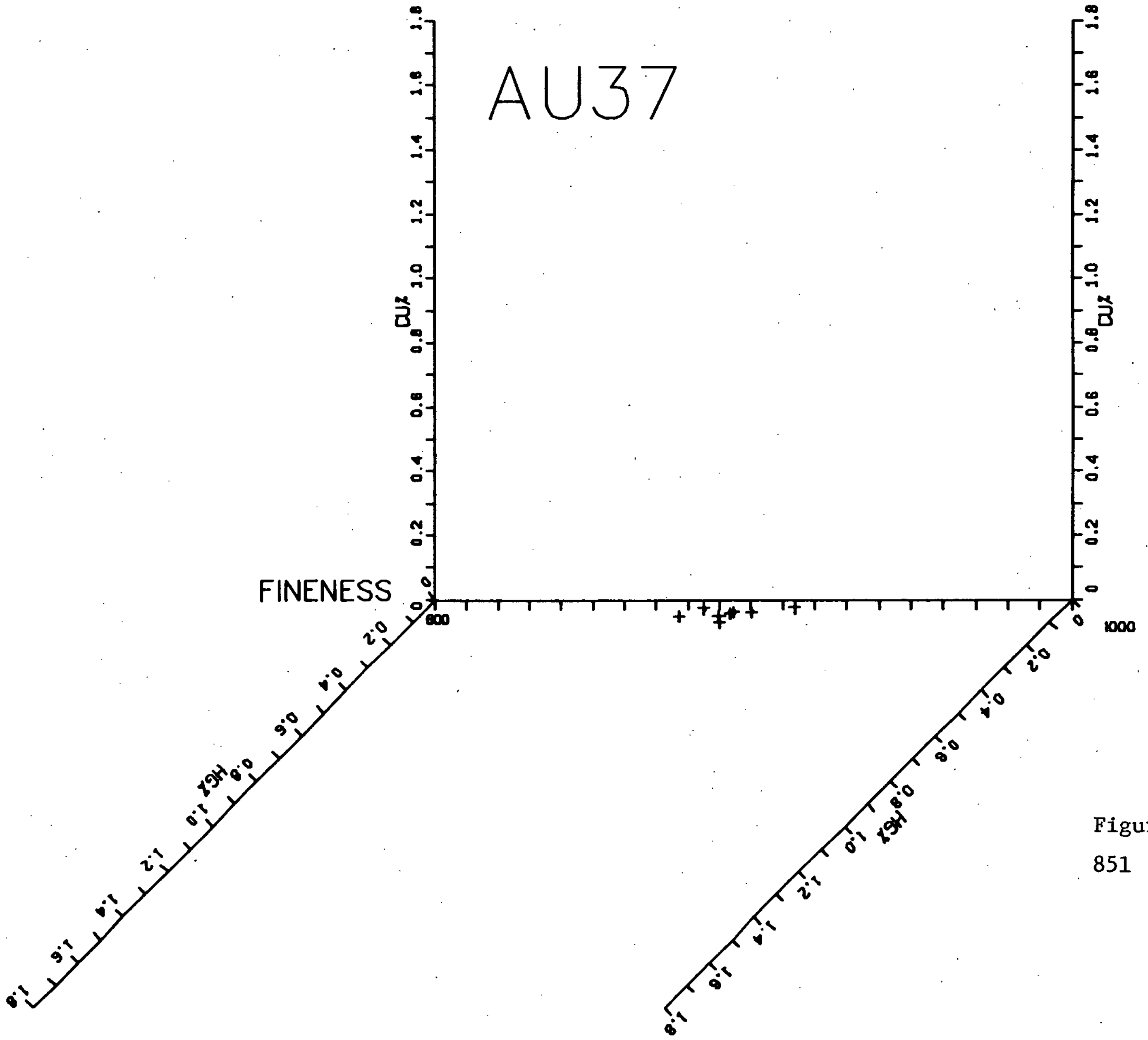


Figure 16a:
851

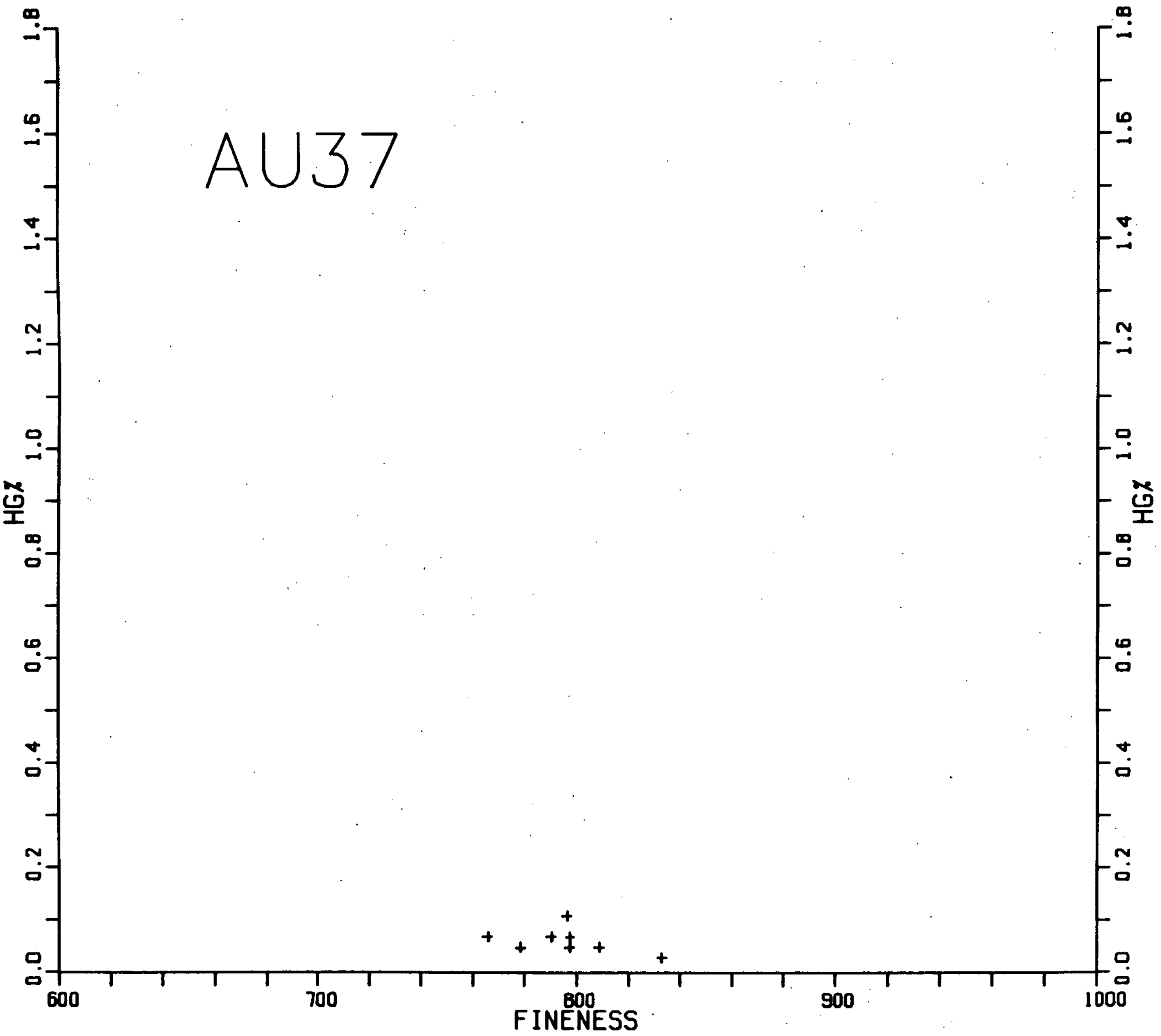


Figure 16b:
851

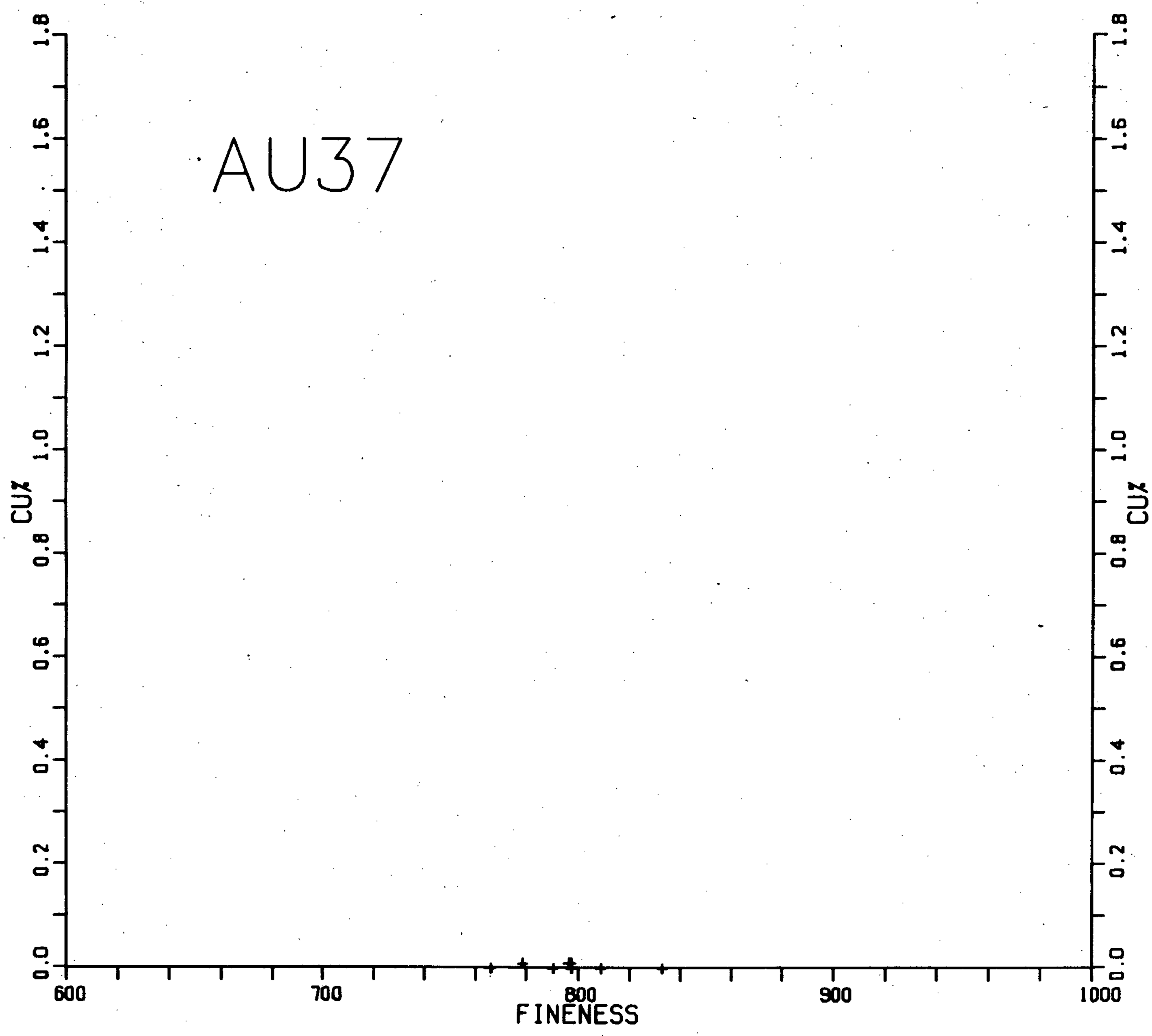


Figure 16c:
851

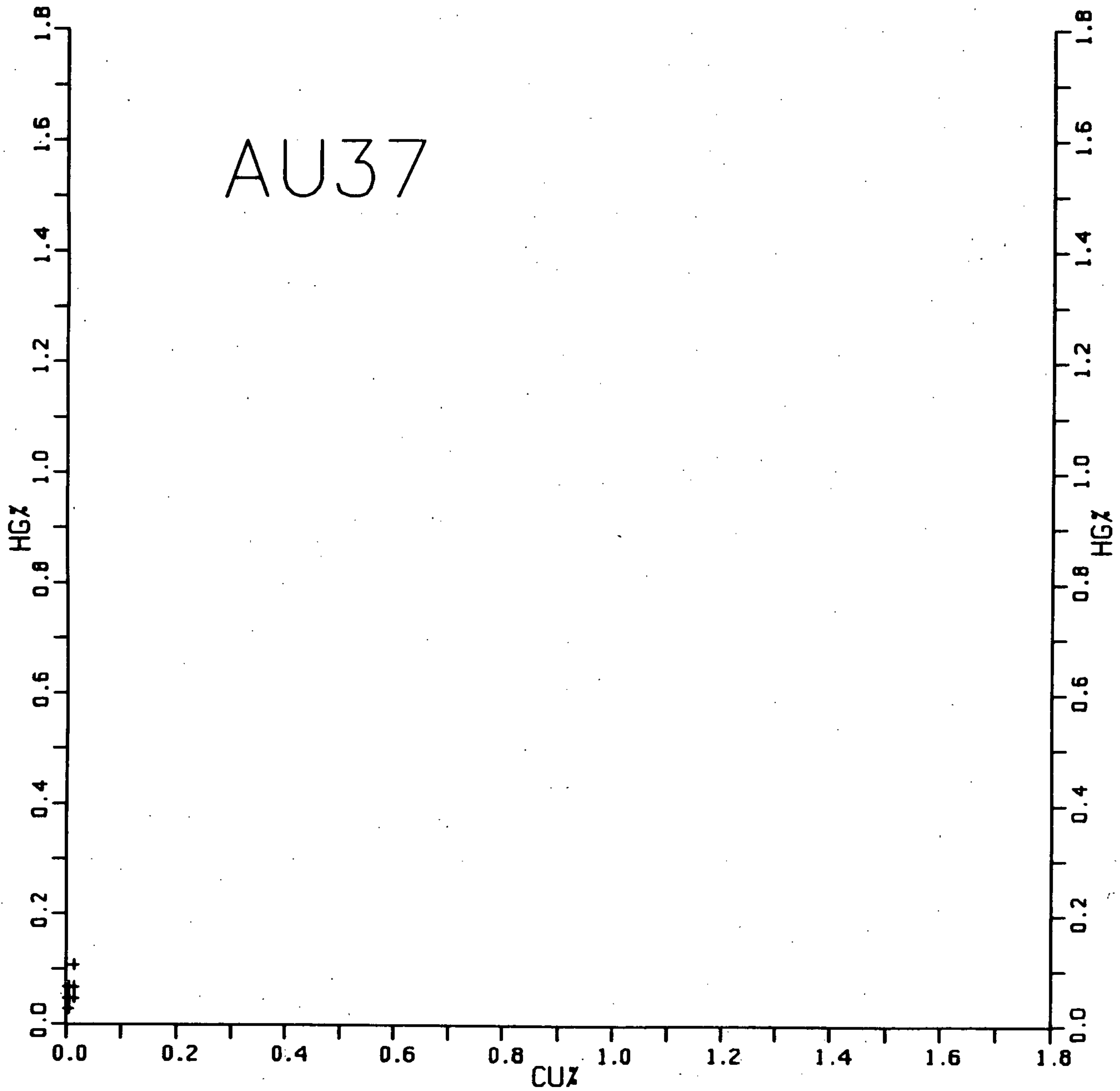


Figure 16d:
851

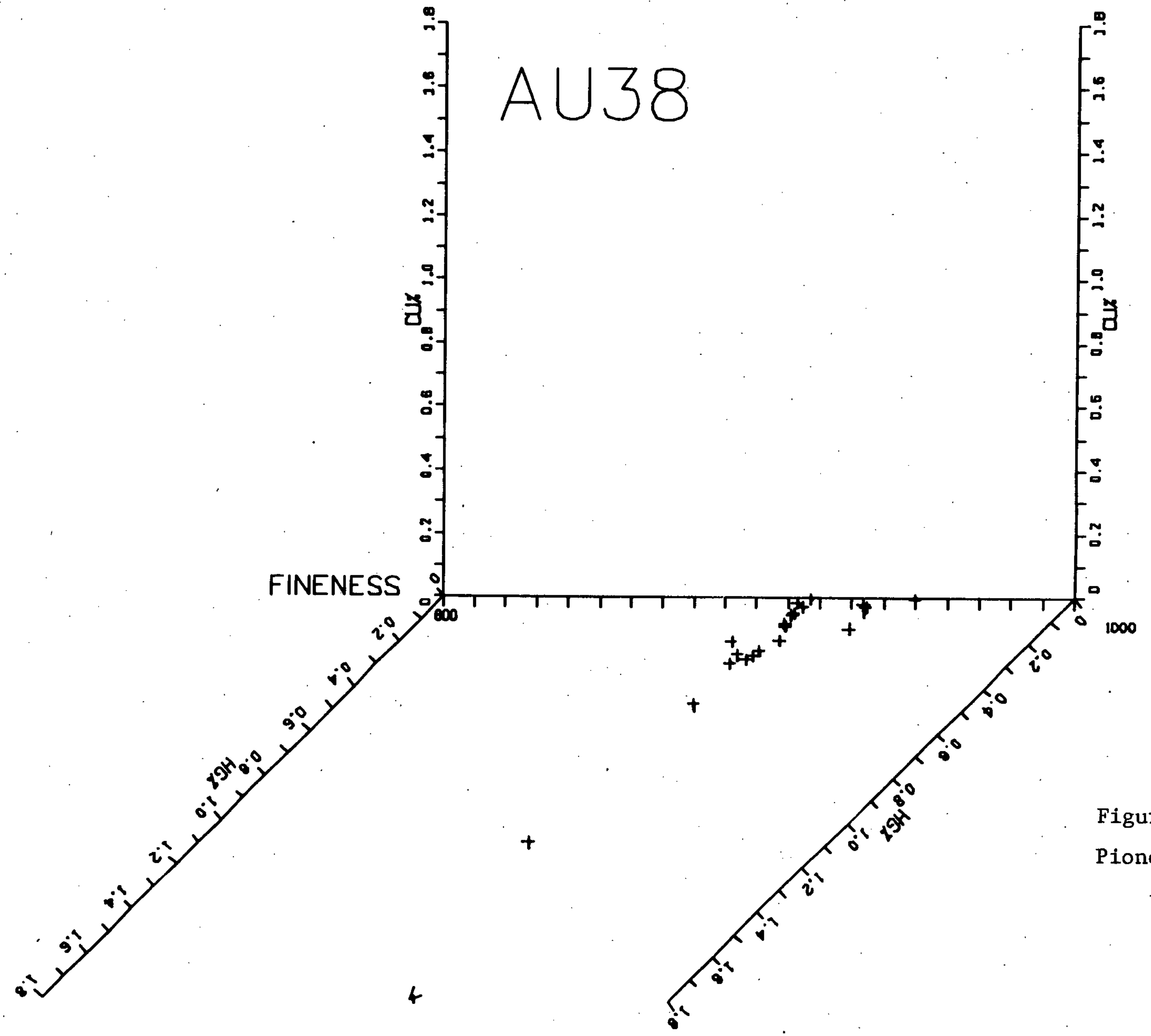


Figure 17a:
Pioneer Mill

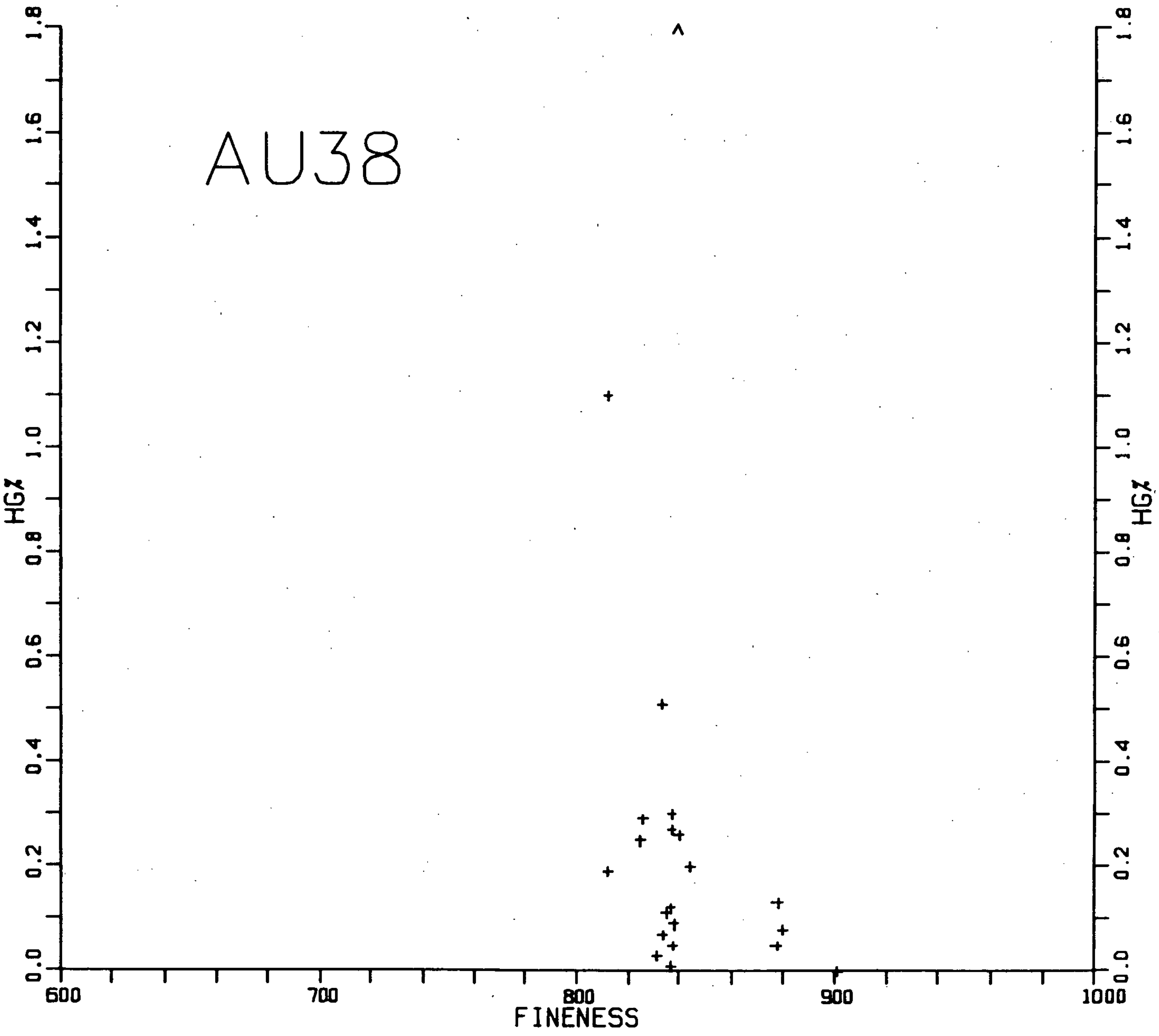


Figure 17b:
Pioneer Mill

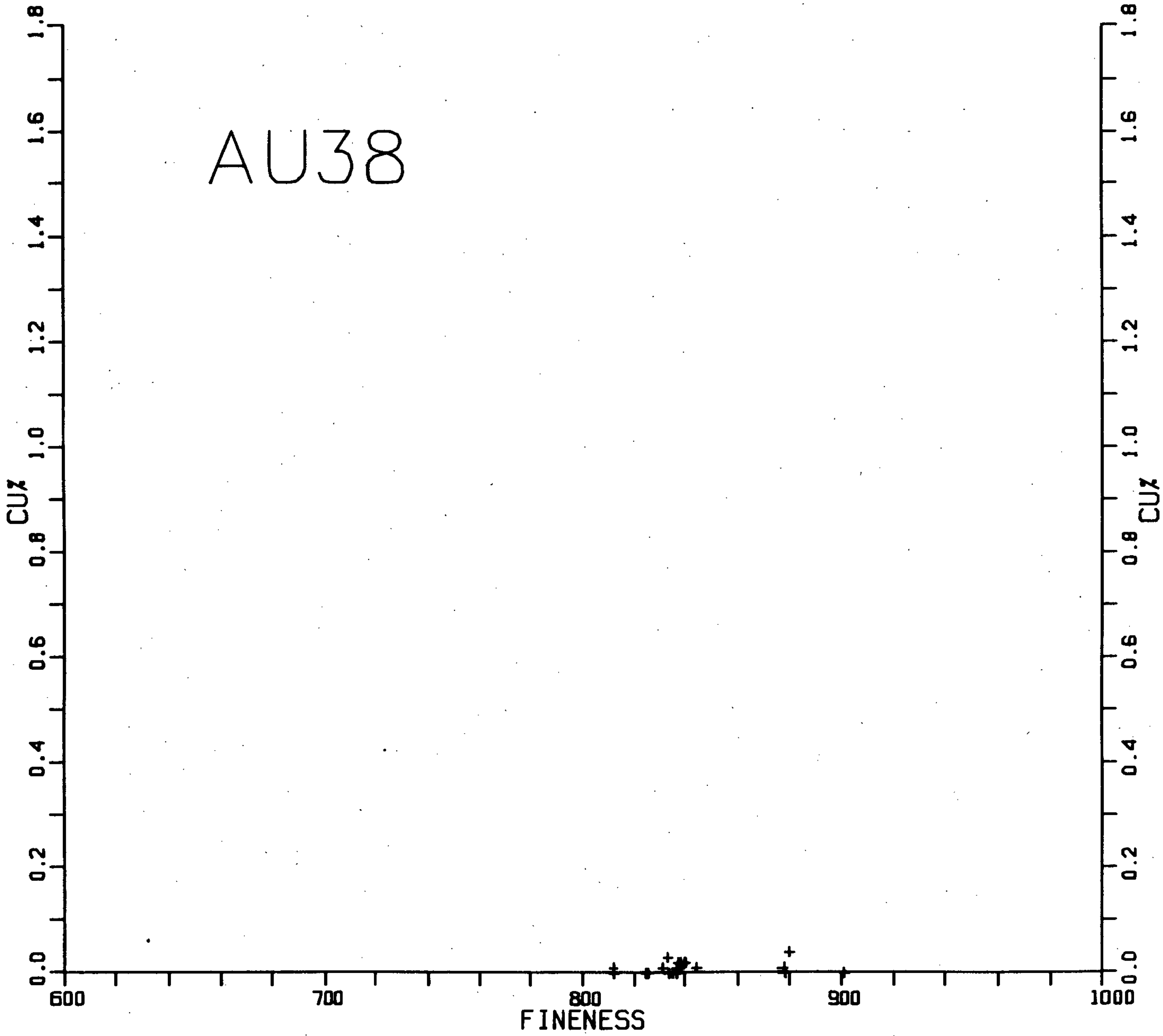


Figure 17c:
Pioneer Mill

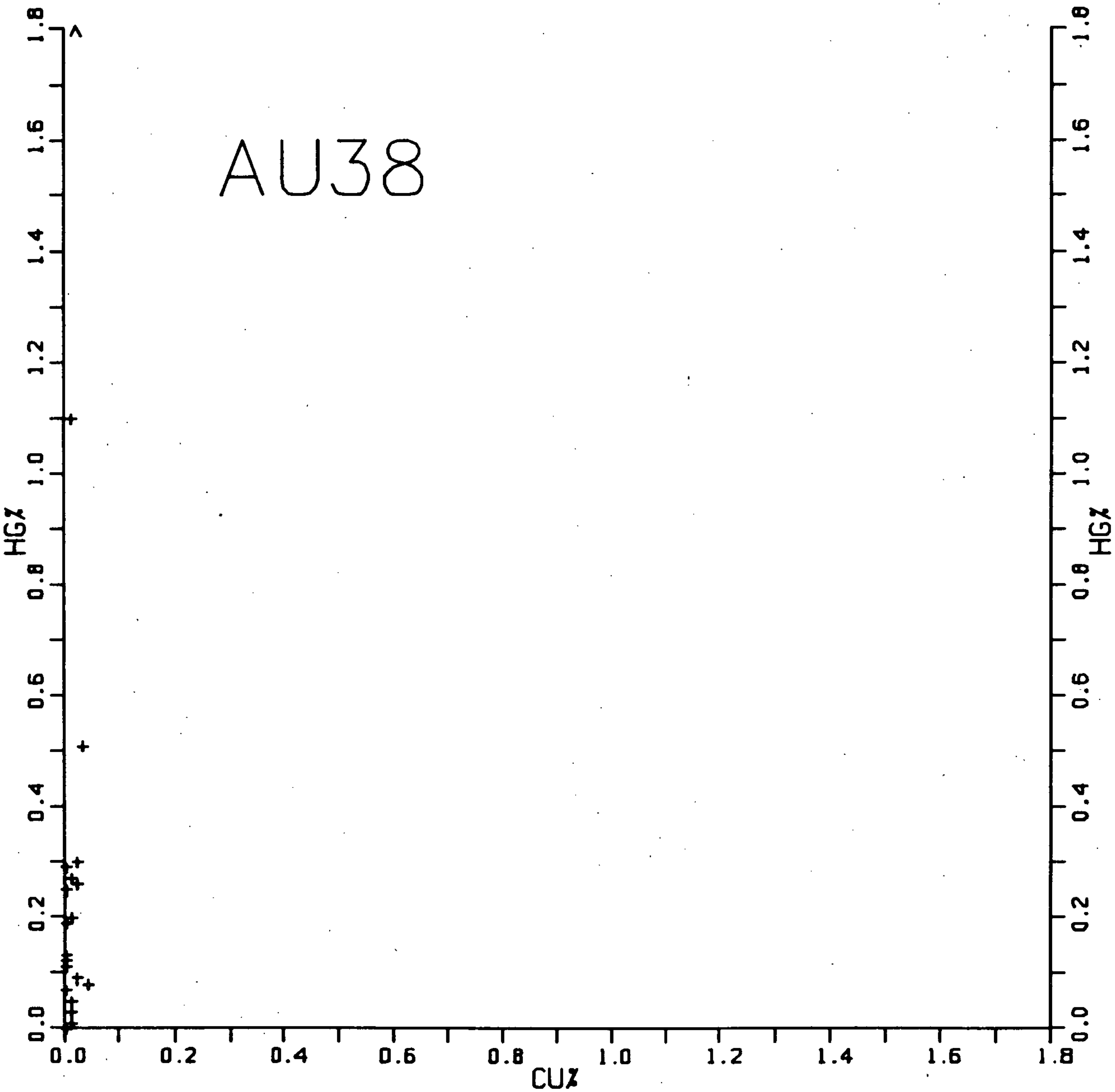


Figure 17d:
Pioneer Mill

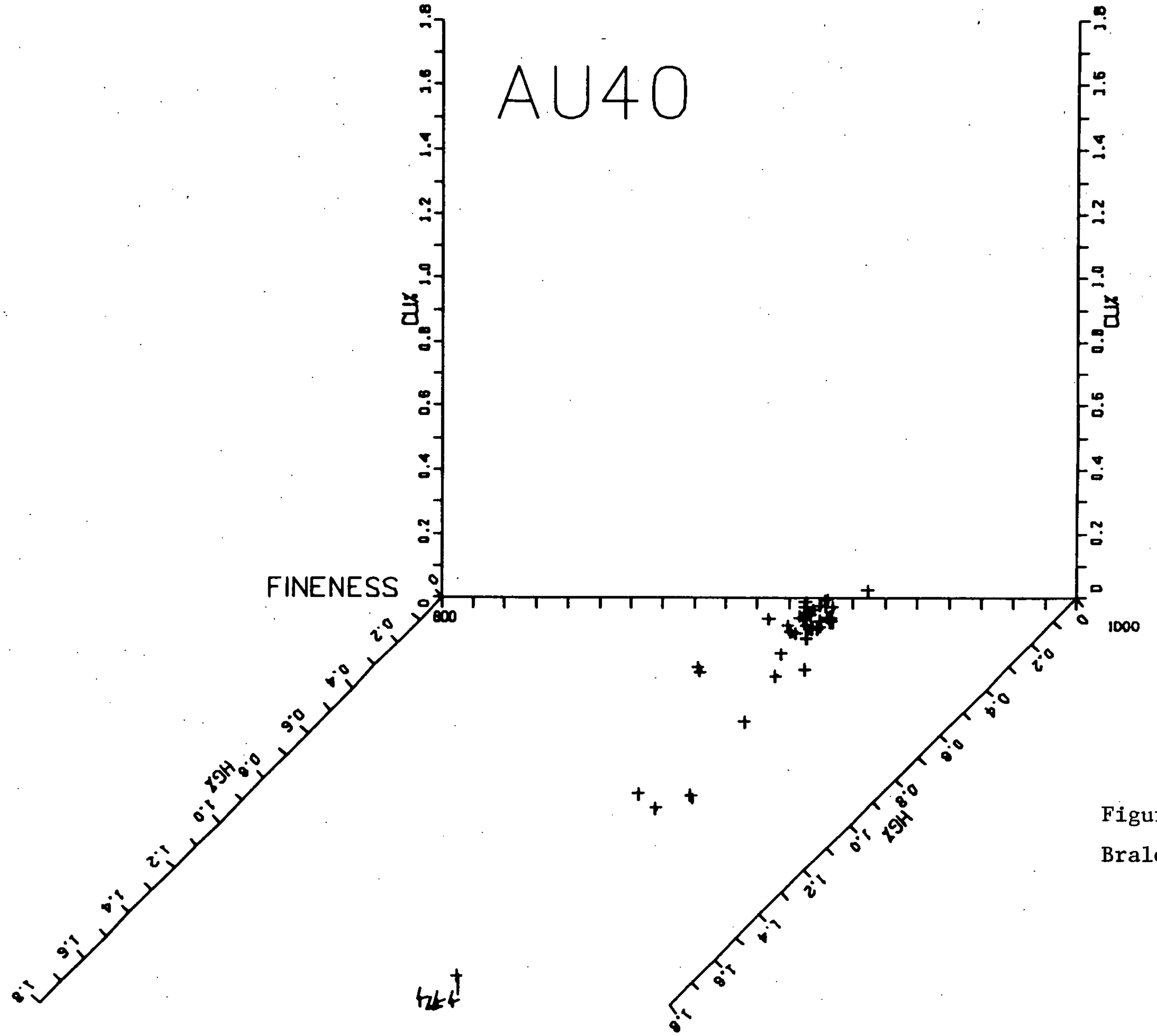


Figure 18a:
Bralorne Mill

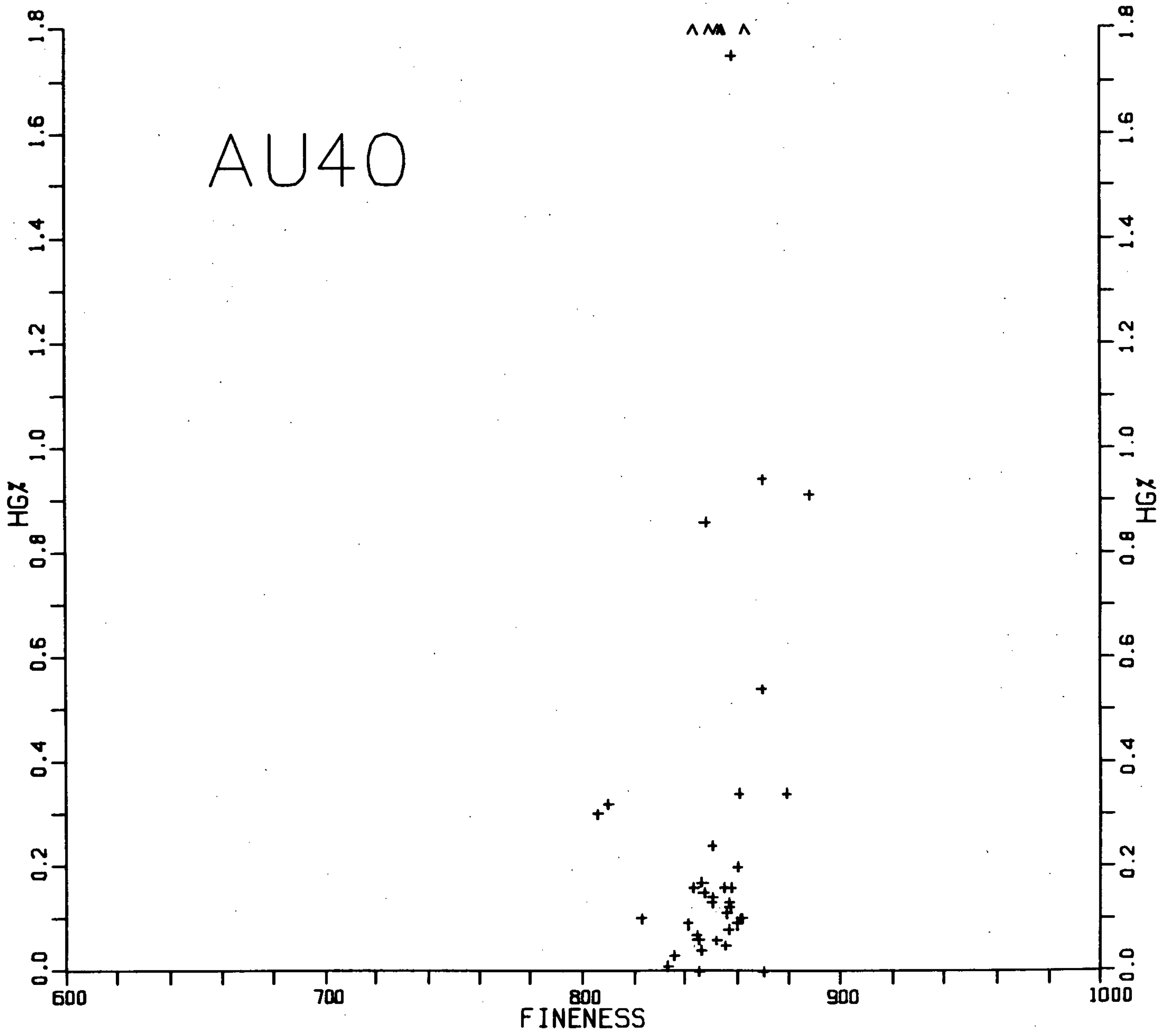


Figure 18b:
Bralorne Mill

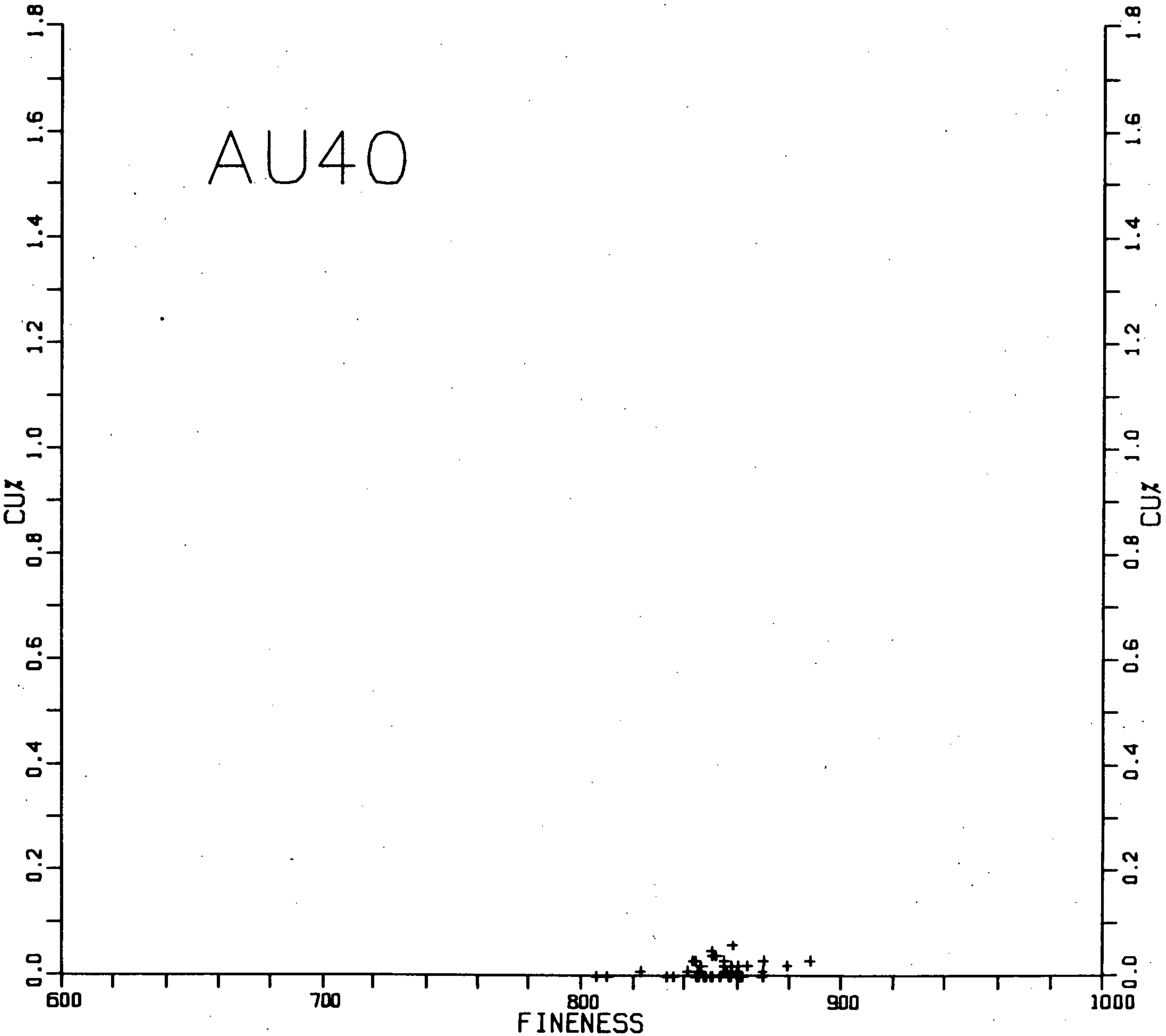


Figure 18c:
Bralorne Mill

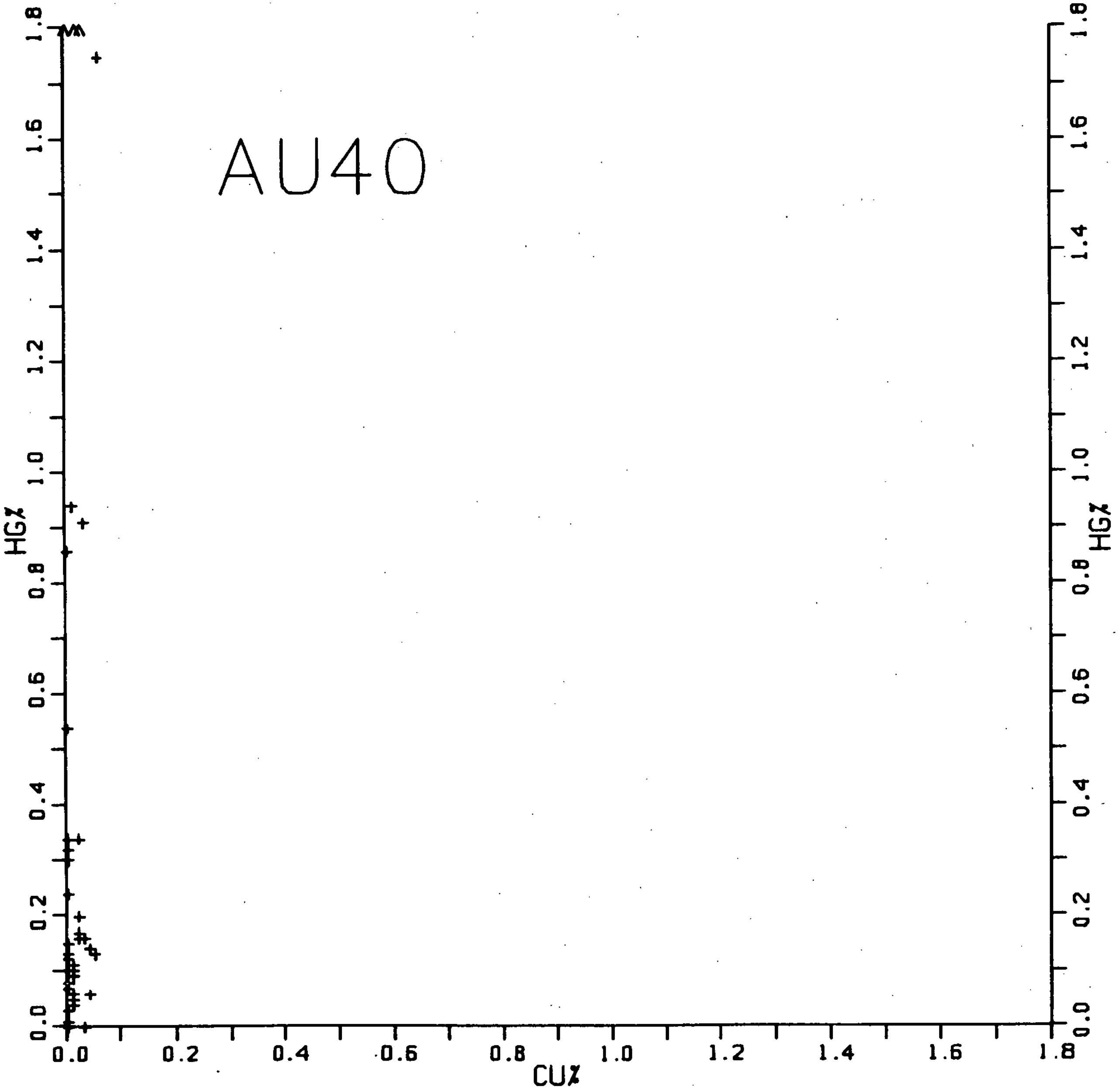


Figure 18d:
Bralorne Mill

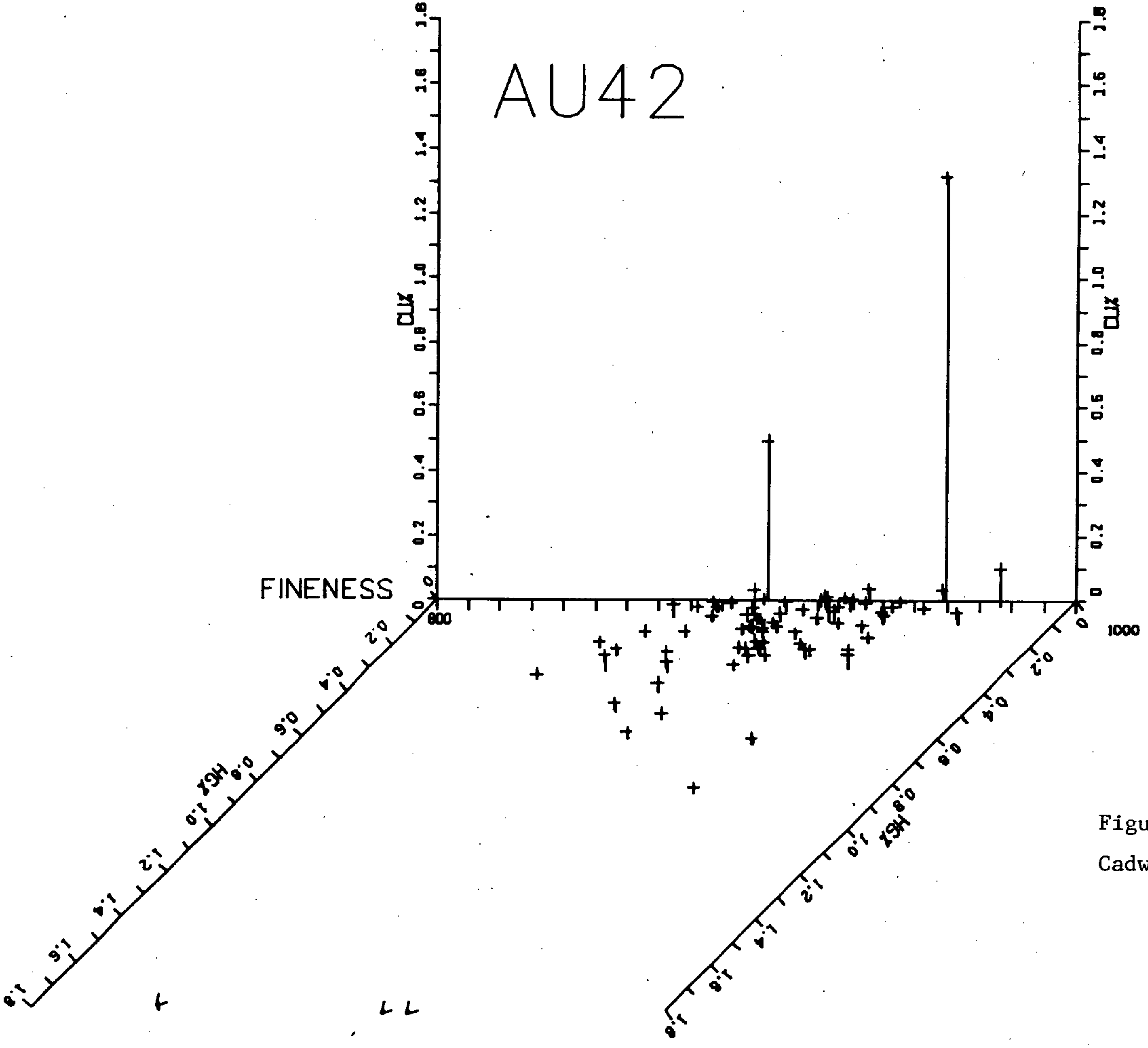


Figure 19a:
Cadwallader

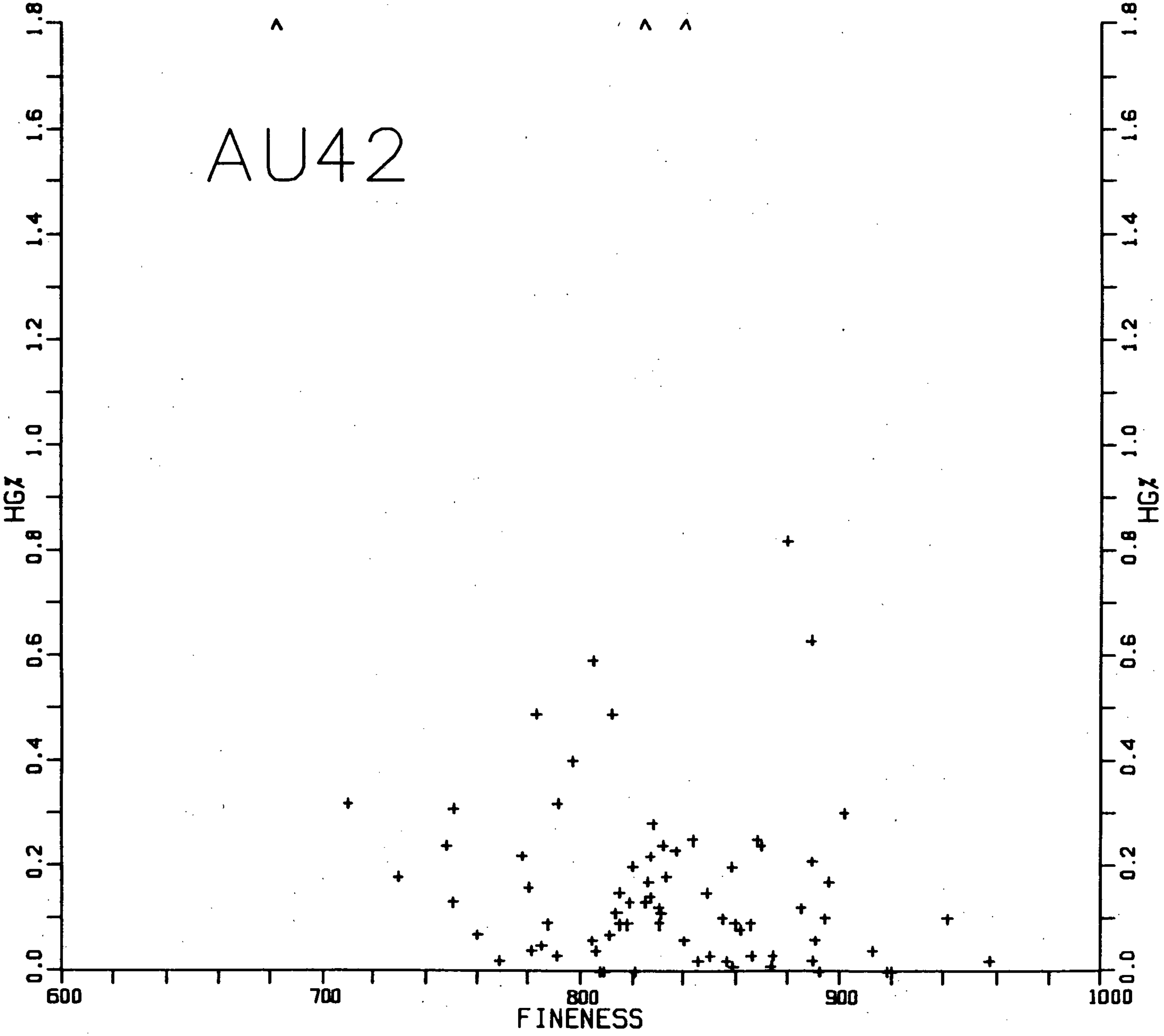


Figure 19b:
Cadwallader

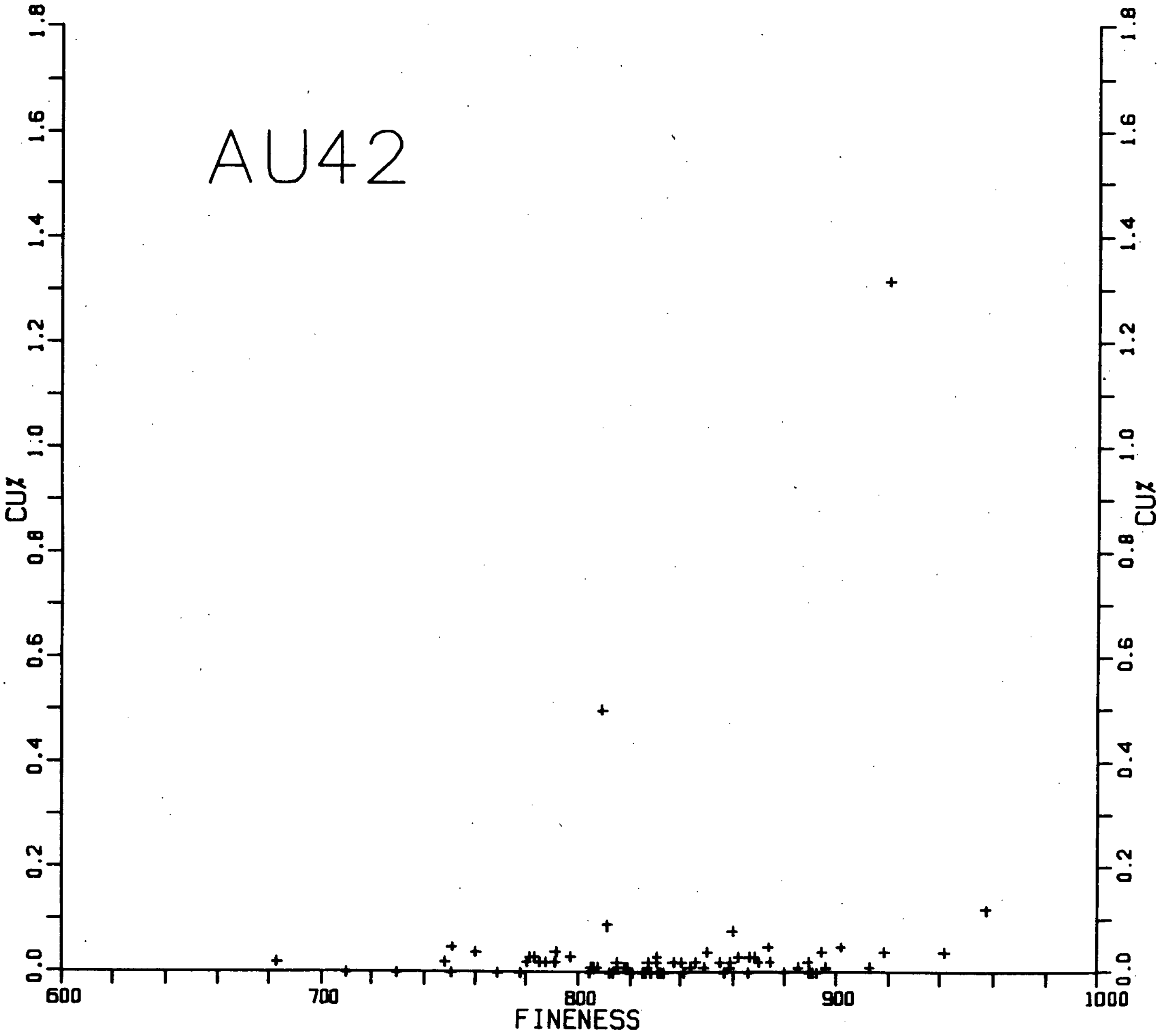


Figure 19c:
Cadwallader

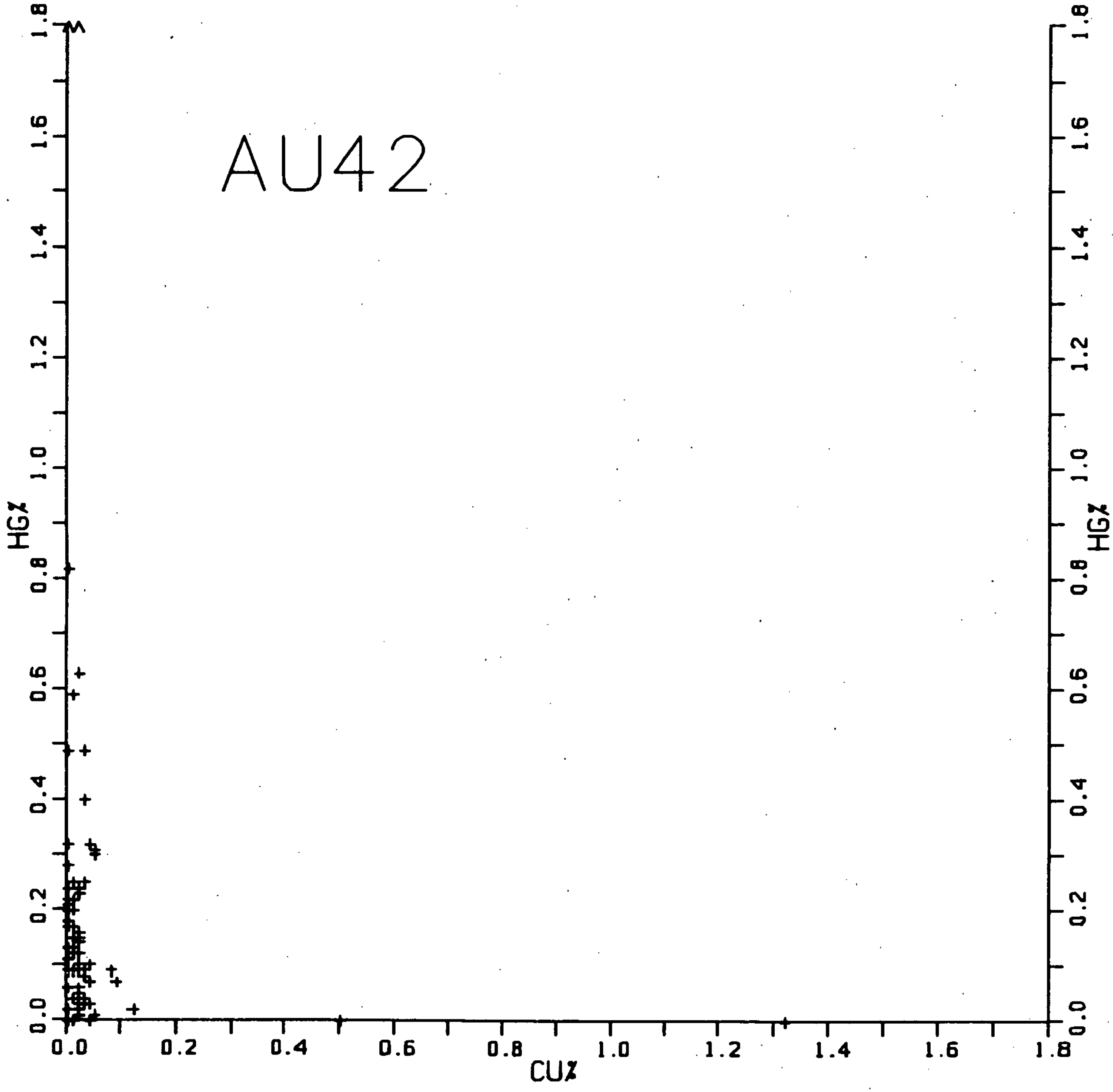


Figure 19d:
Cadwallader

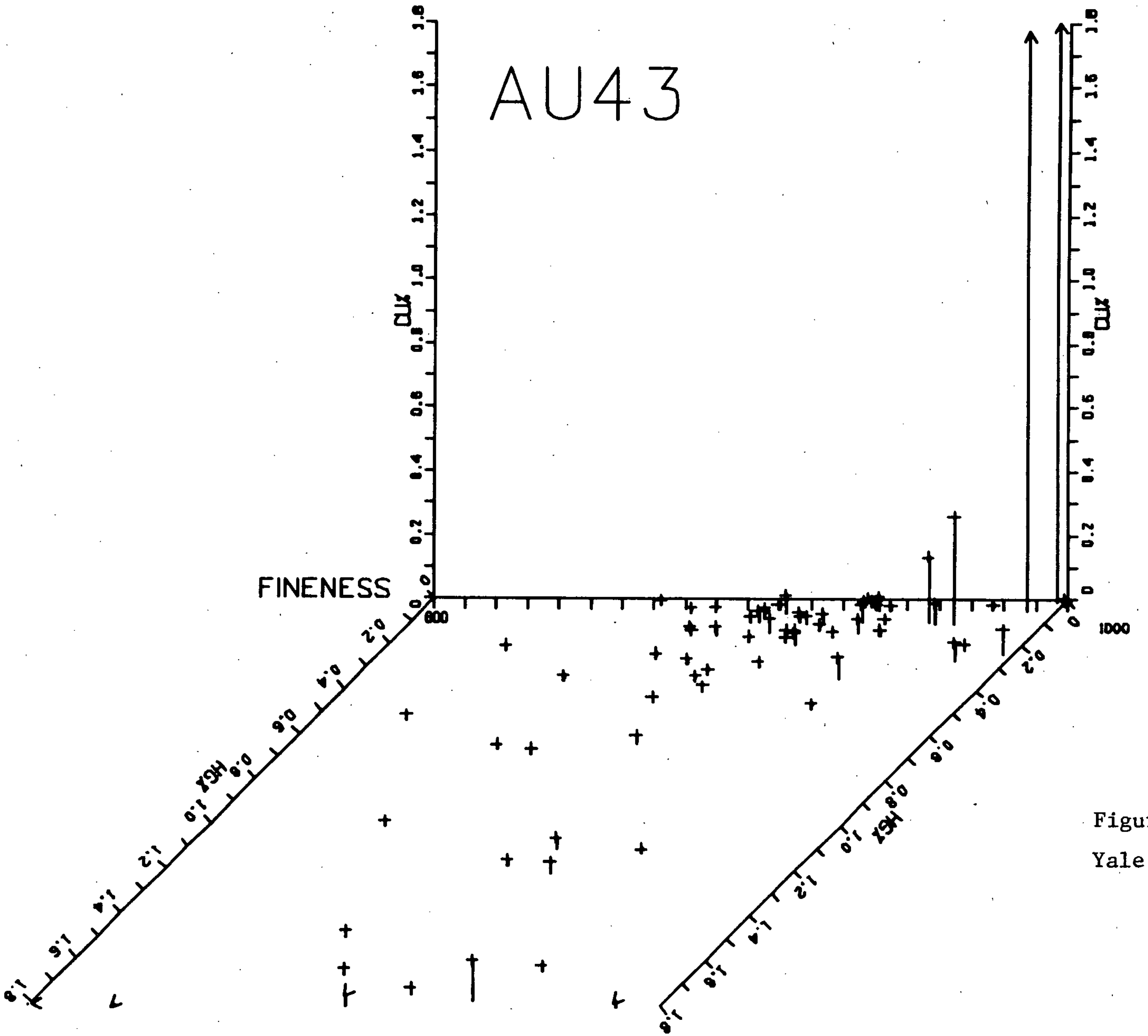


Figure 20a:
Yale

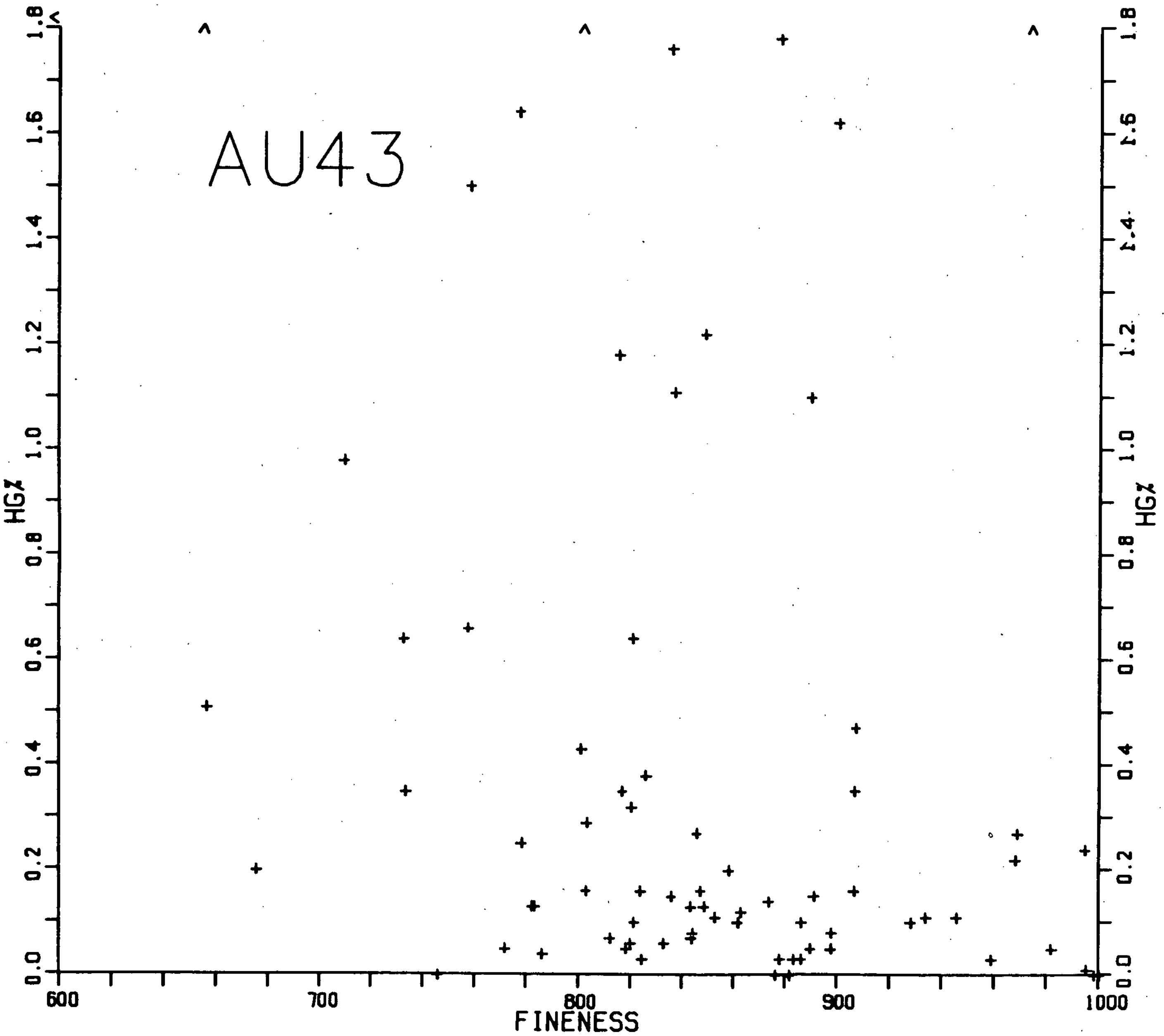


Figure 20b:
Yale

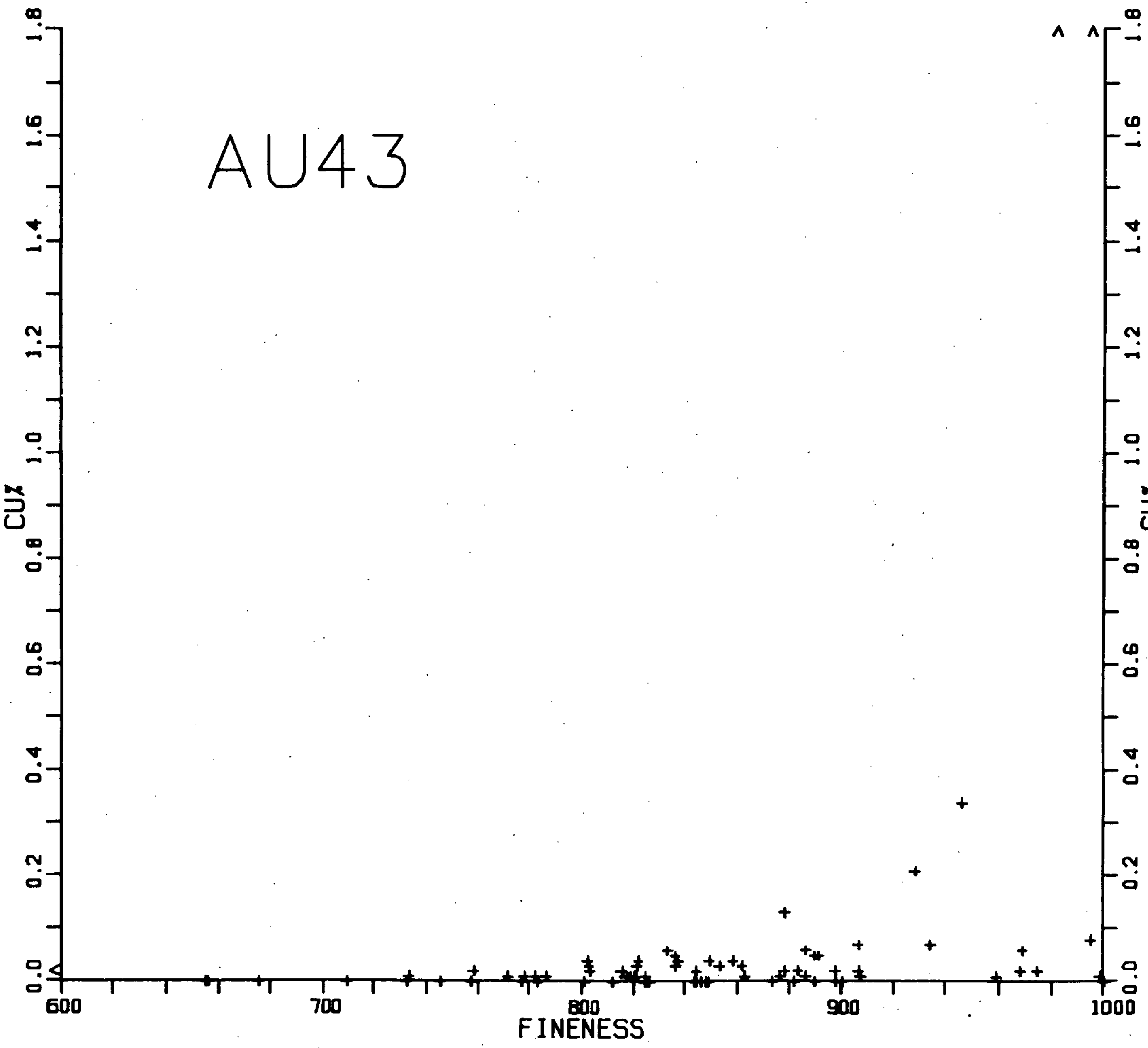


Figure 20c:
Yale

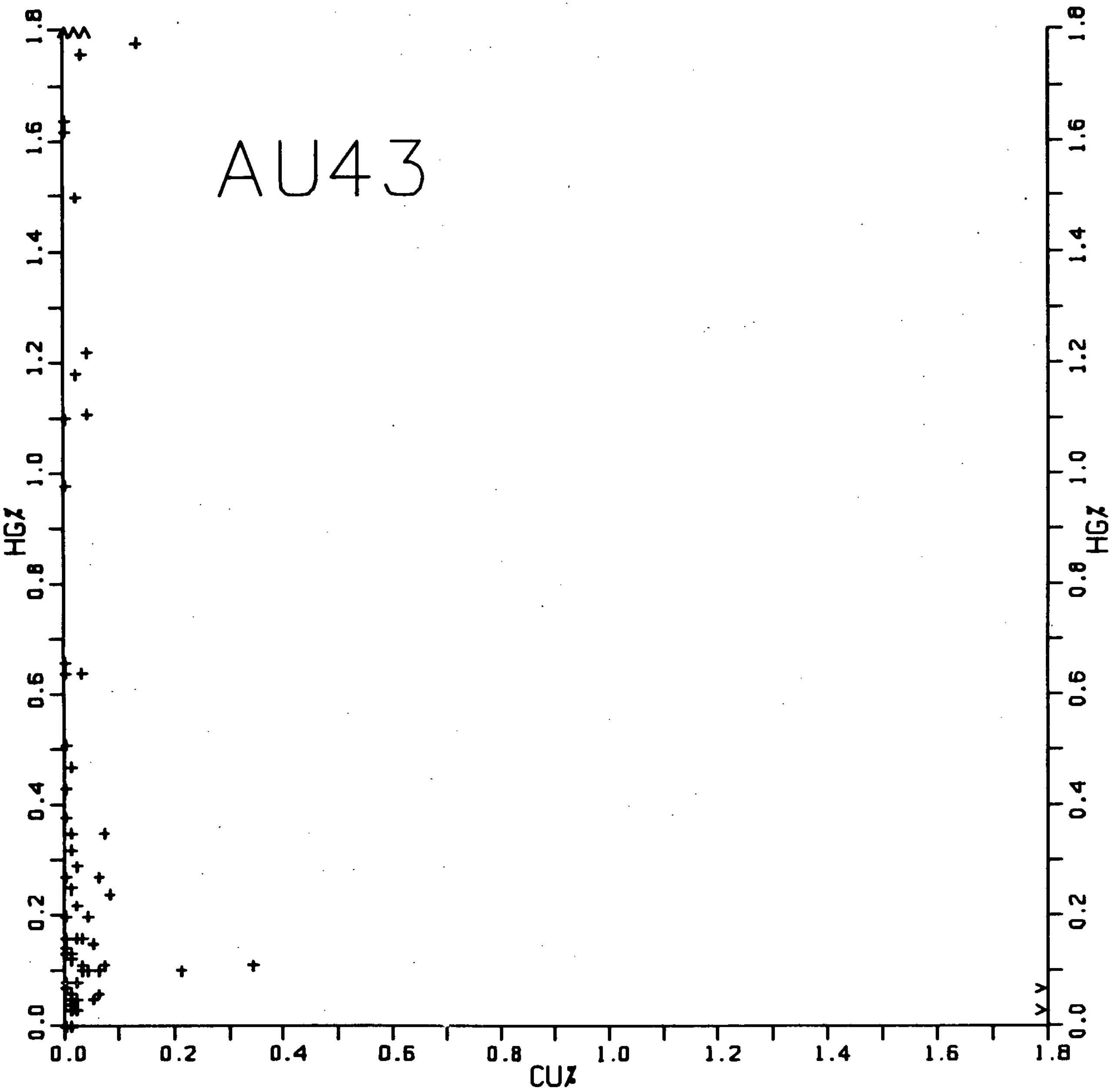


Figure 20d:
Yale

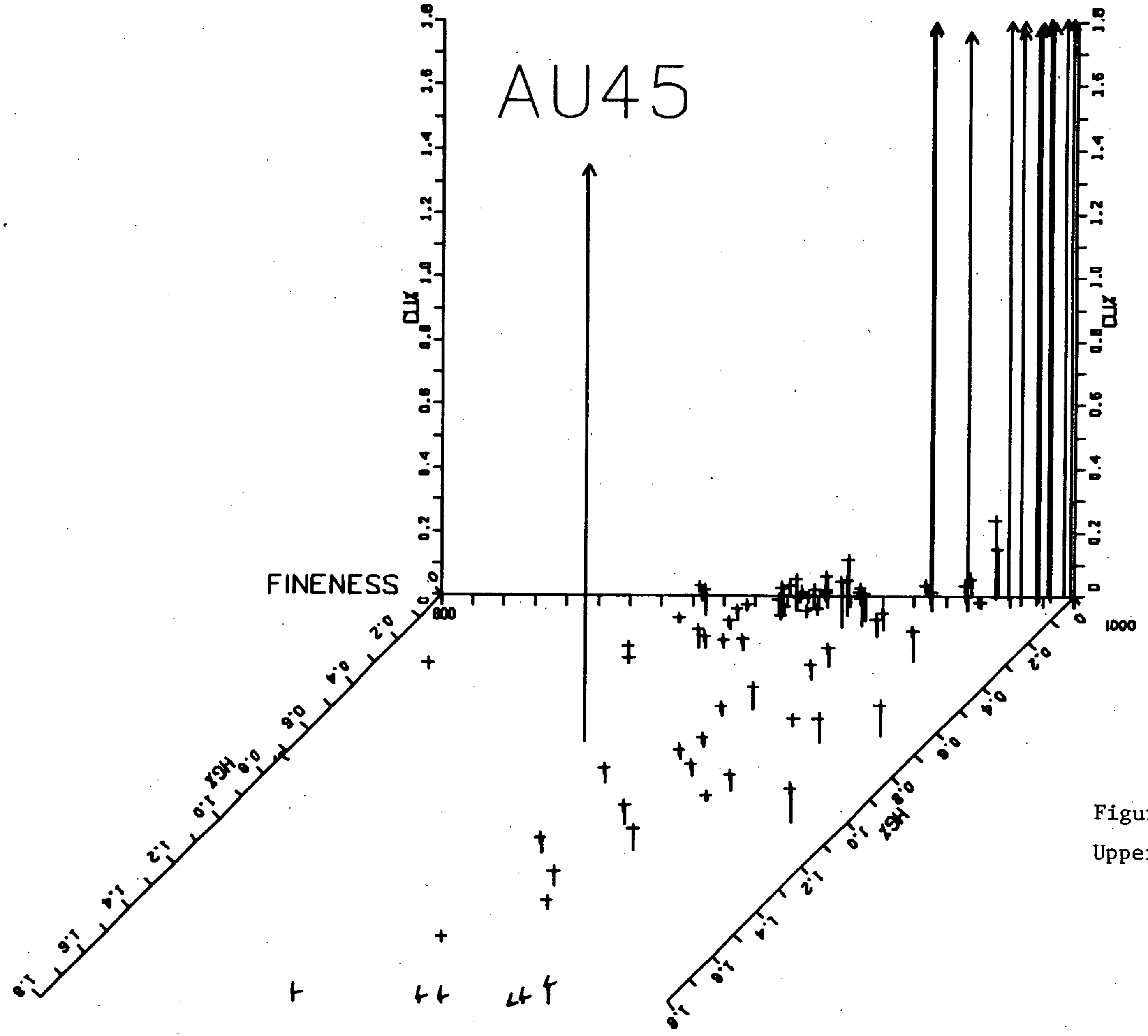


Figure 21a:
Upper Bridge

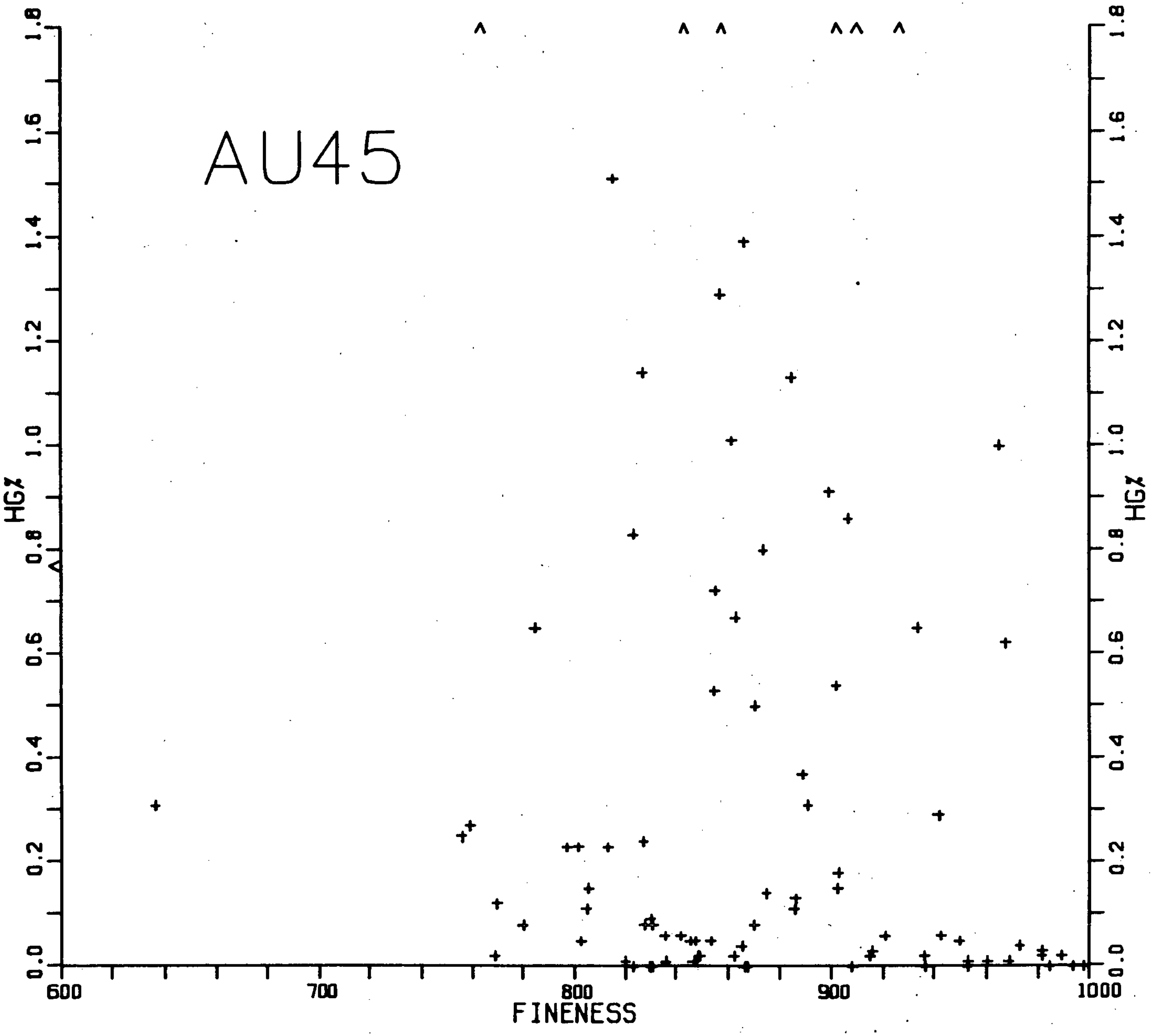


Figure 21b:
Upper Bridge

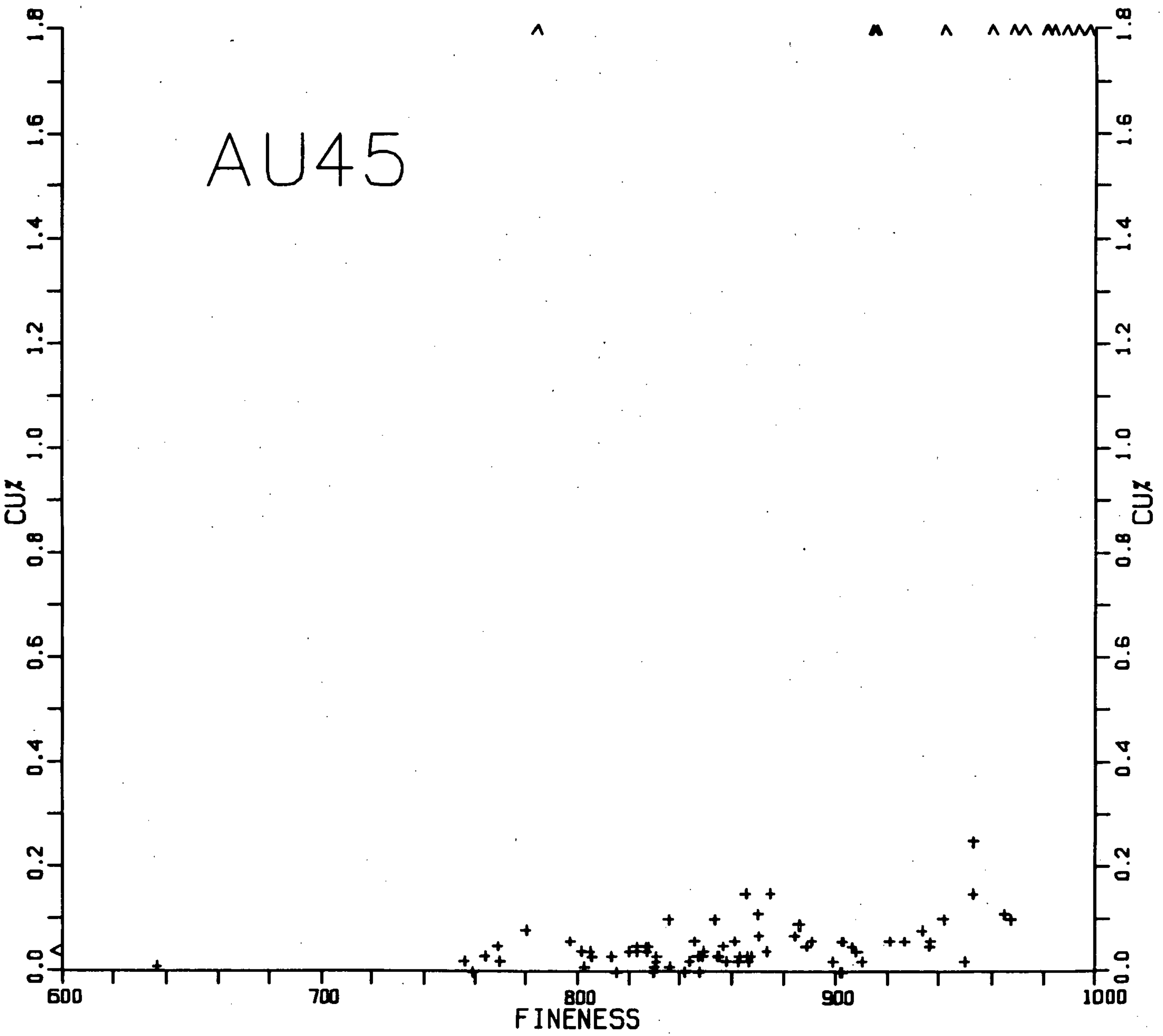


Figure 21c:
Upper Bridge

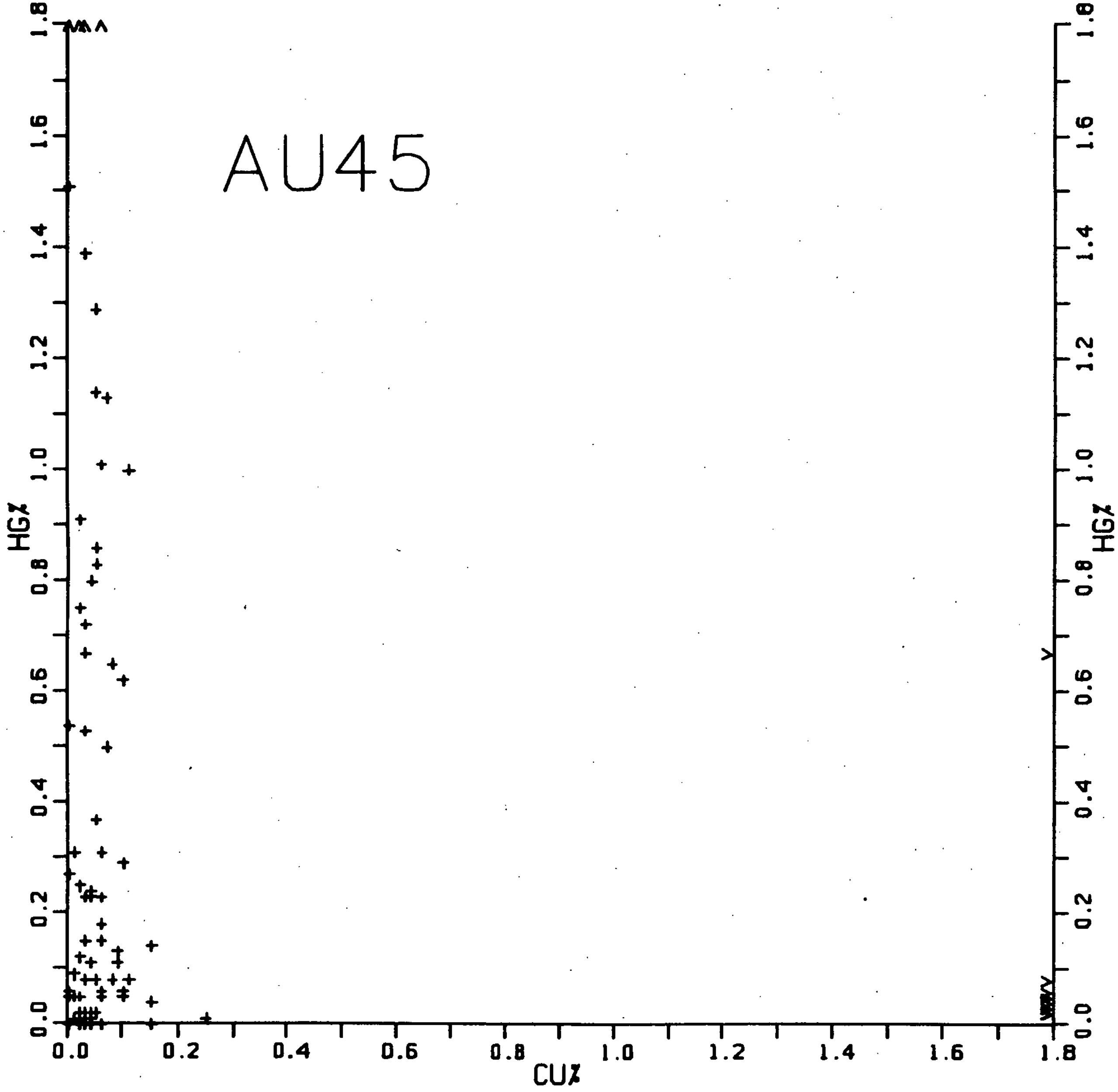


Figure 21d:
Upper Bridge

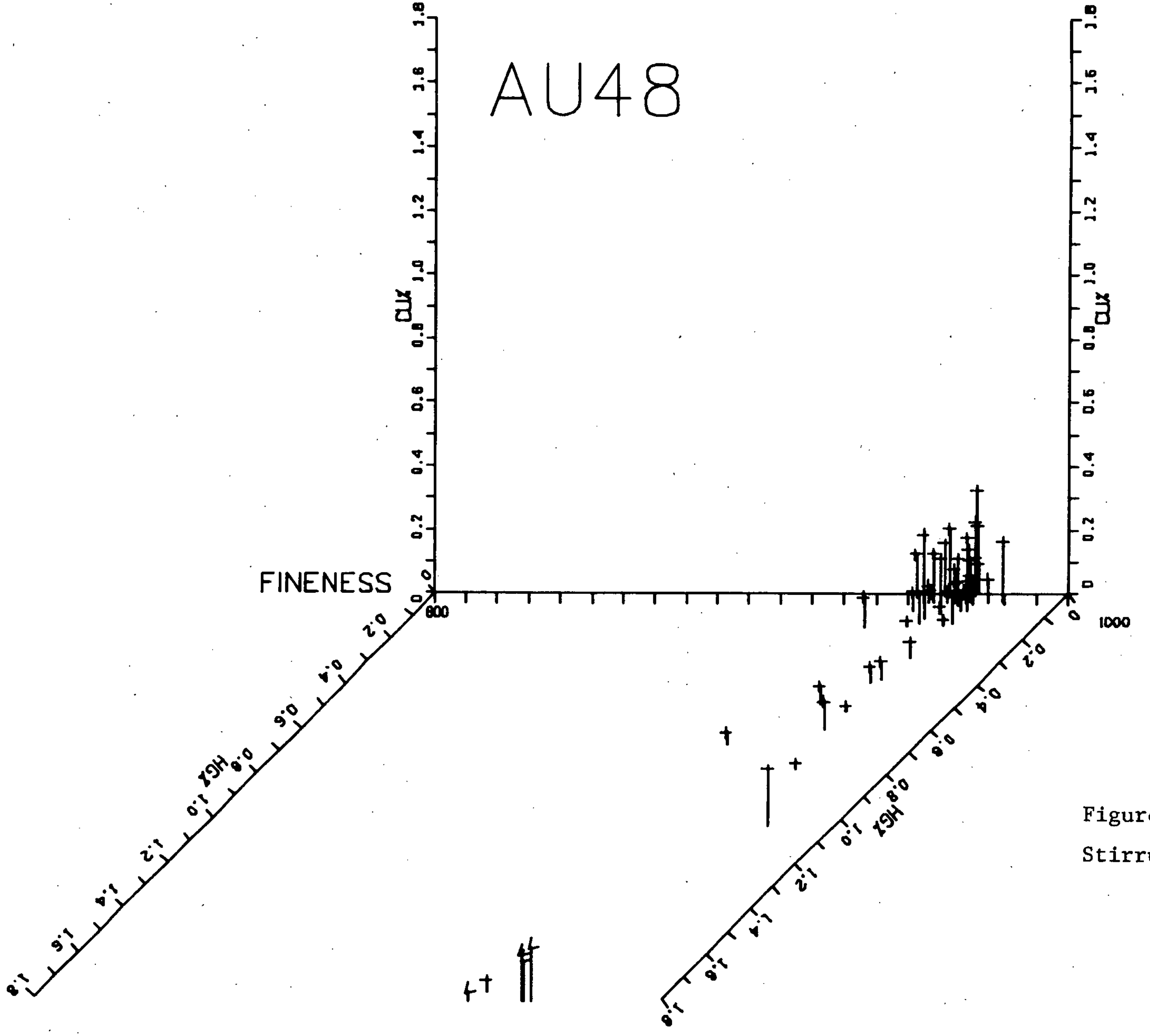


Figure 22a:
Stirrup

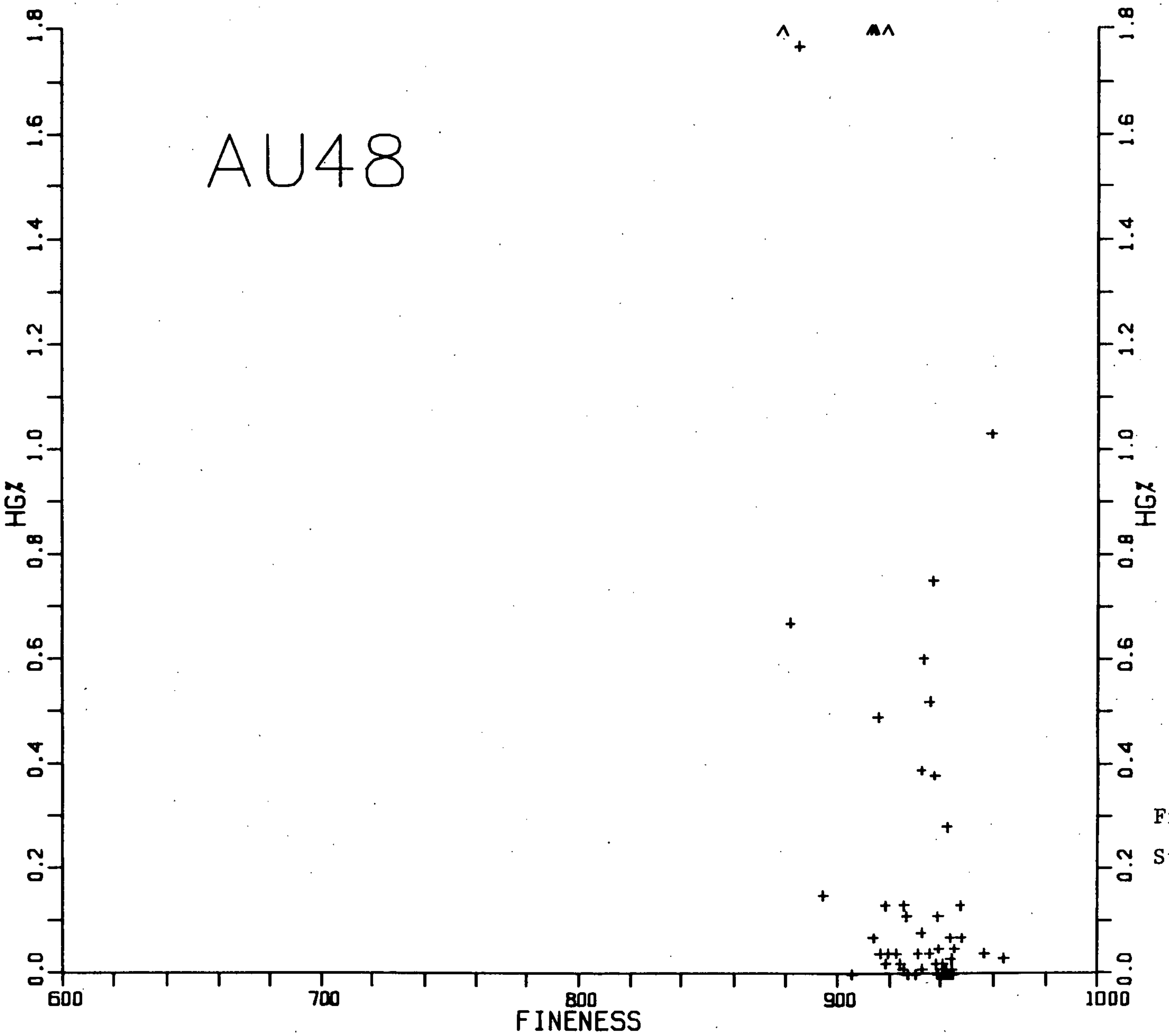


Figure 22b:
Stirrup

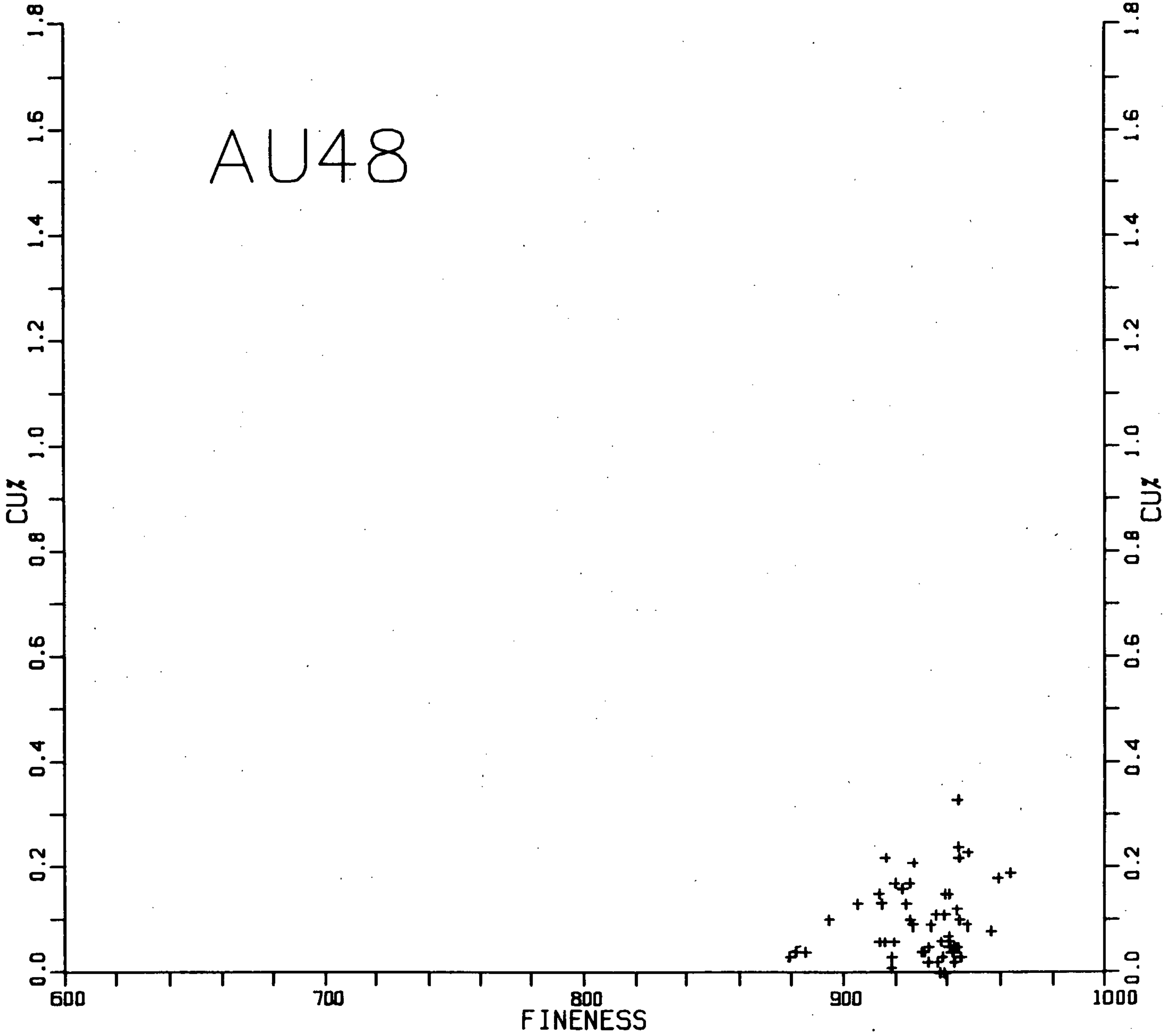


Figure 22c:
Stirrup

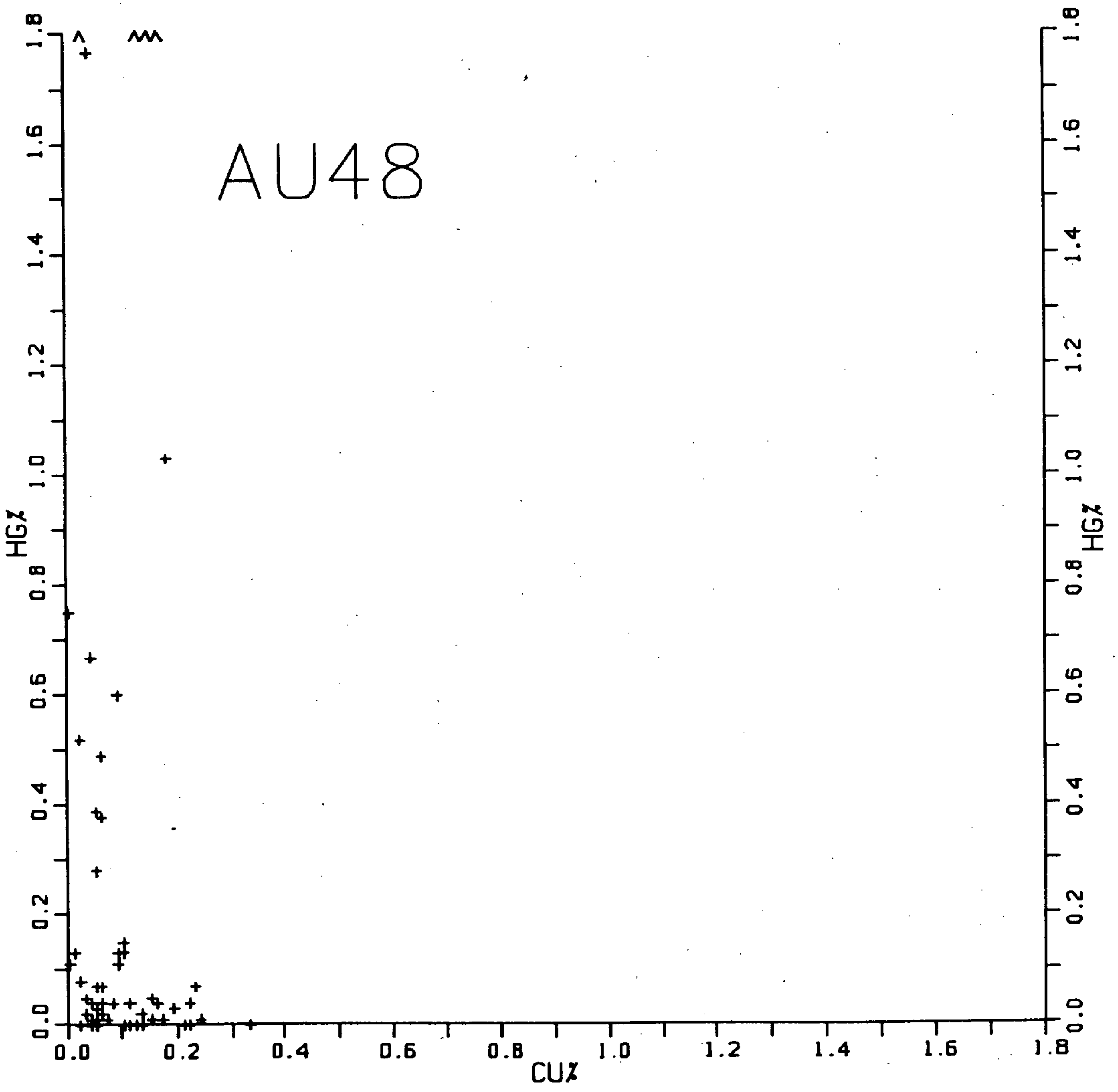


Figure 22c:
Stirrup

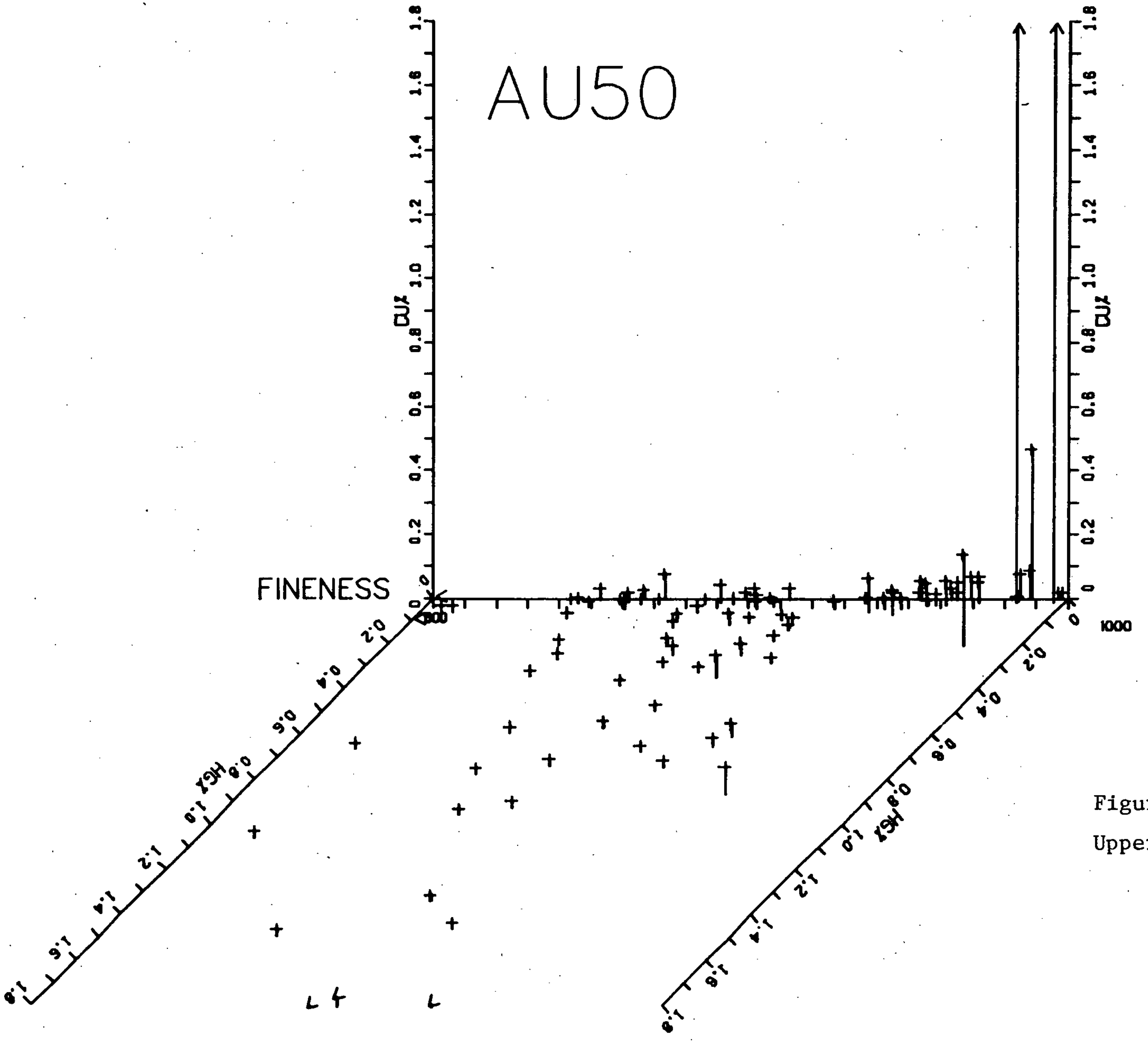


Figure 23a:
Upper Fraser

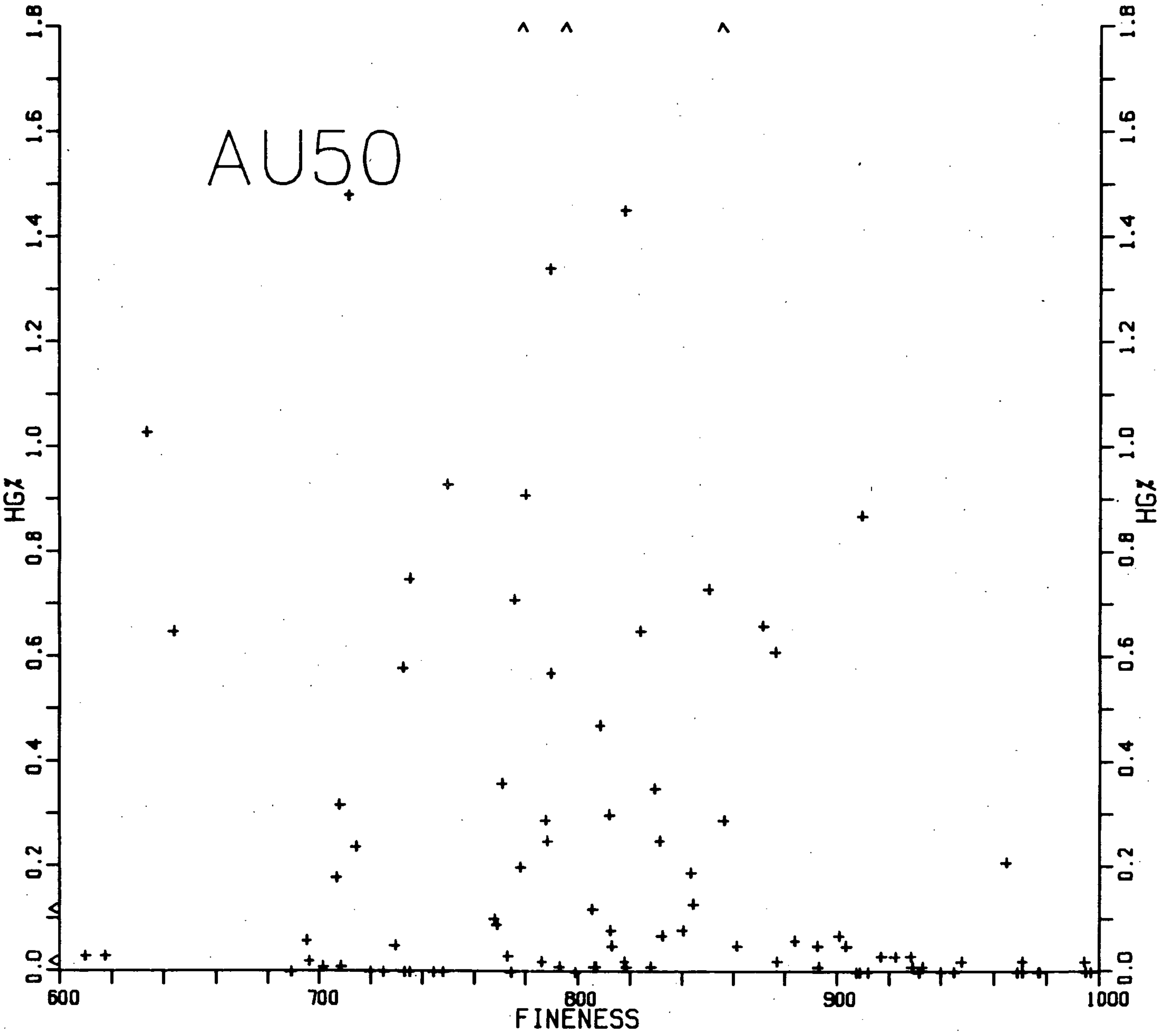


Figure 23b:
Upper Fraser

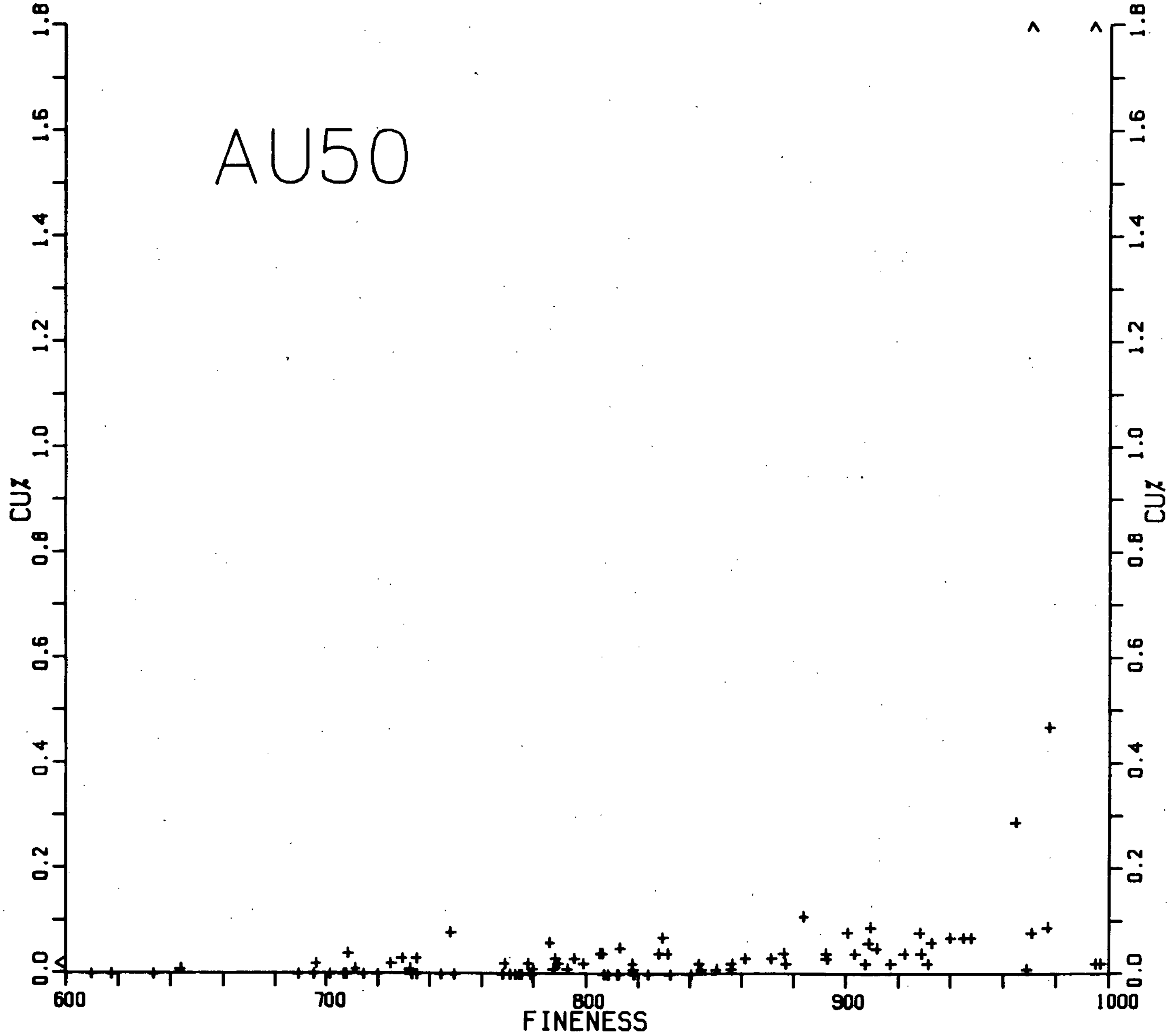


Figure 23c:
Upper Fraser

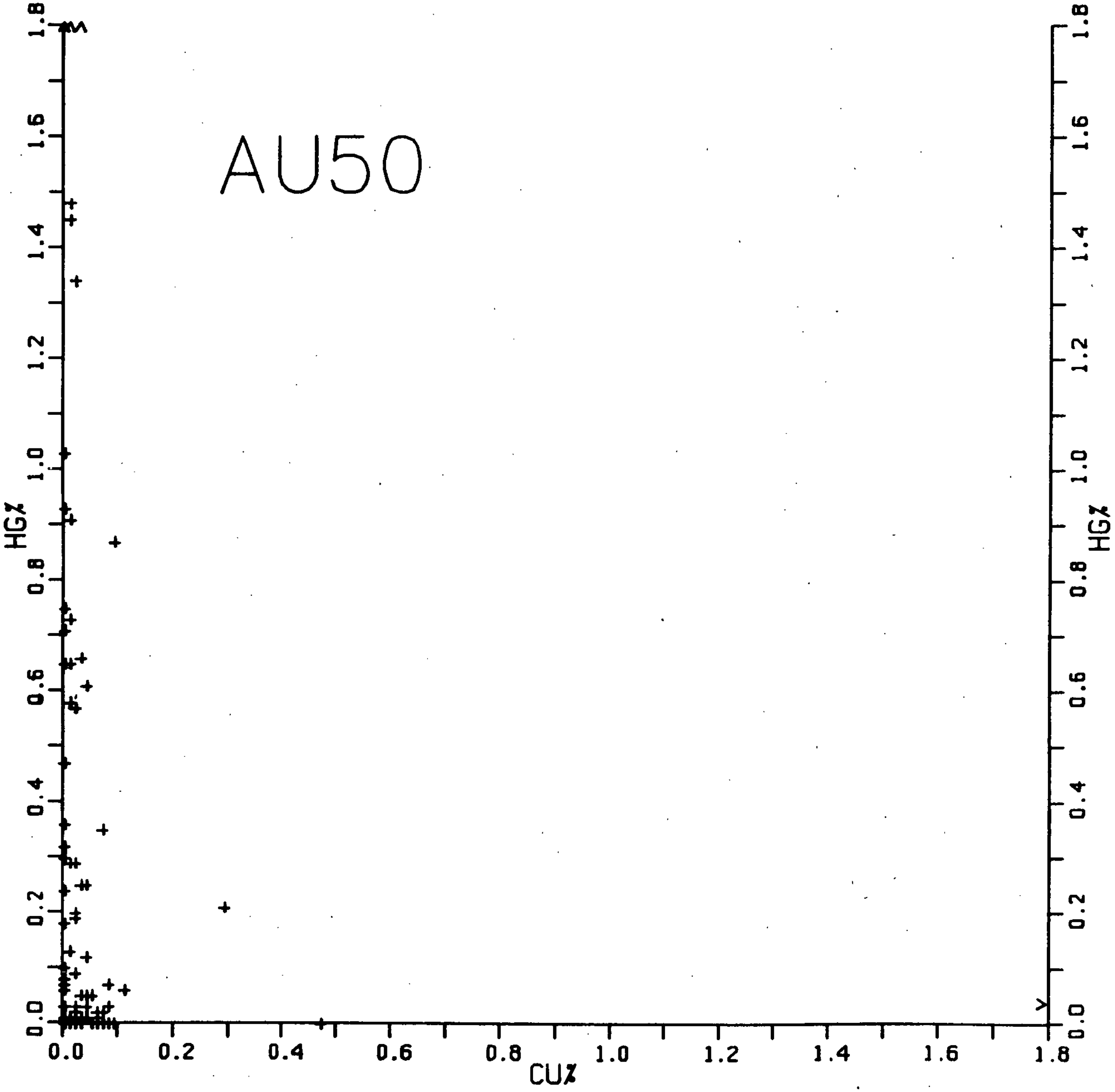


Figure 23d:
Upper Fraser

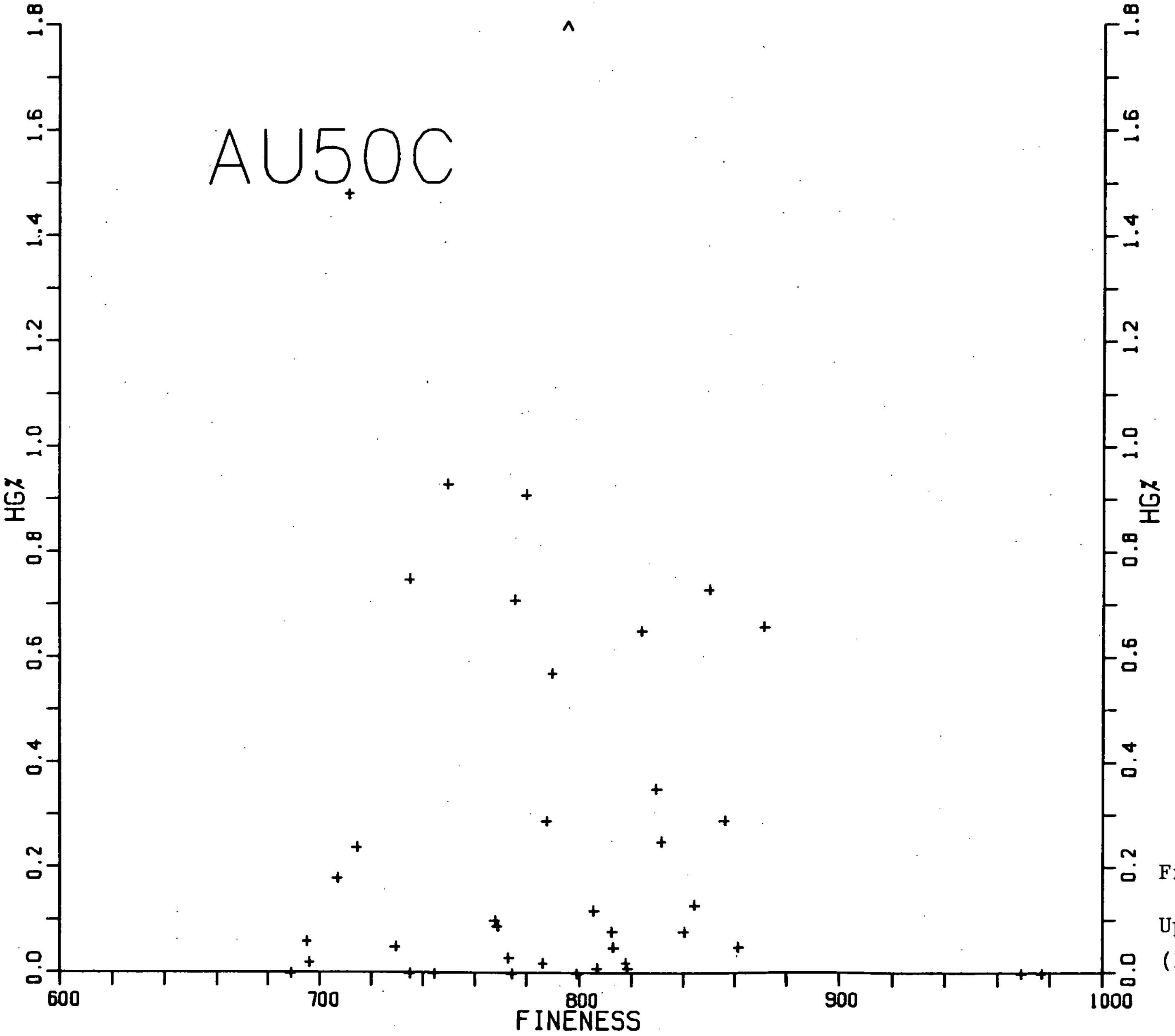


Figure 23e:

Upper Fraser

(Rimmed)

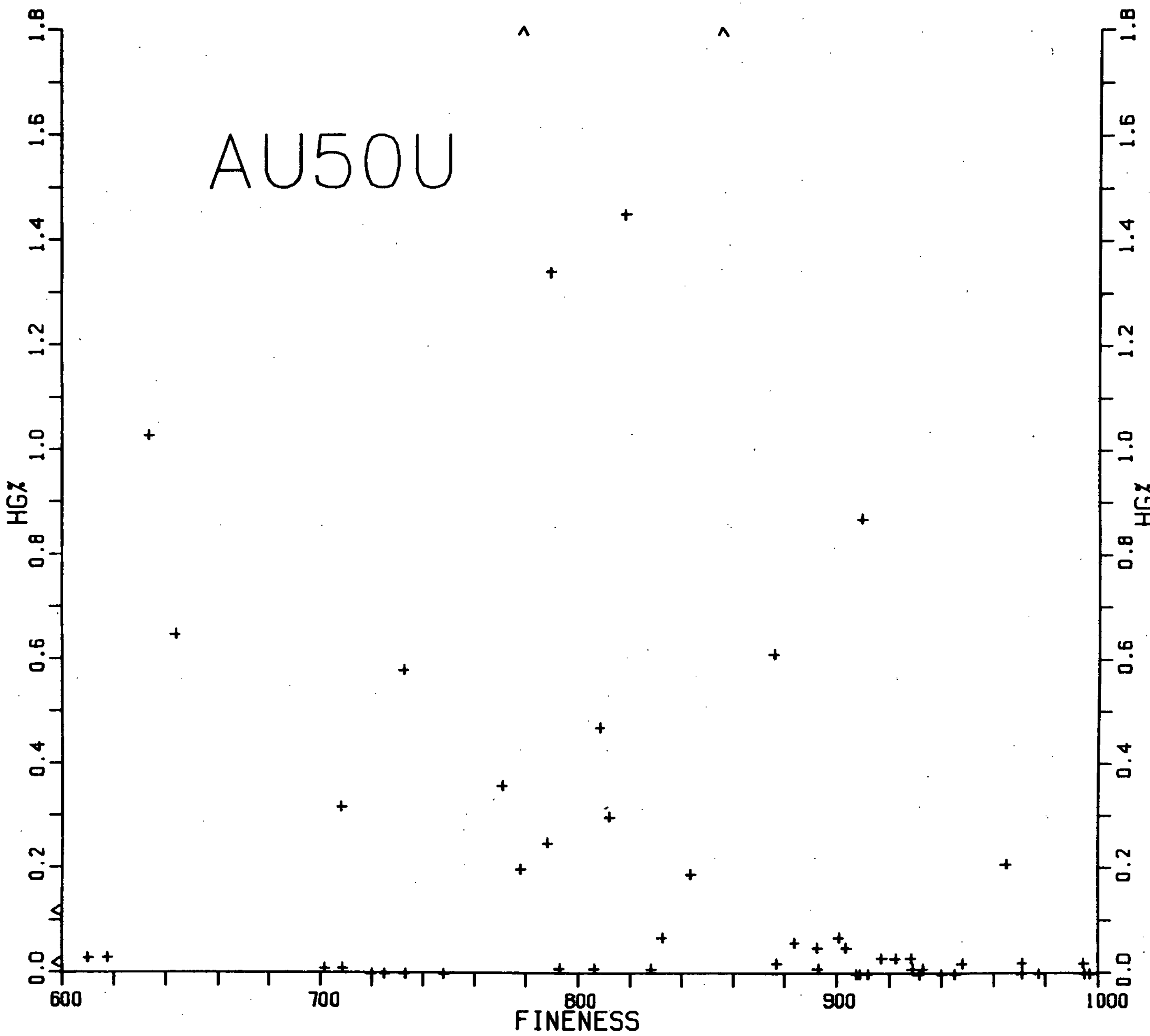


Figure 23f:

Upper Fraser

(Unrimmed)

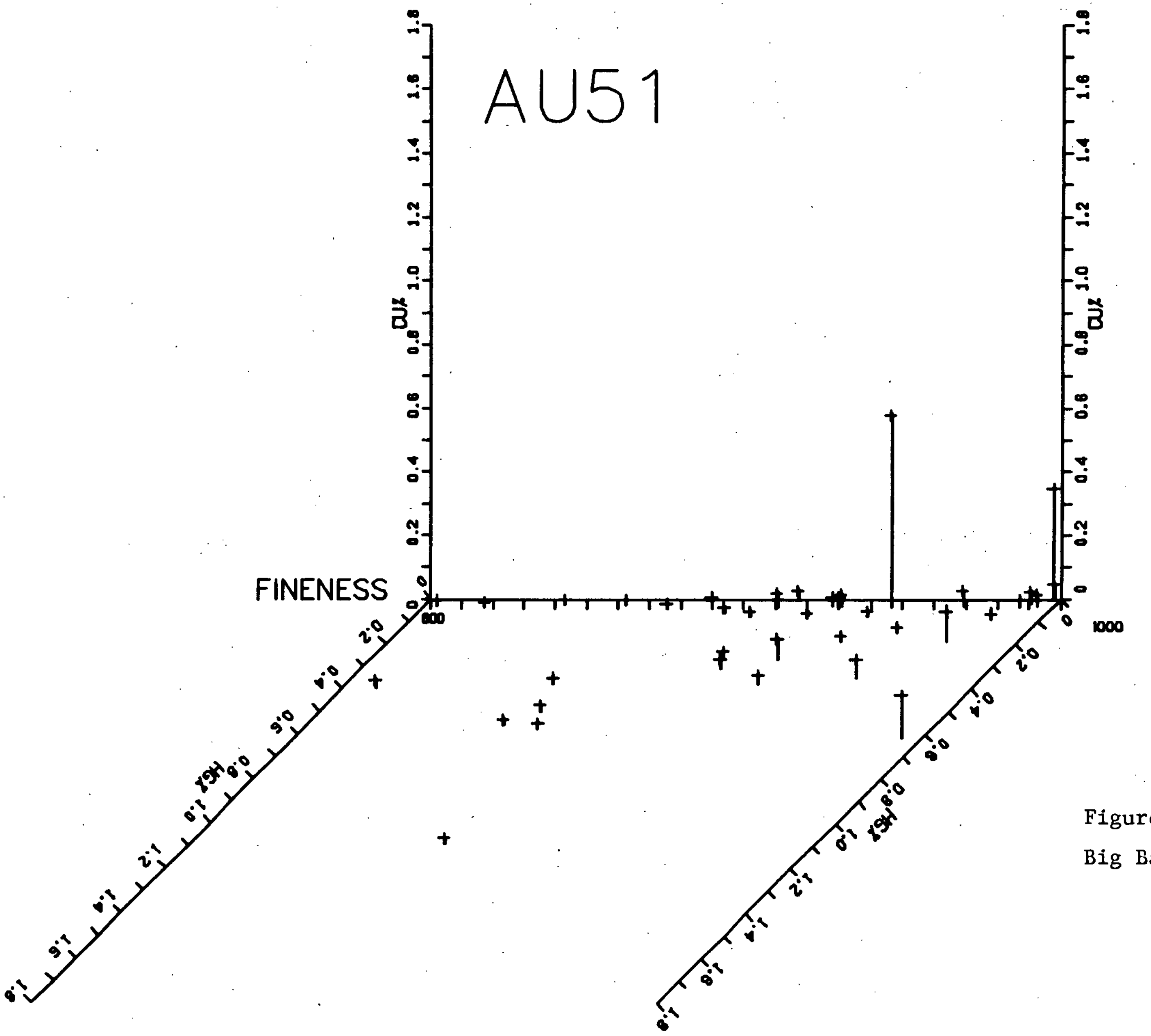


Figure 24a:
Big Bar

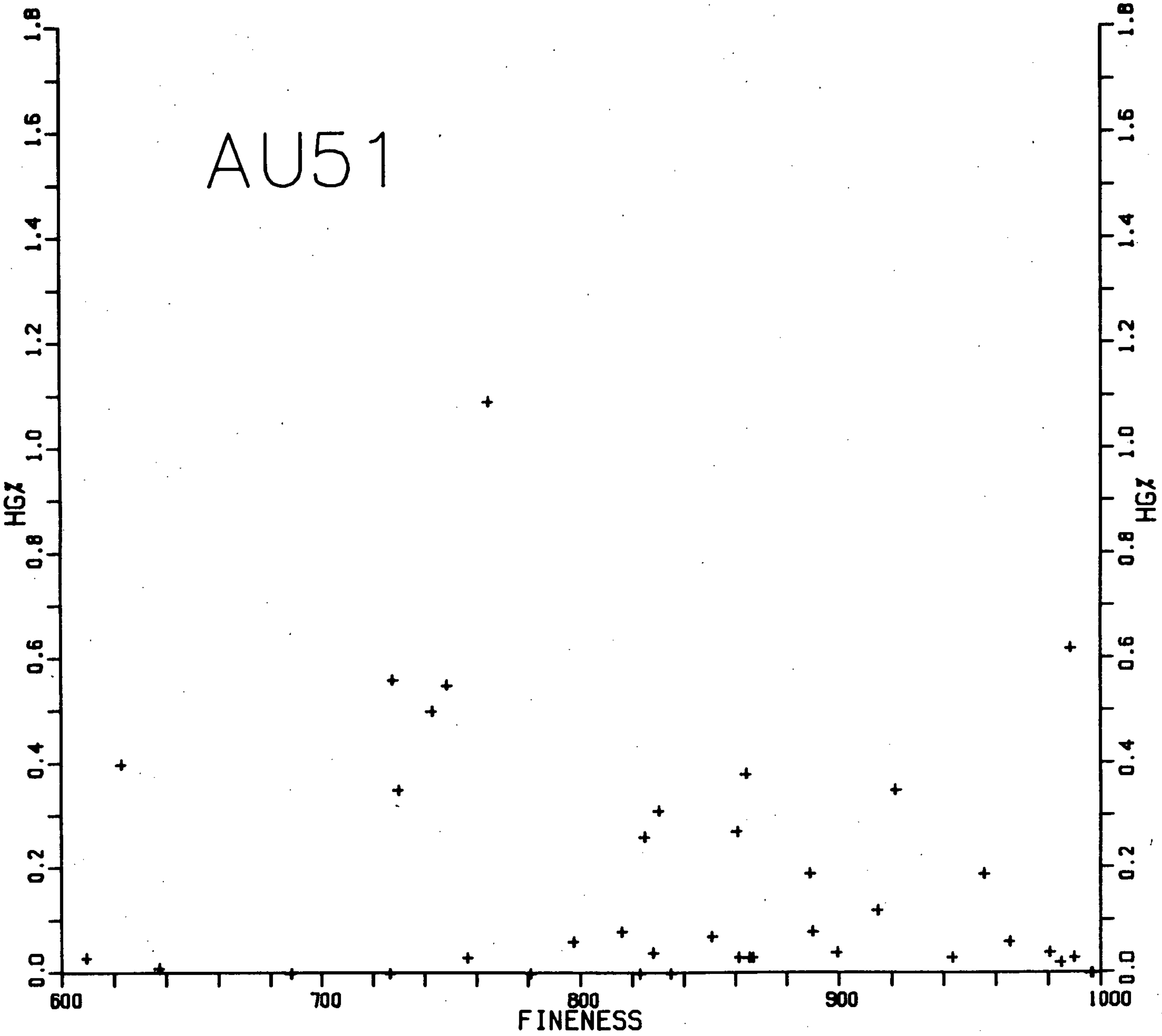


Figure 24b:
Big Bar

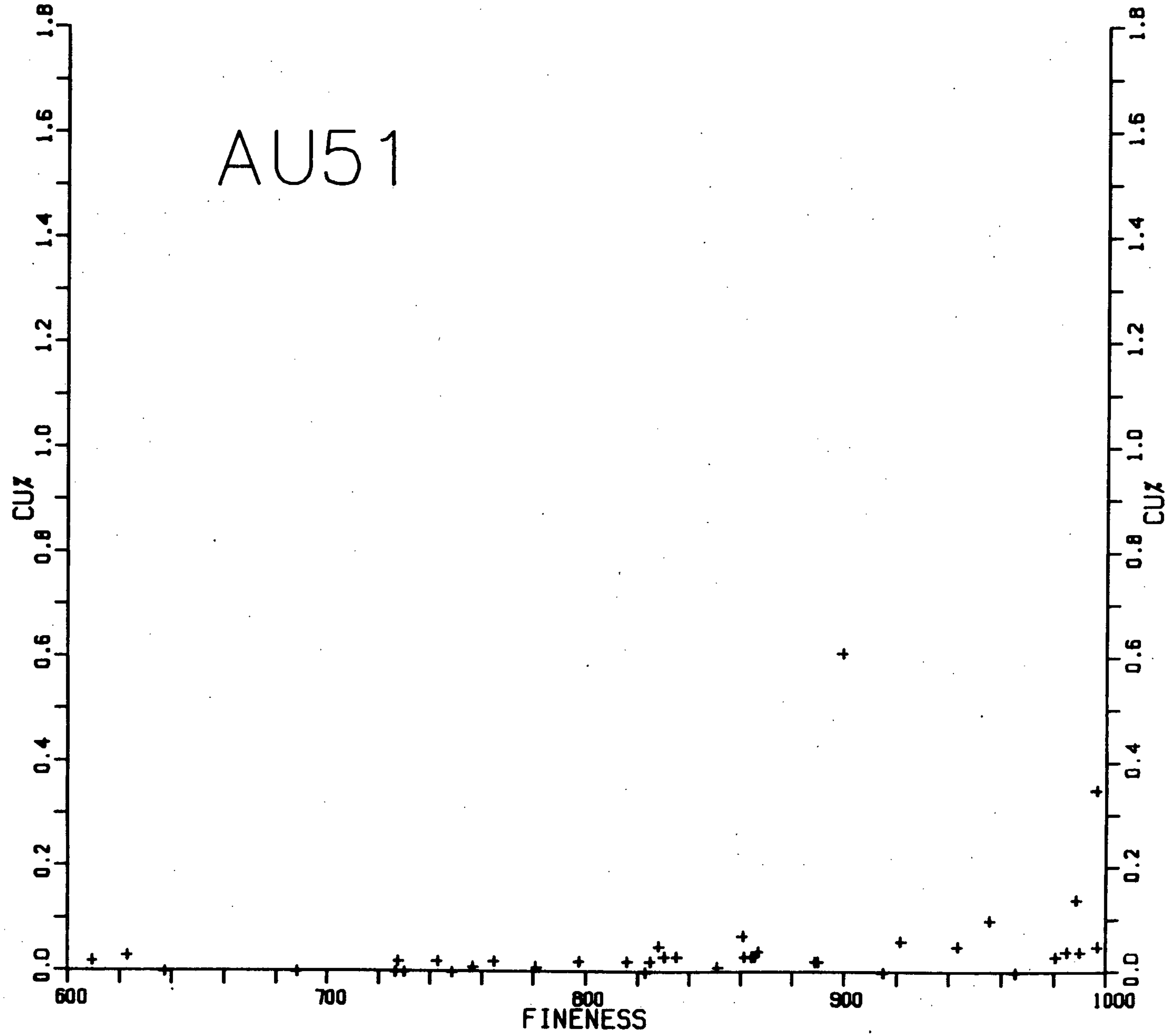


Figure 24c:
Big Bar

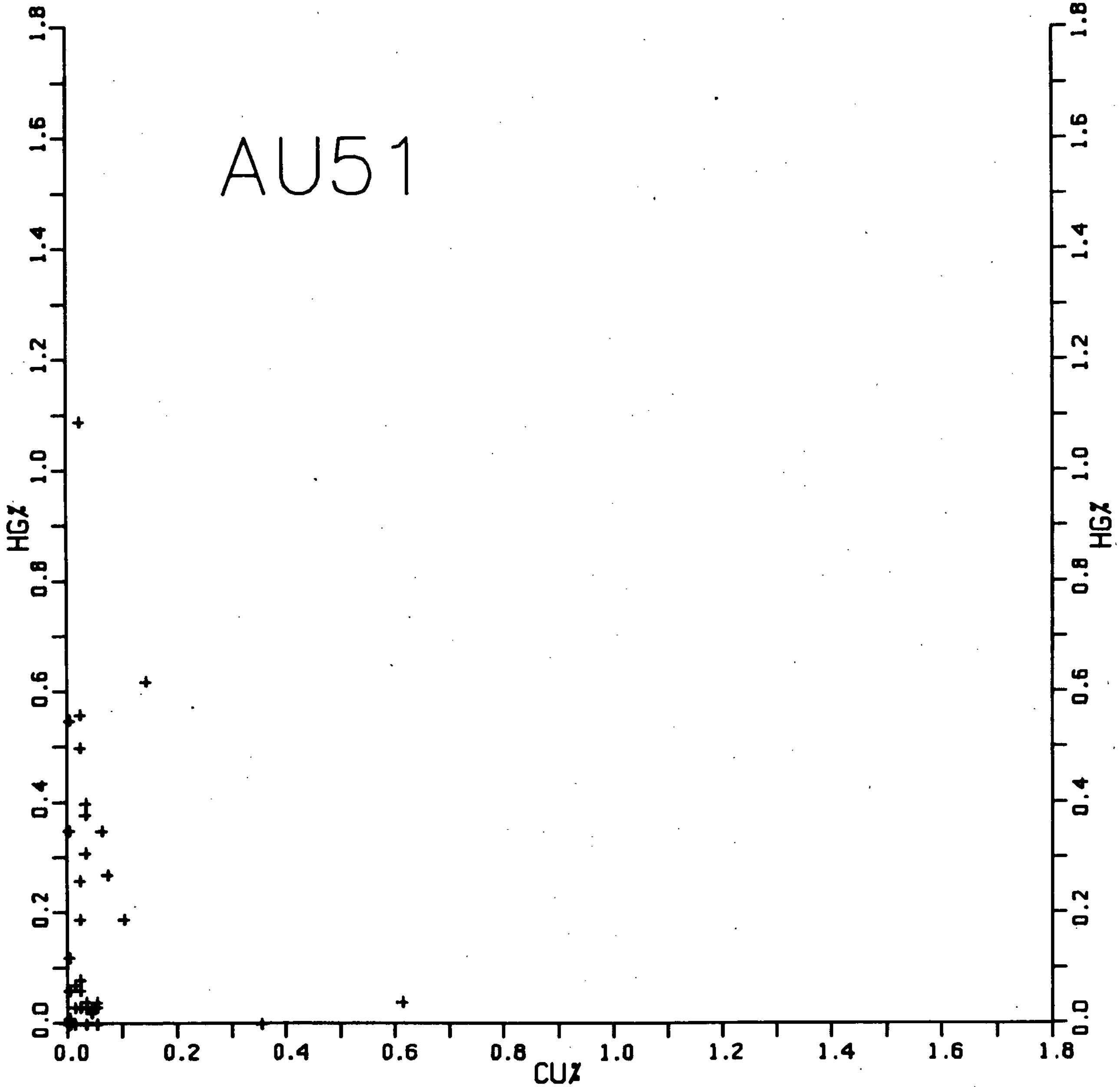


Figure 24d:
Big Bar

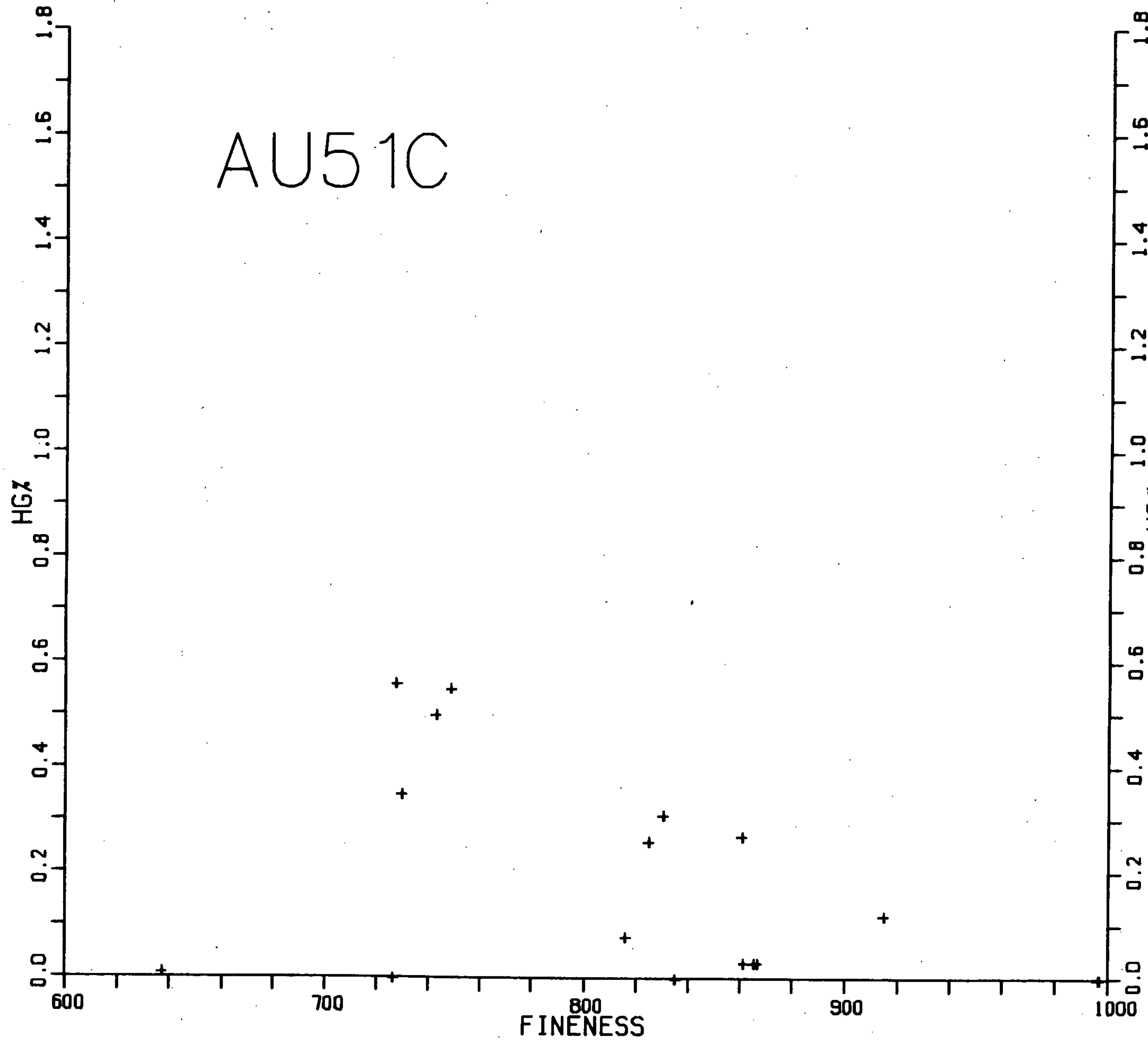


Figure 24e:

Big Bar (Rimmed)

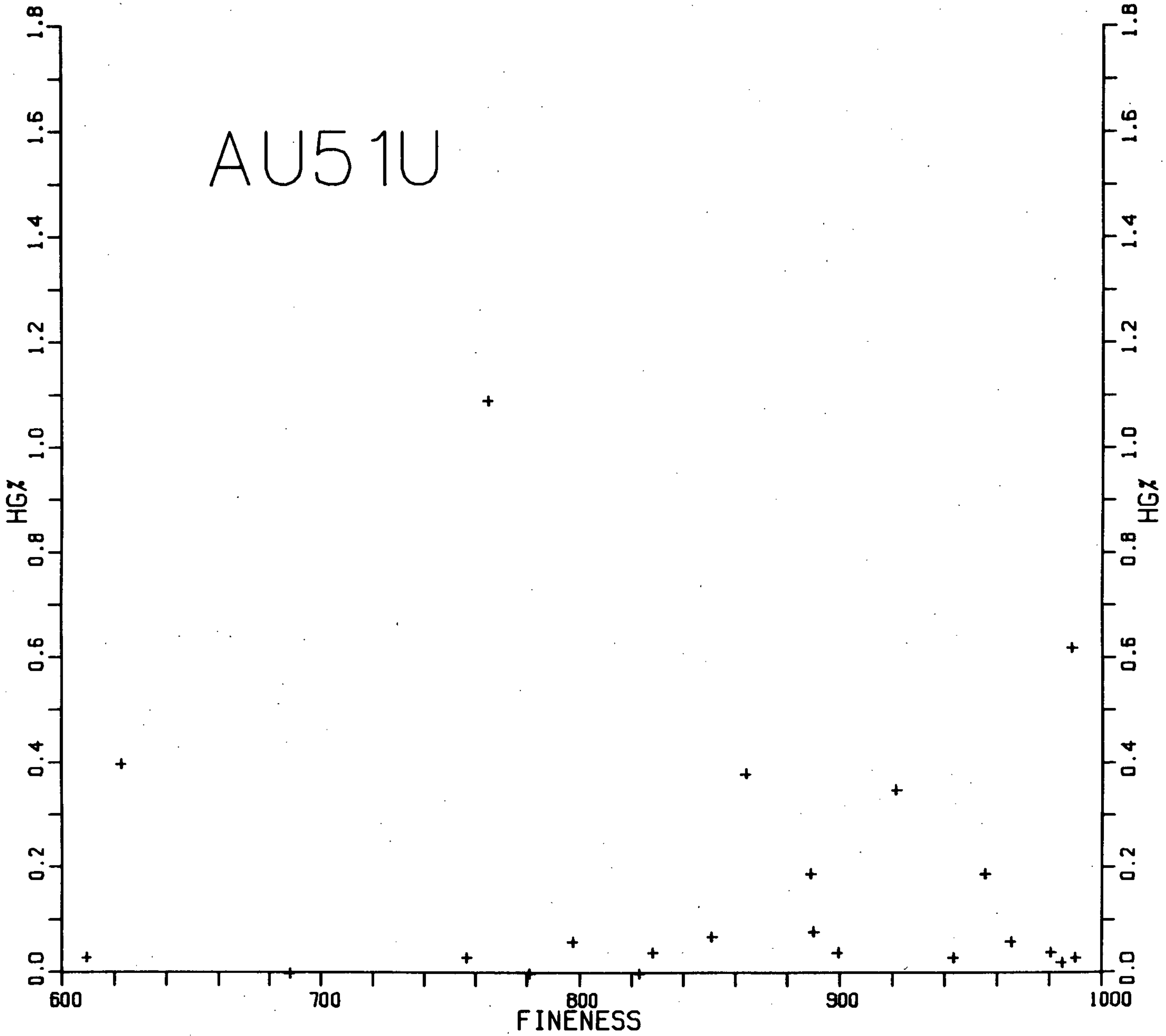


Figure 24f:

Big Bar

(Unrimmed)

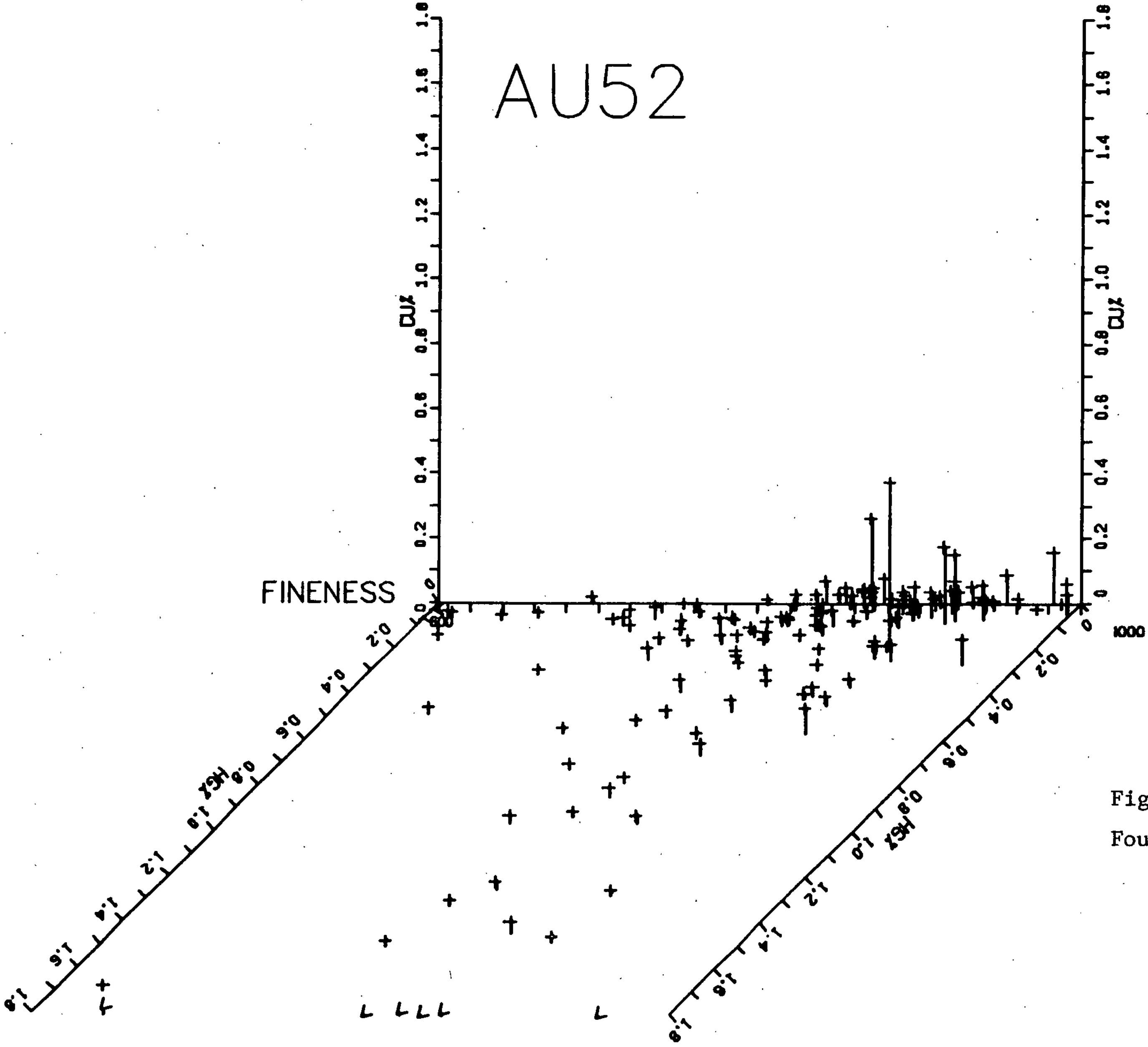


Figure 25a:
Fountain Bar

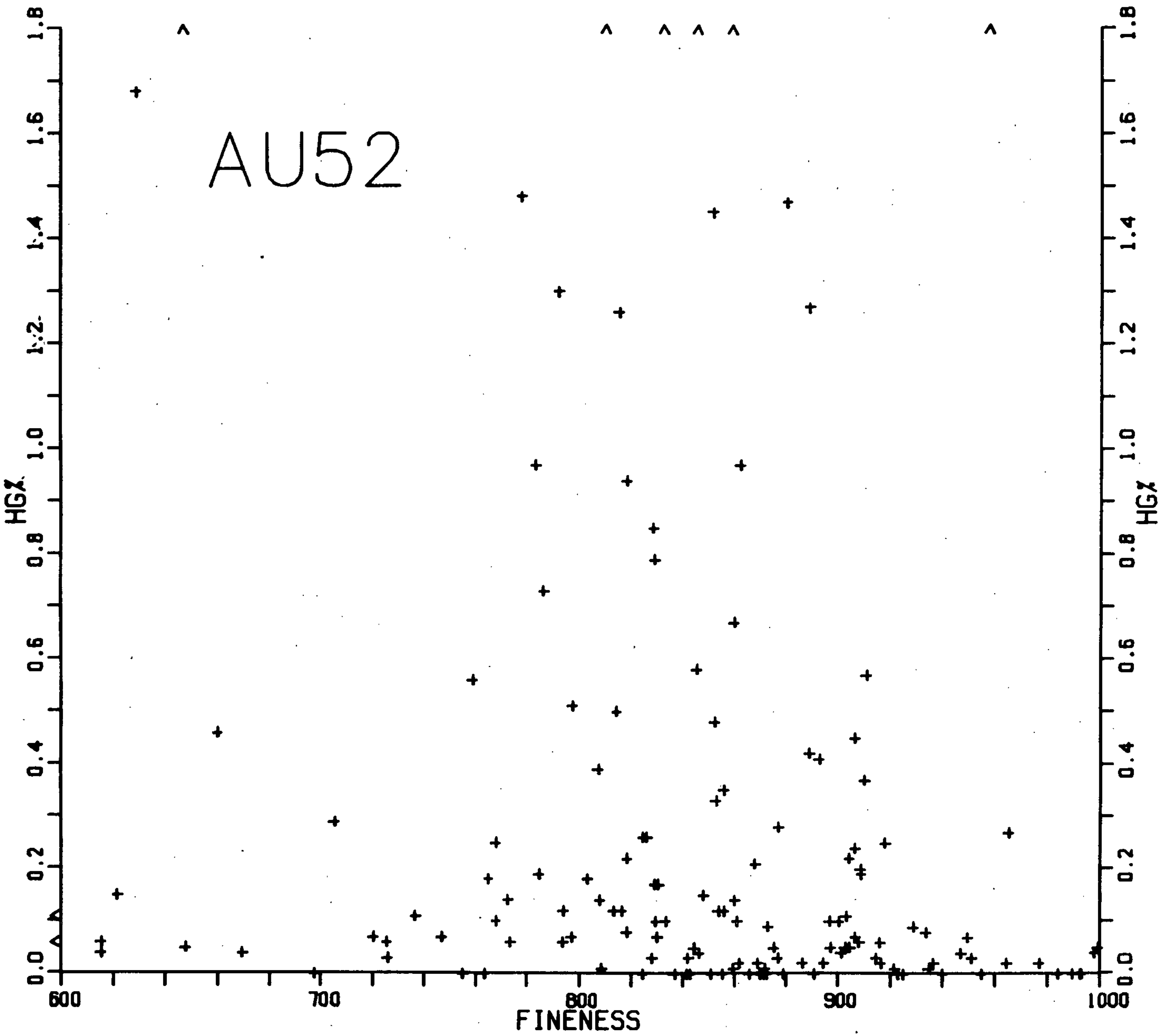


Figure 25b:
Fountain Bar

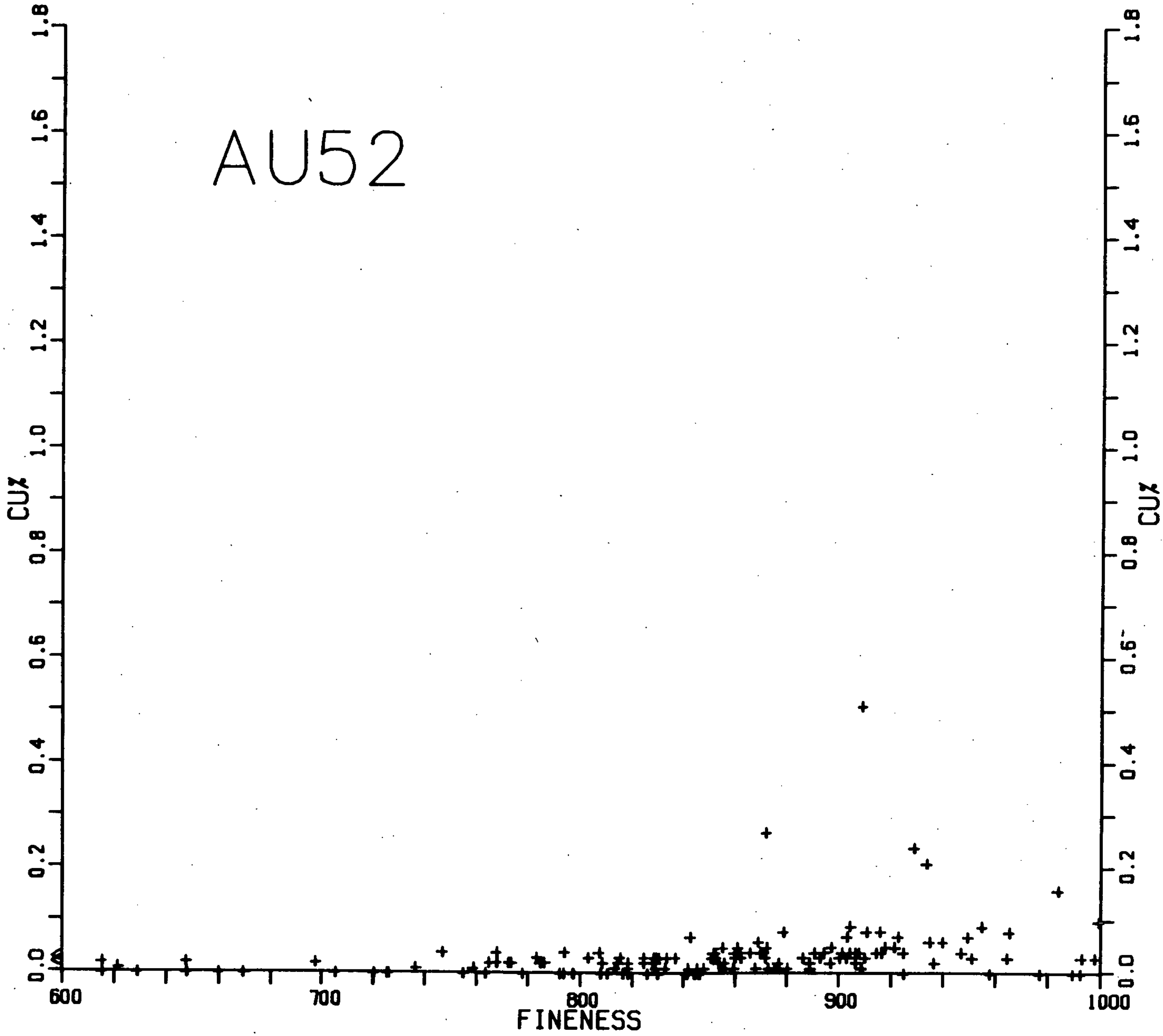


Figure 25c:
Fountain Bar

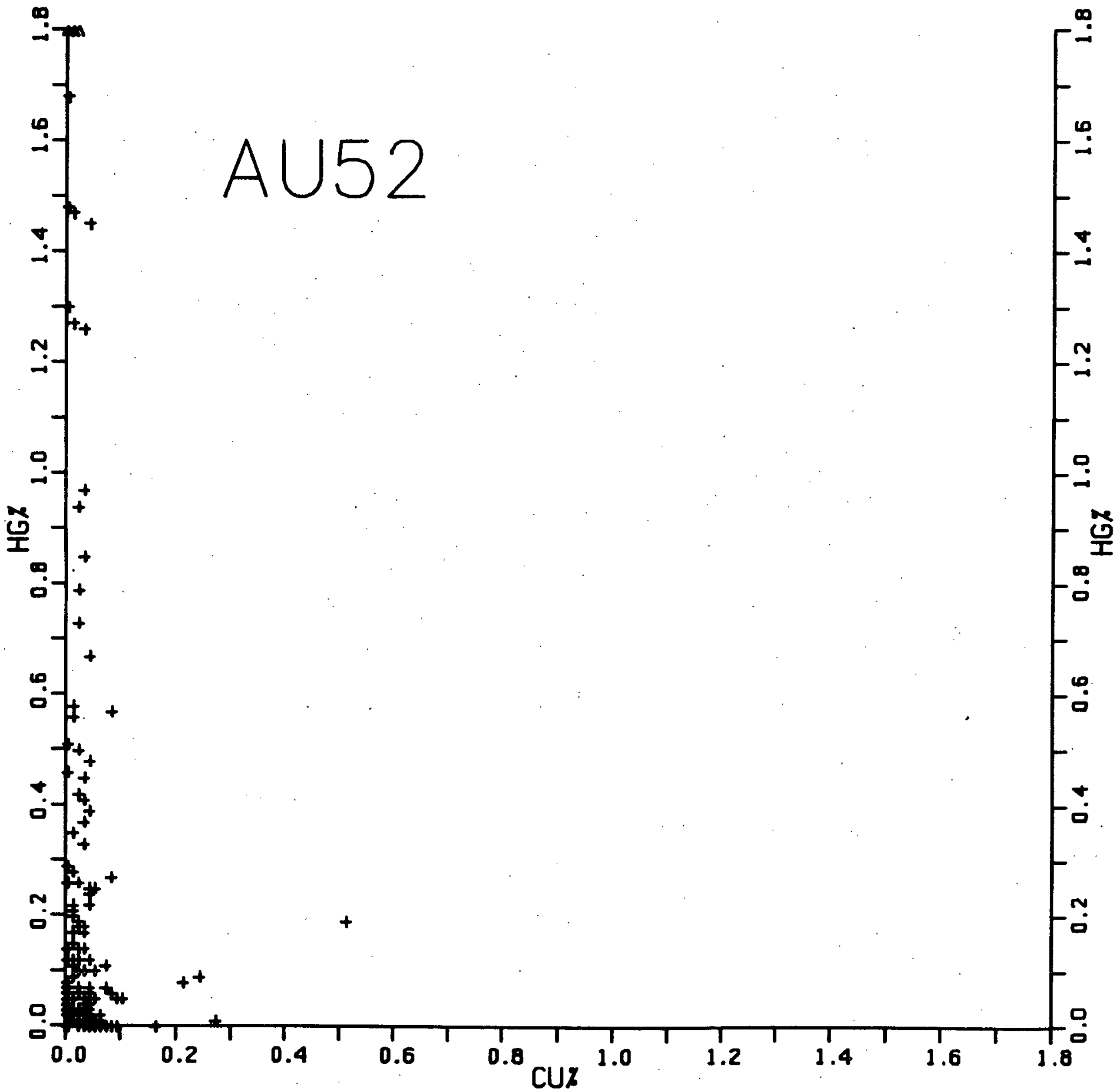


Figure 25d:
Fountain Bar

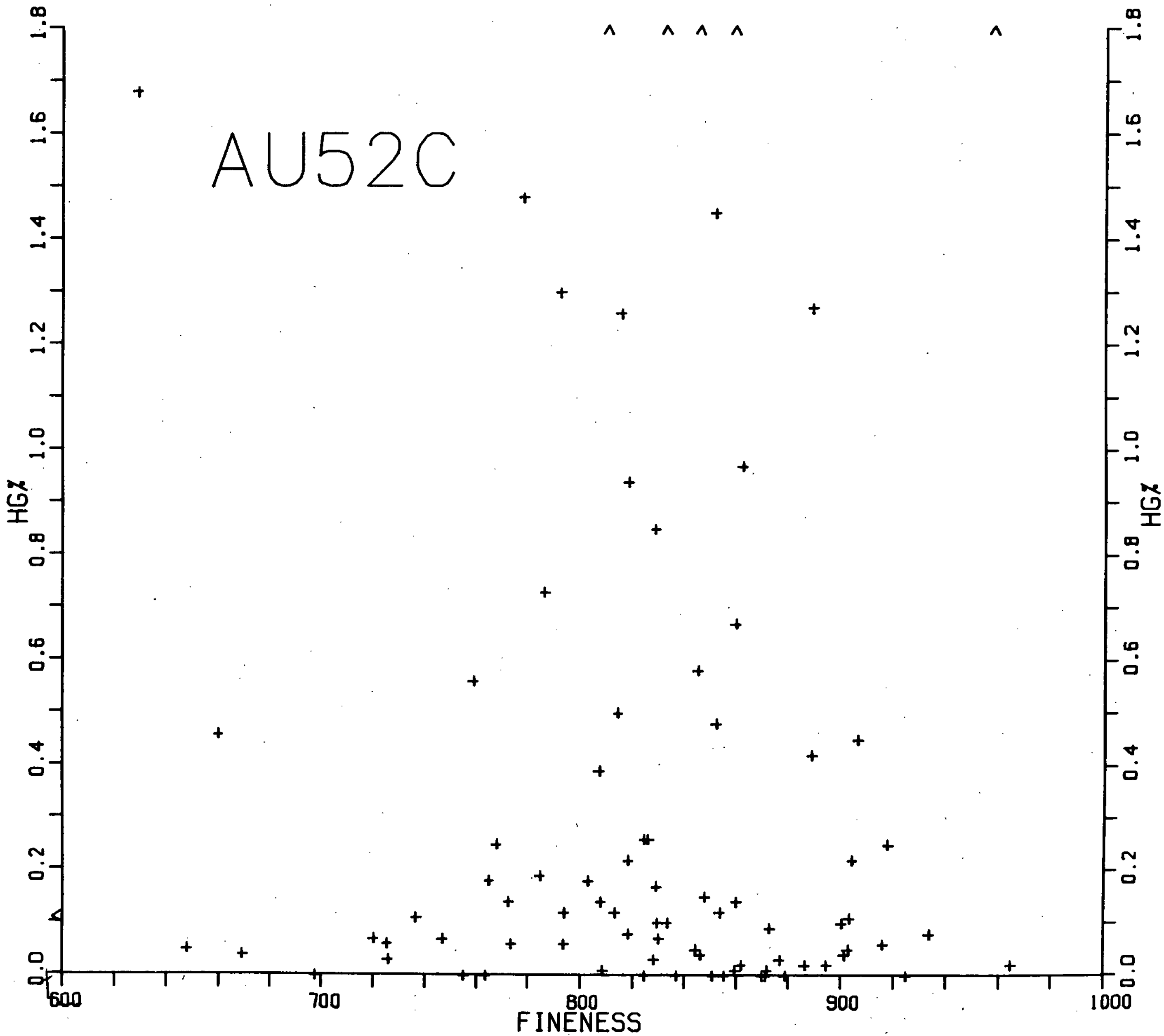


Figure 25e:

Fountain Bar

(Rimmed)

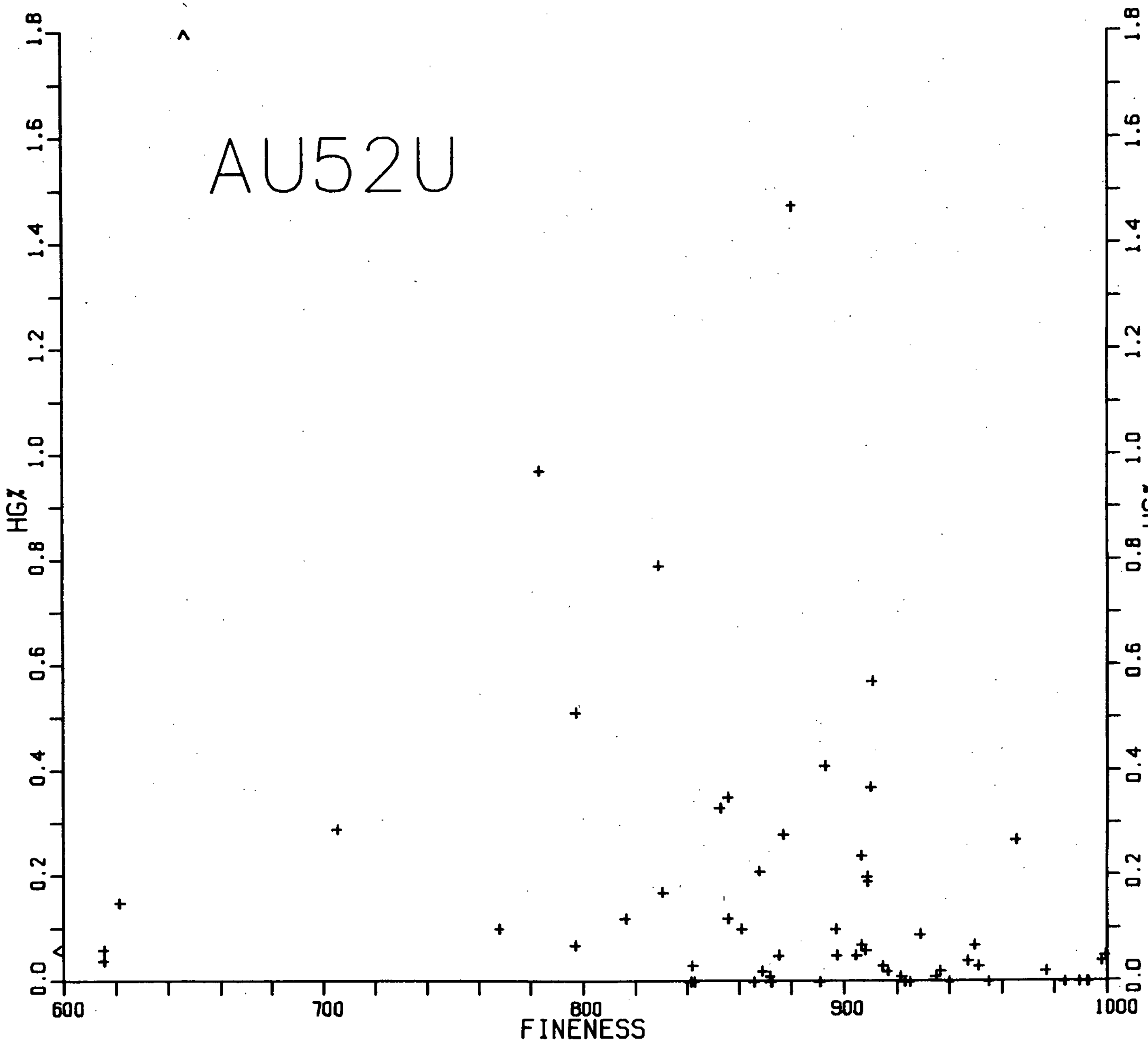


Figure 25f:

Fountain Bar

(Unrimmed)

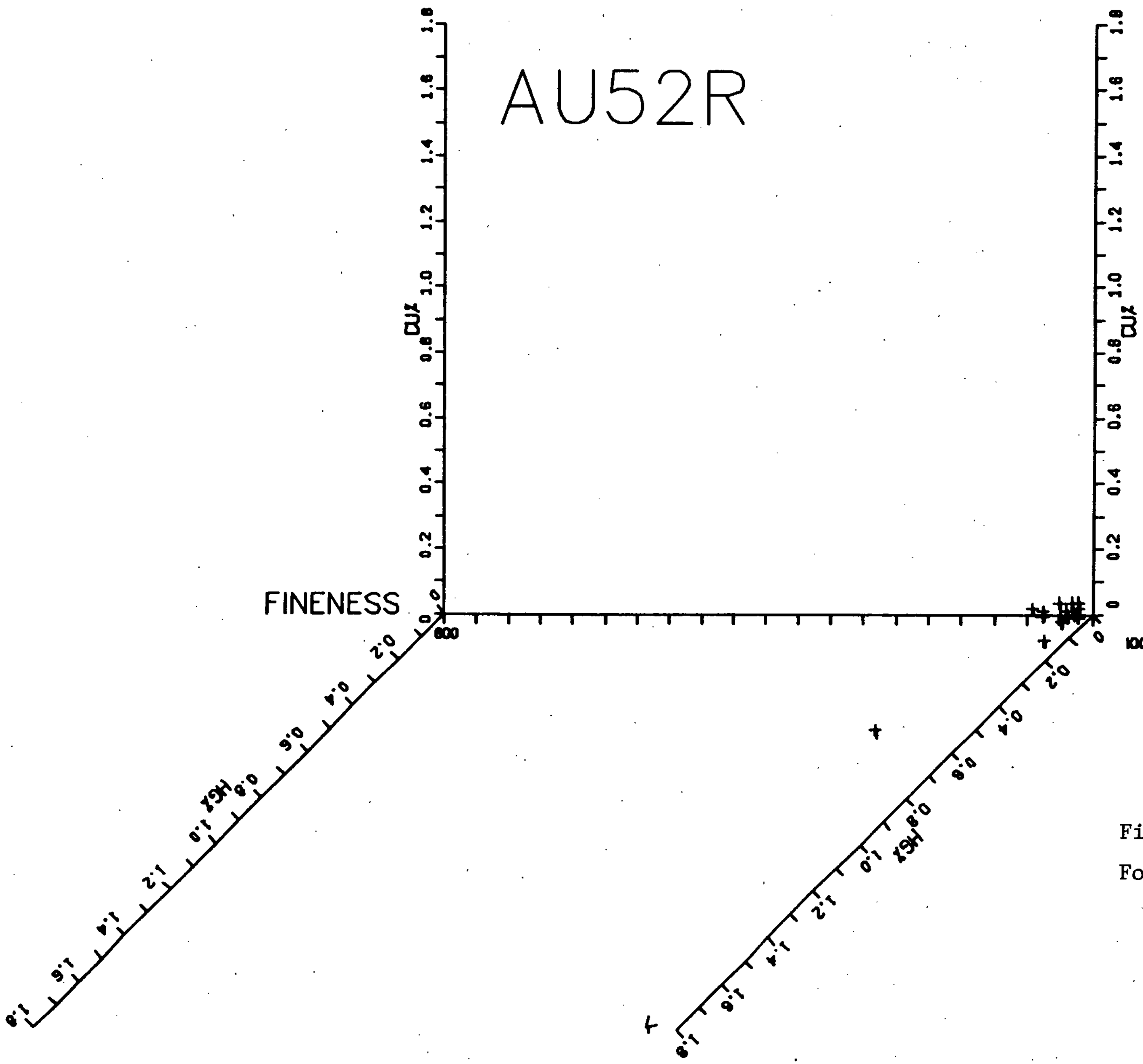


Figure 26a:
Fountain Rim

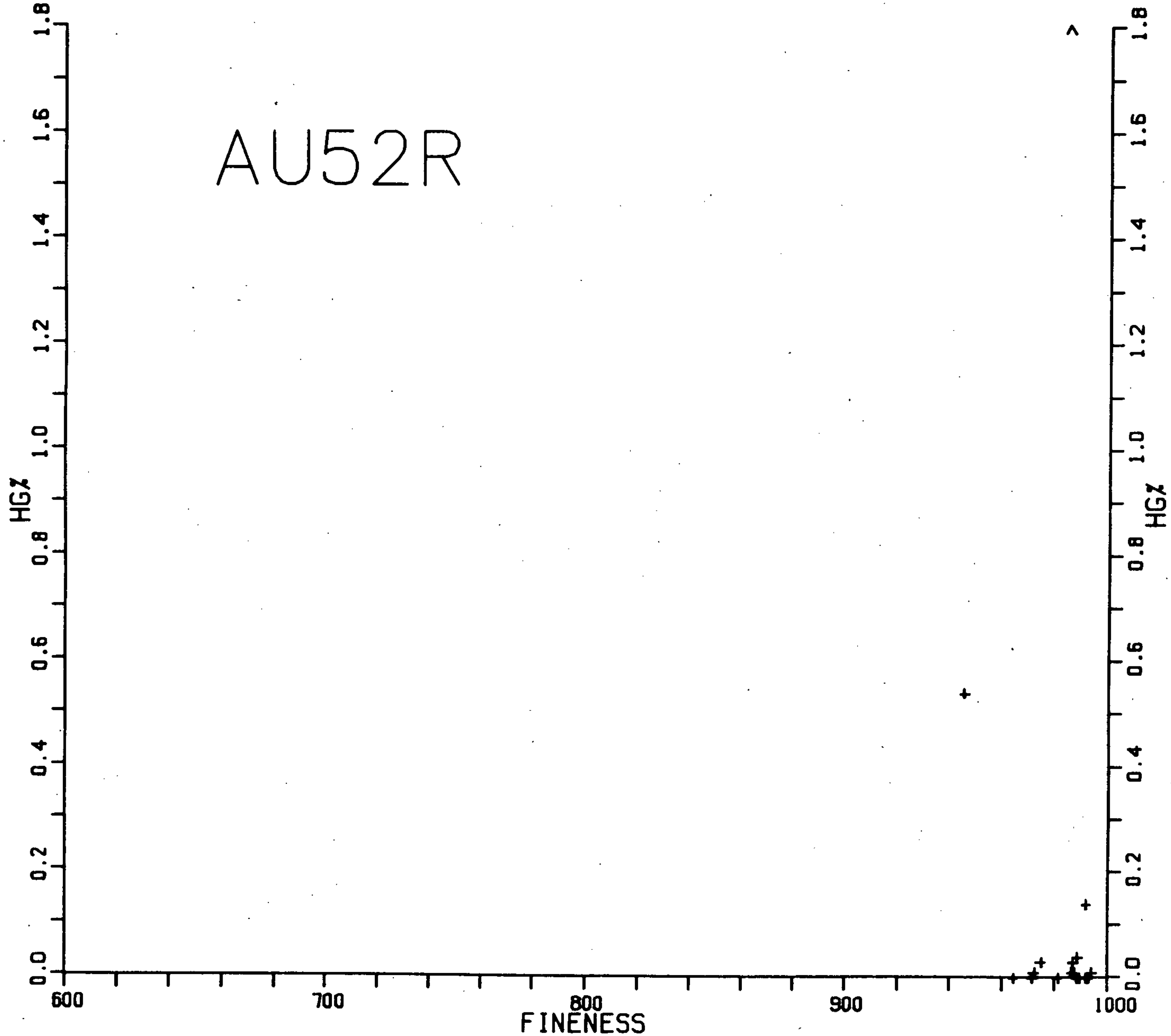


Figure 26b:

Fountain Rim

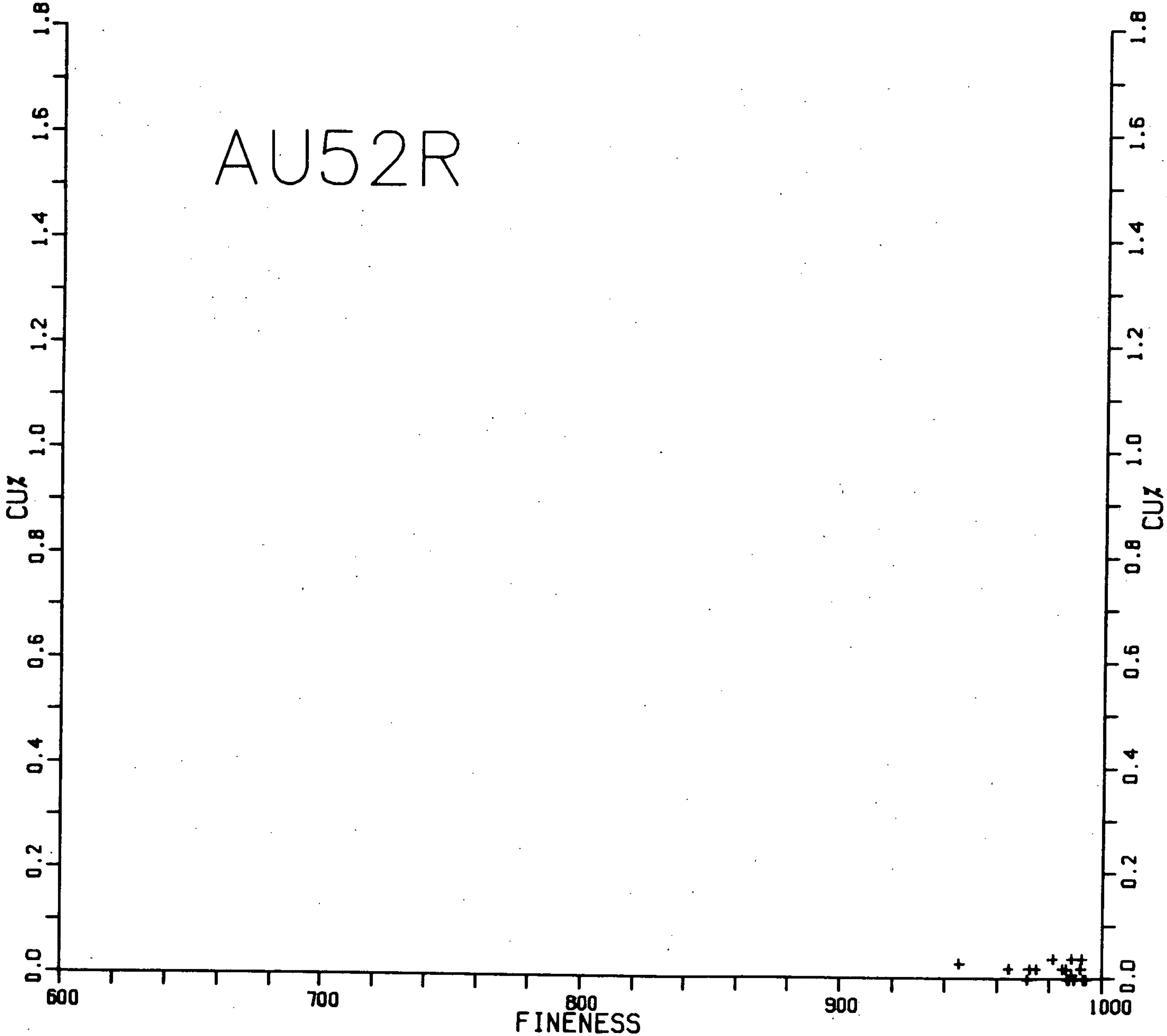


Figure 26c:
Fountain Rim

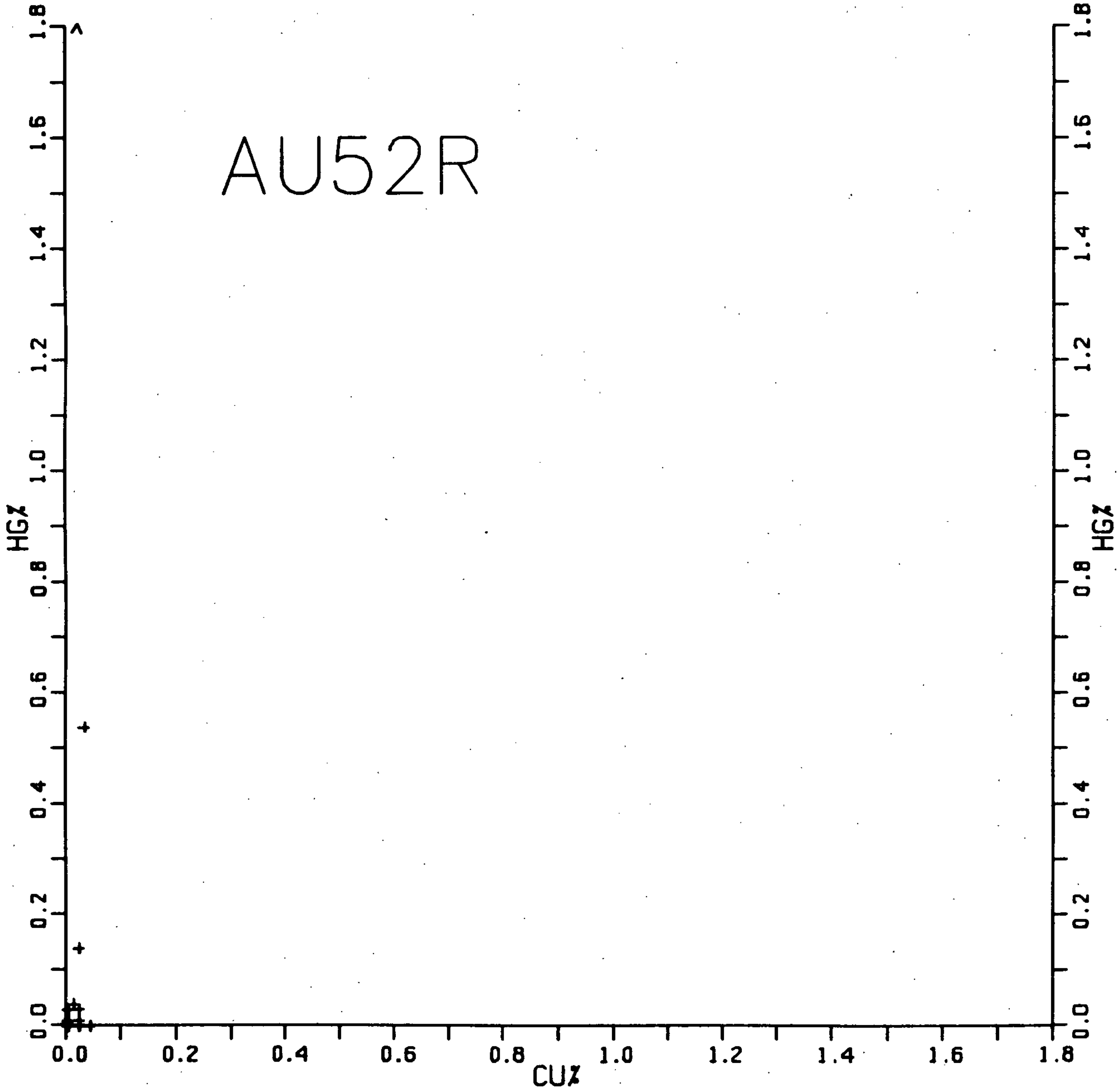


Figure 26d:
Fountain Rim

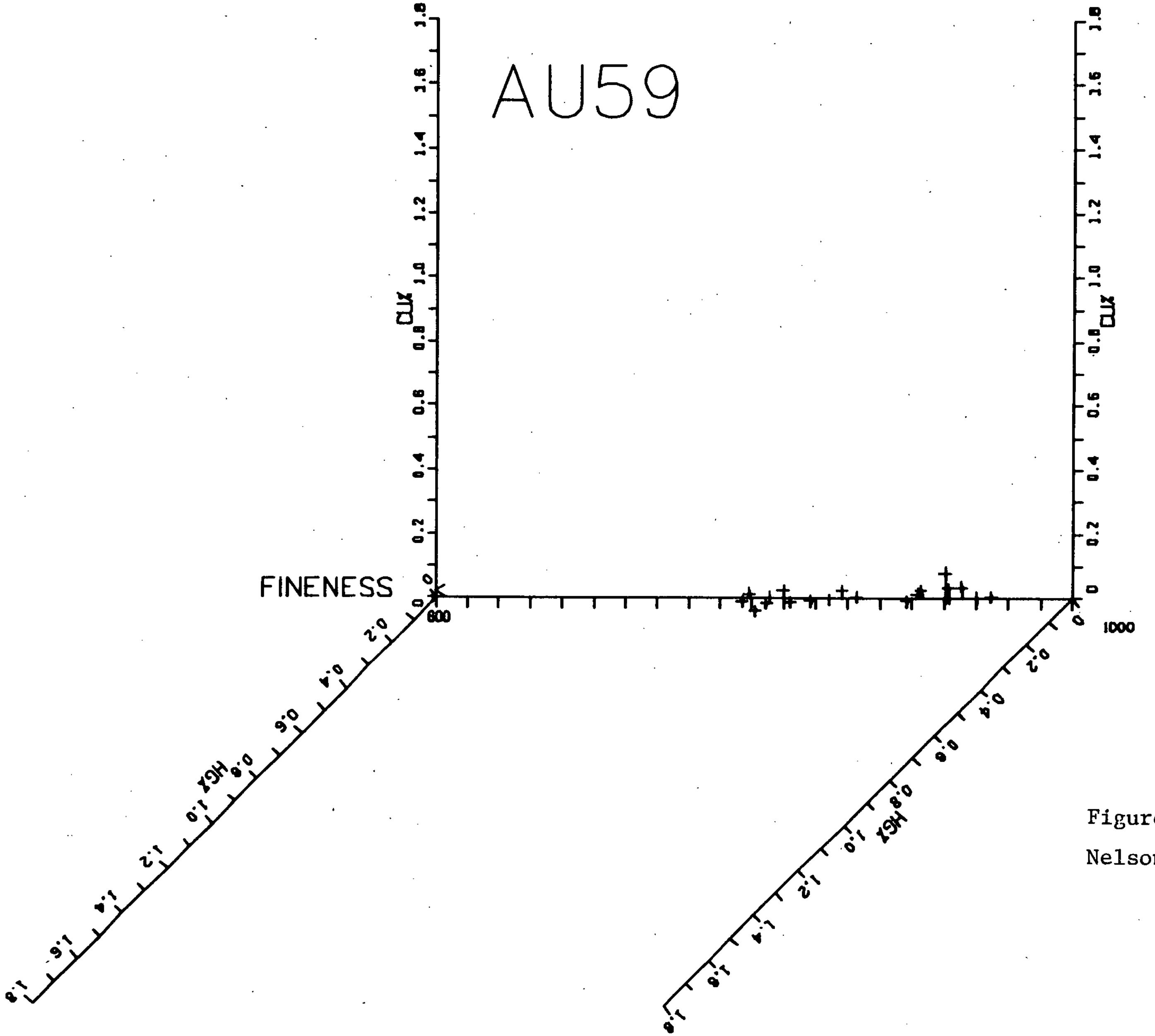


Figure 27a:
Nelson

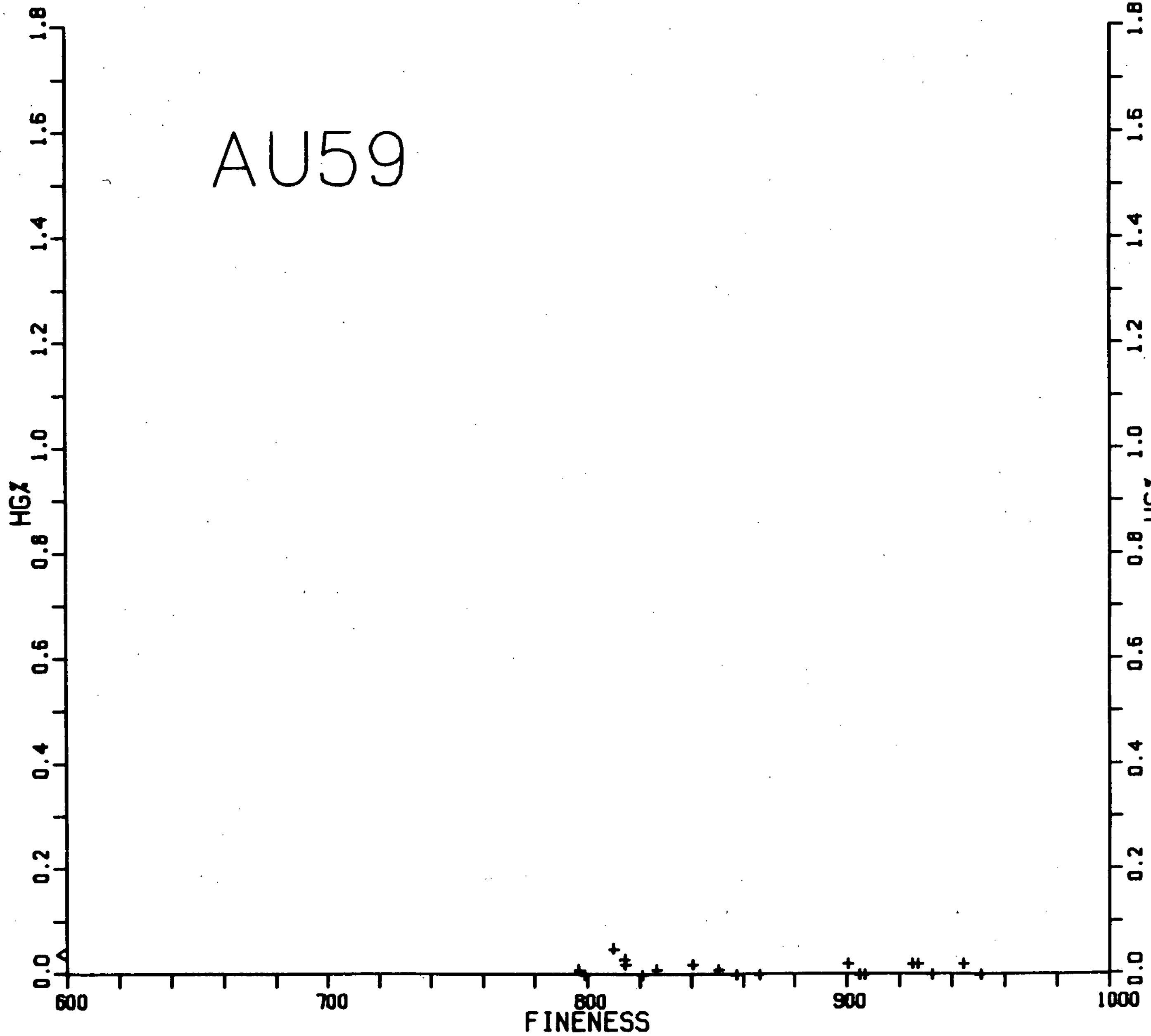


Figure 27b:
Nelson

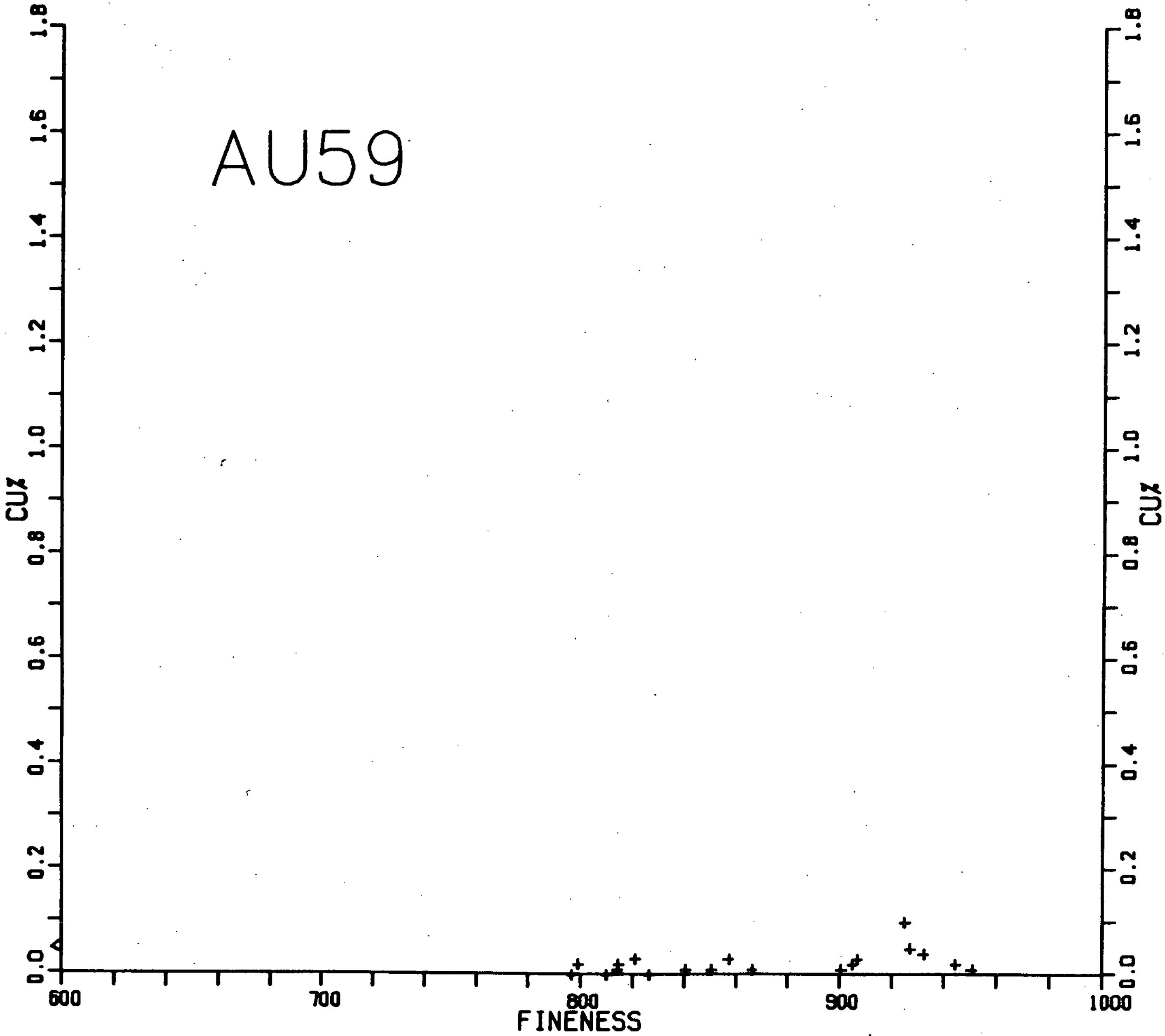


Figure 27c:
Nelson

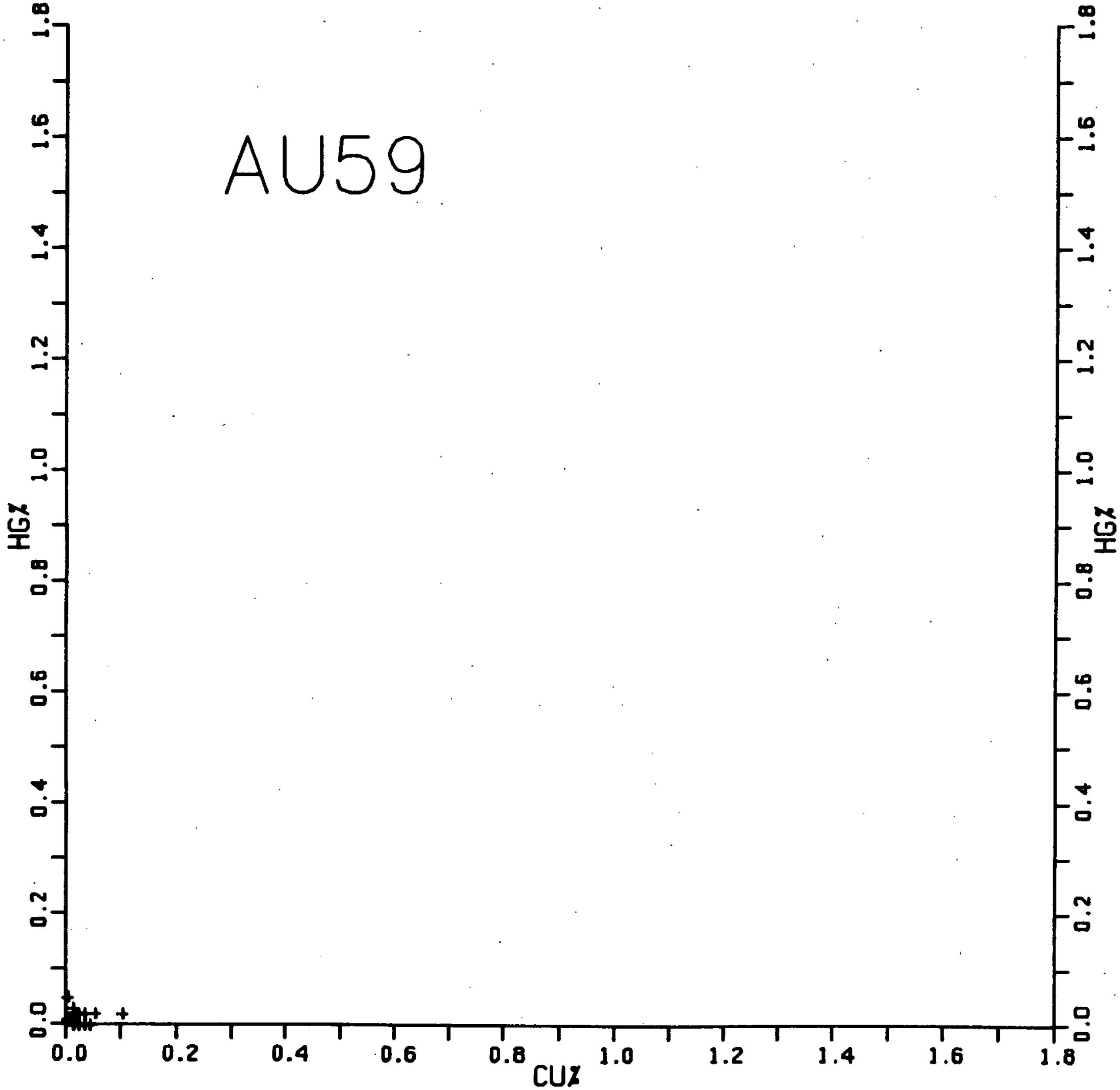


Figure 27d:
Nelson

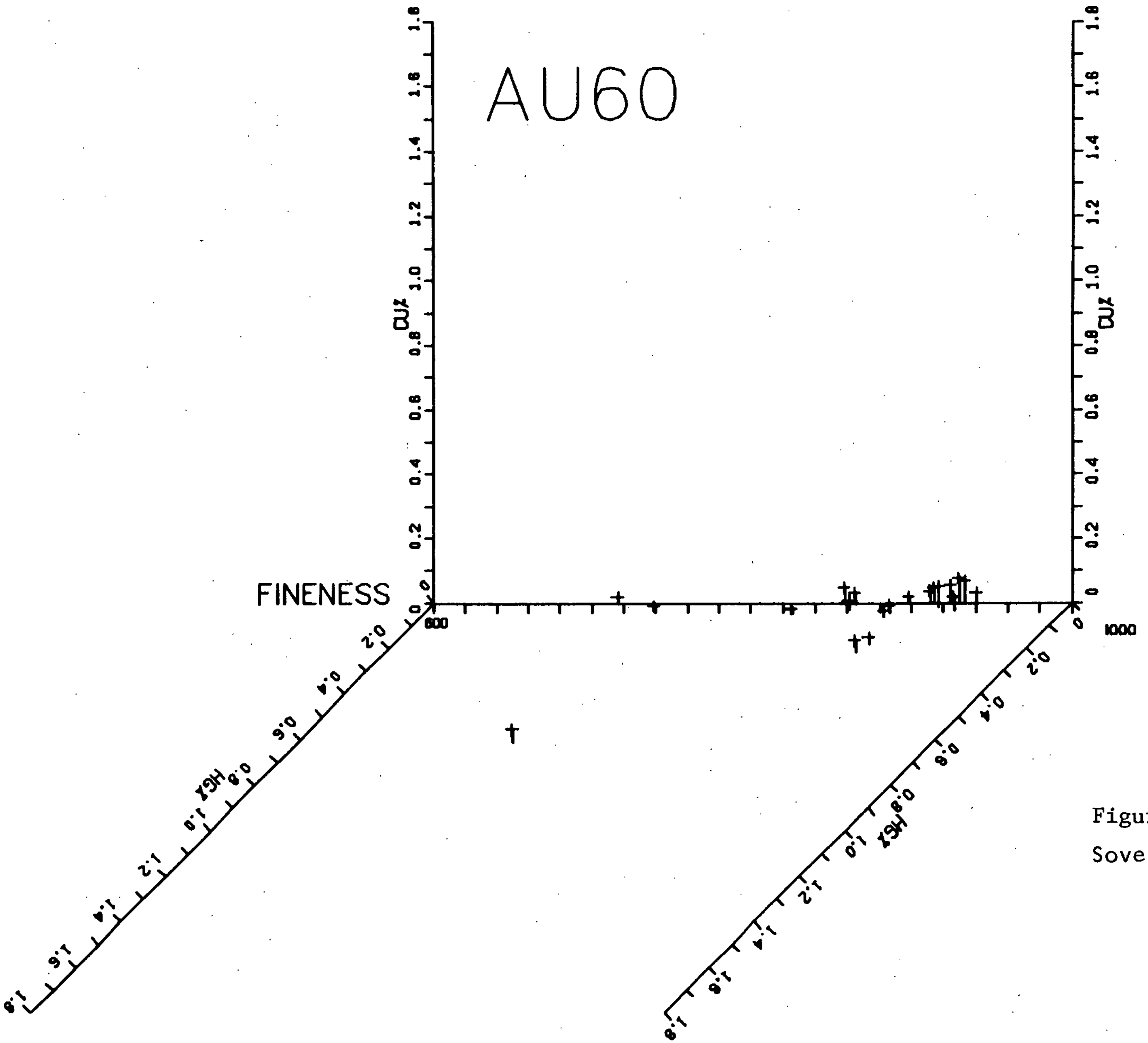


Figure 28a:
Sovereign

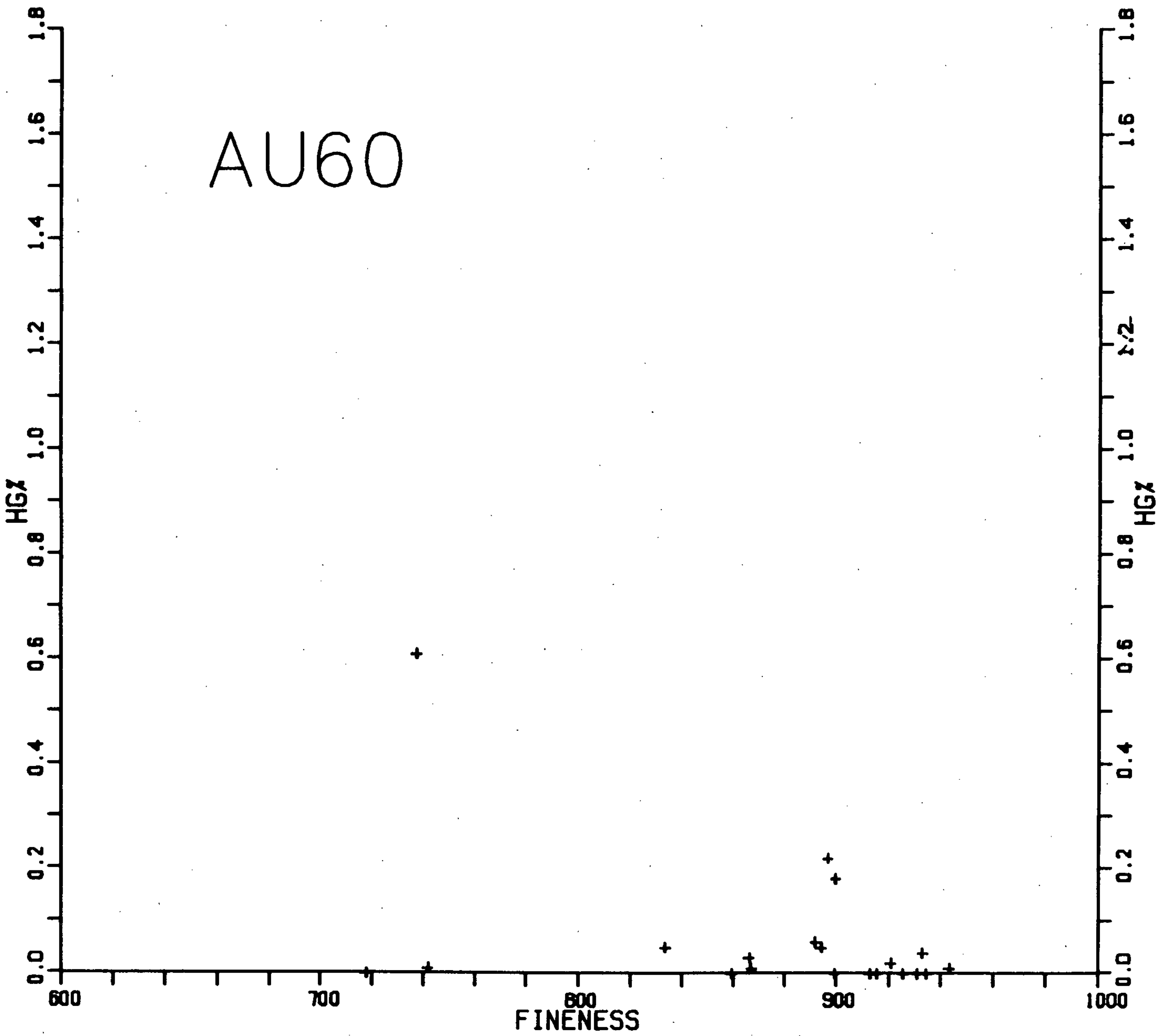


Figure 28b:
Sovereign

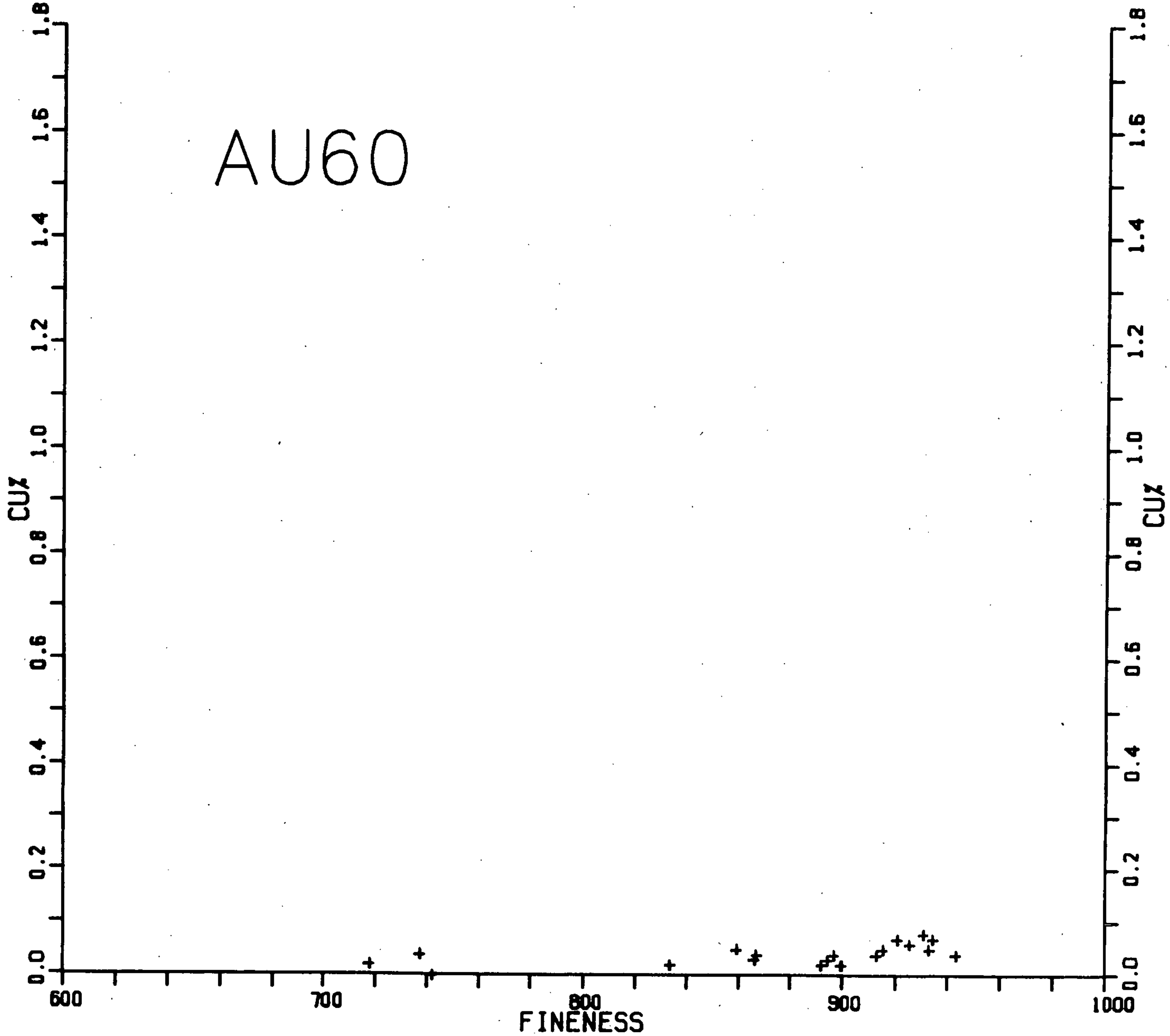


Figure 28c:

Sovereign

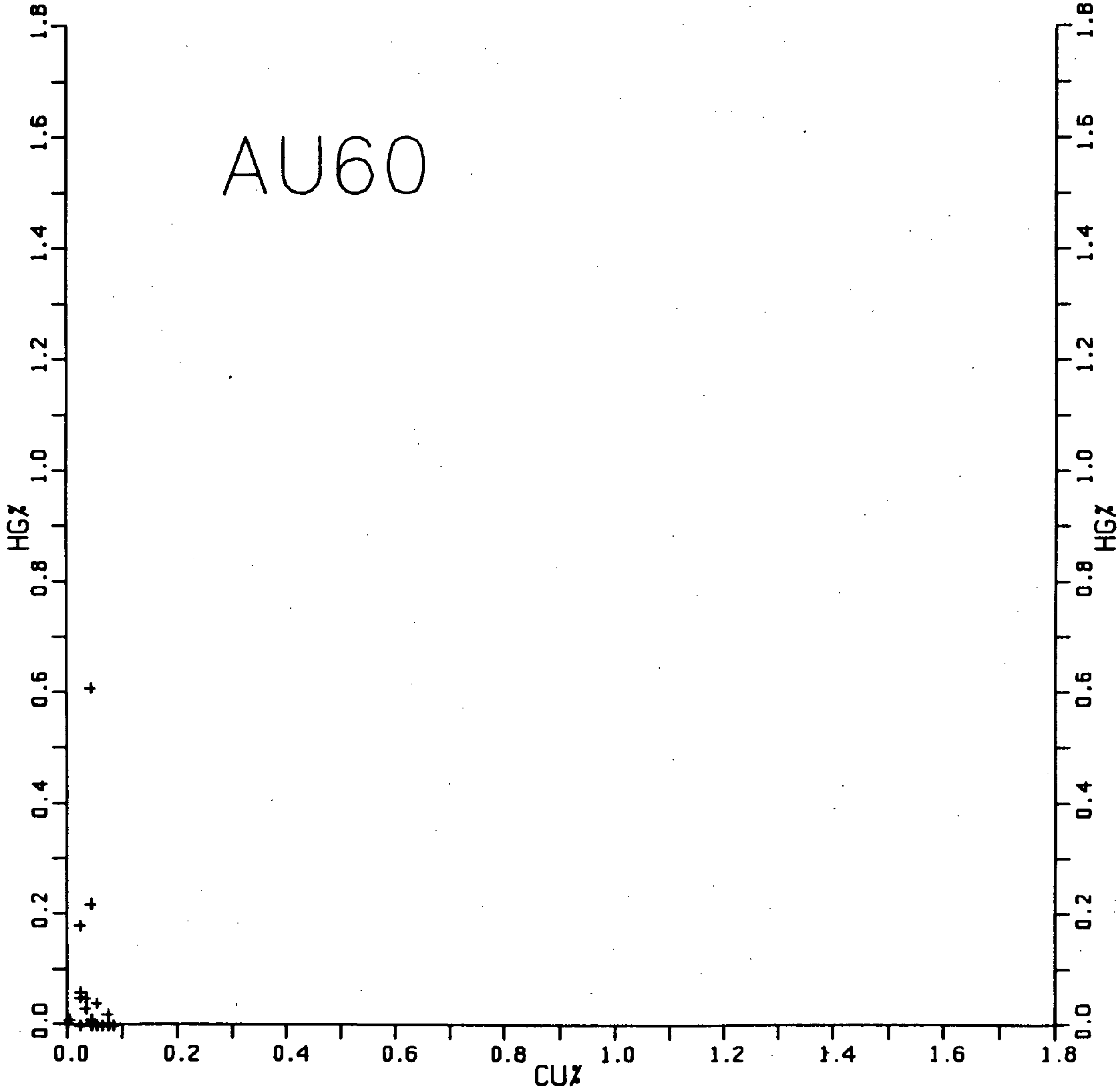


Figure 28d:

Sovereign

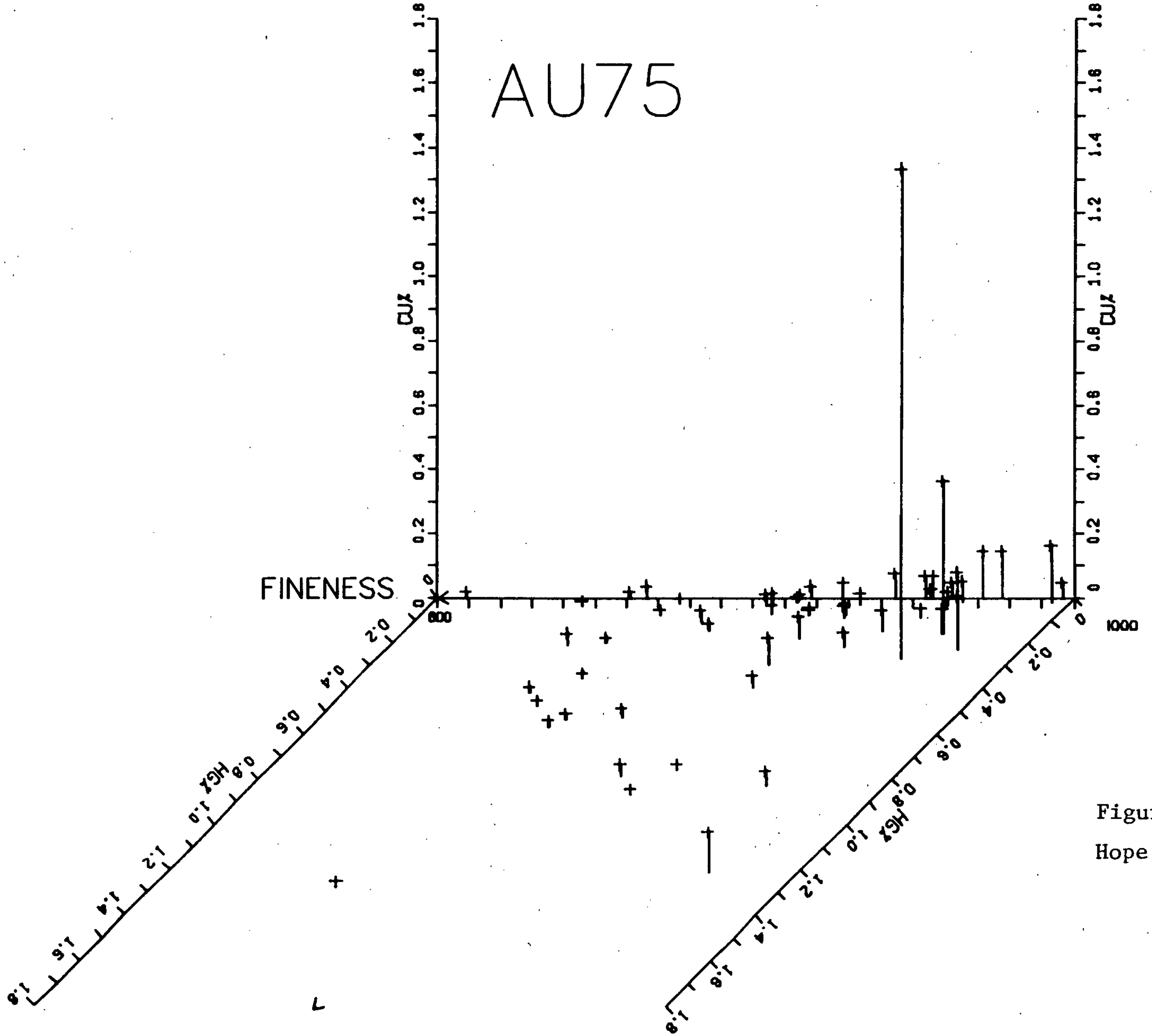


Figure 29a:
Hope

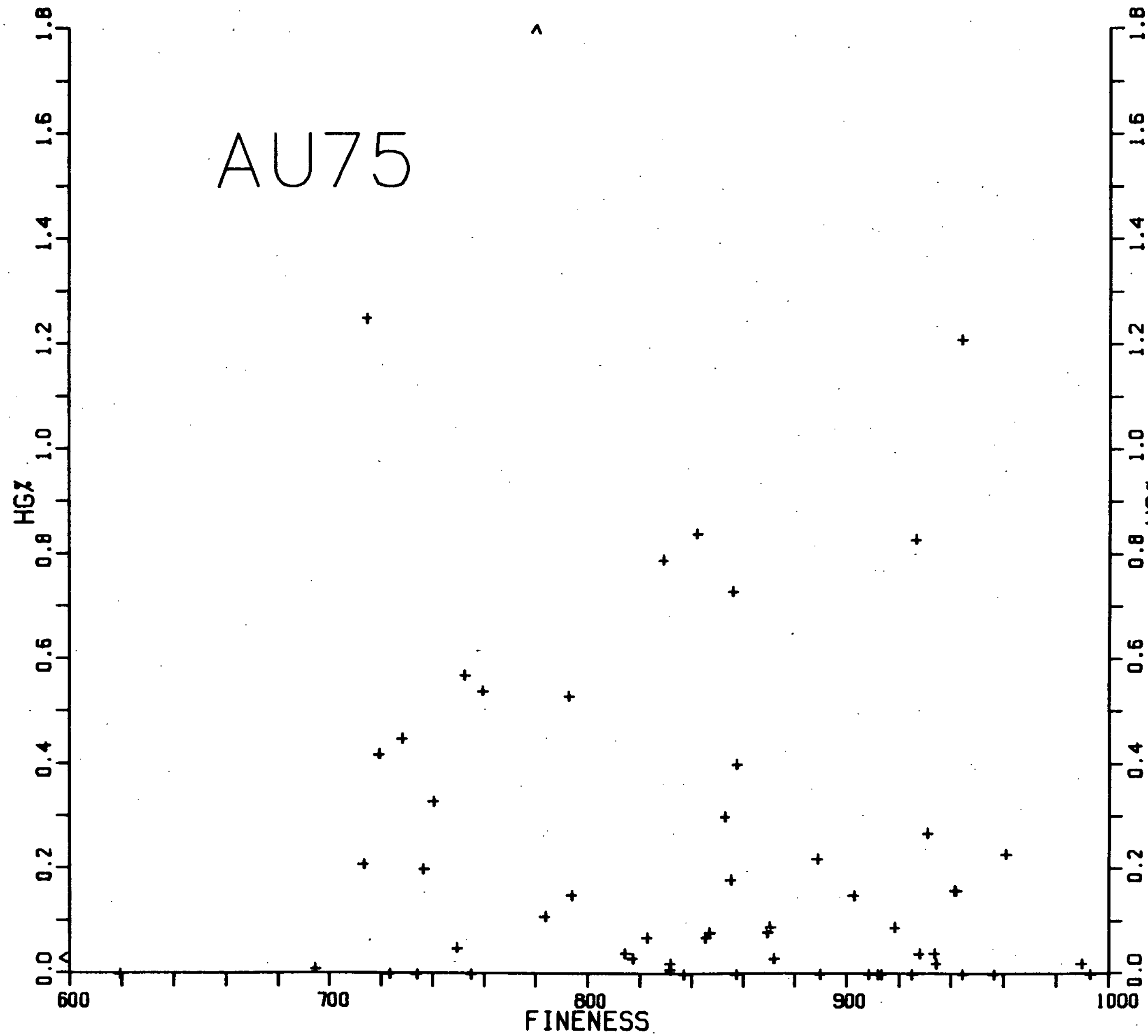


Figure 29b:
Hope

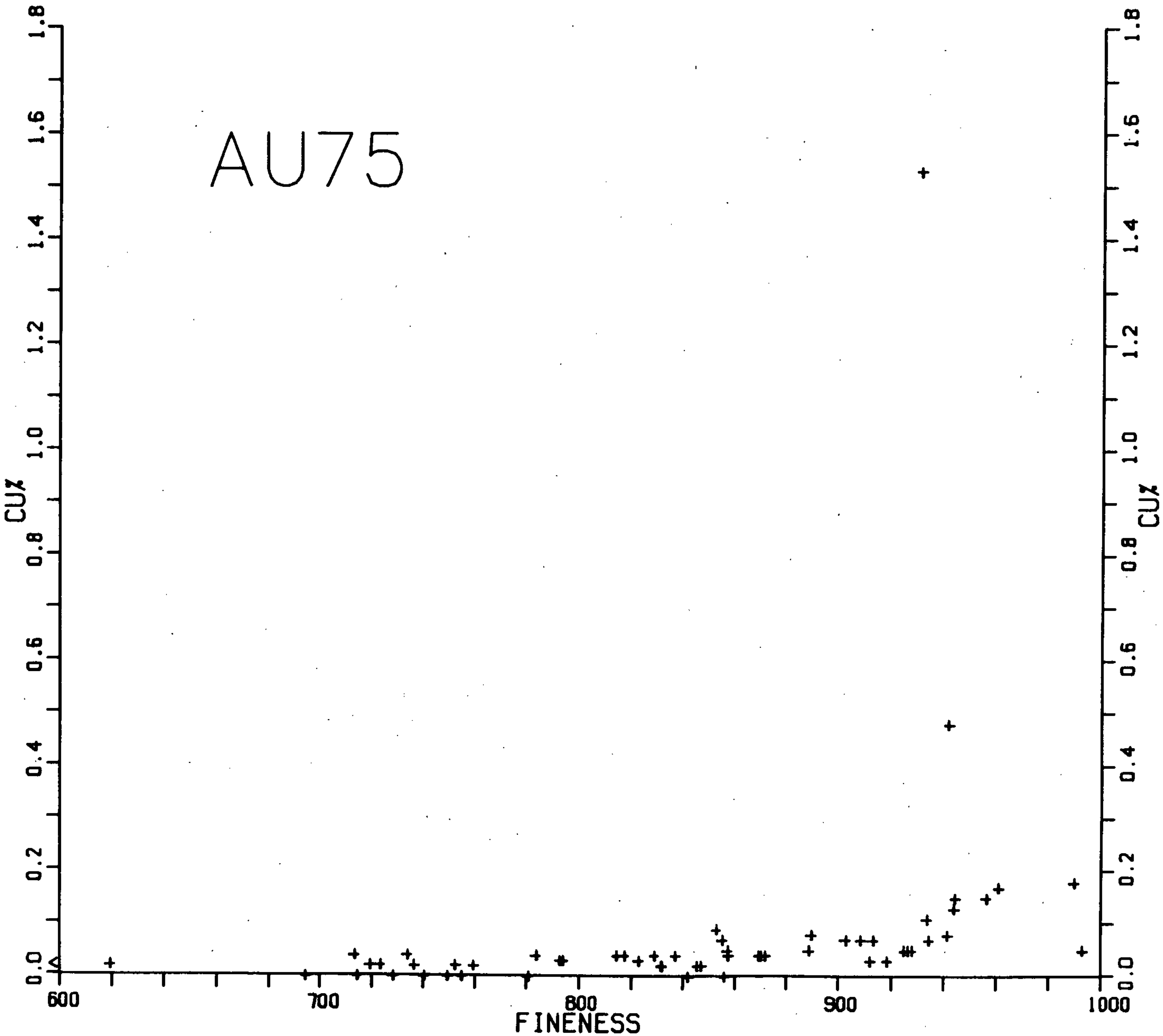


Figure 29c:
Hope

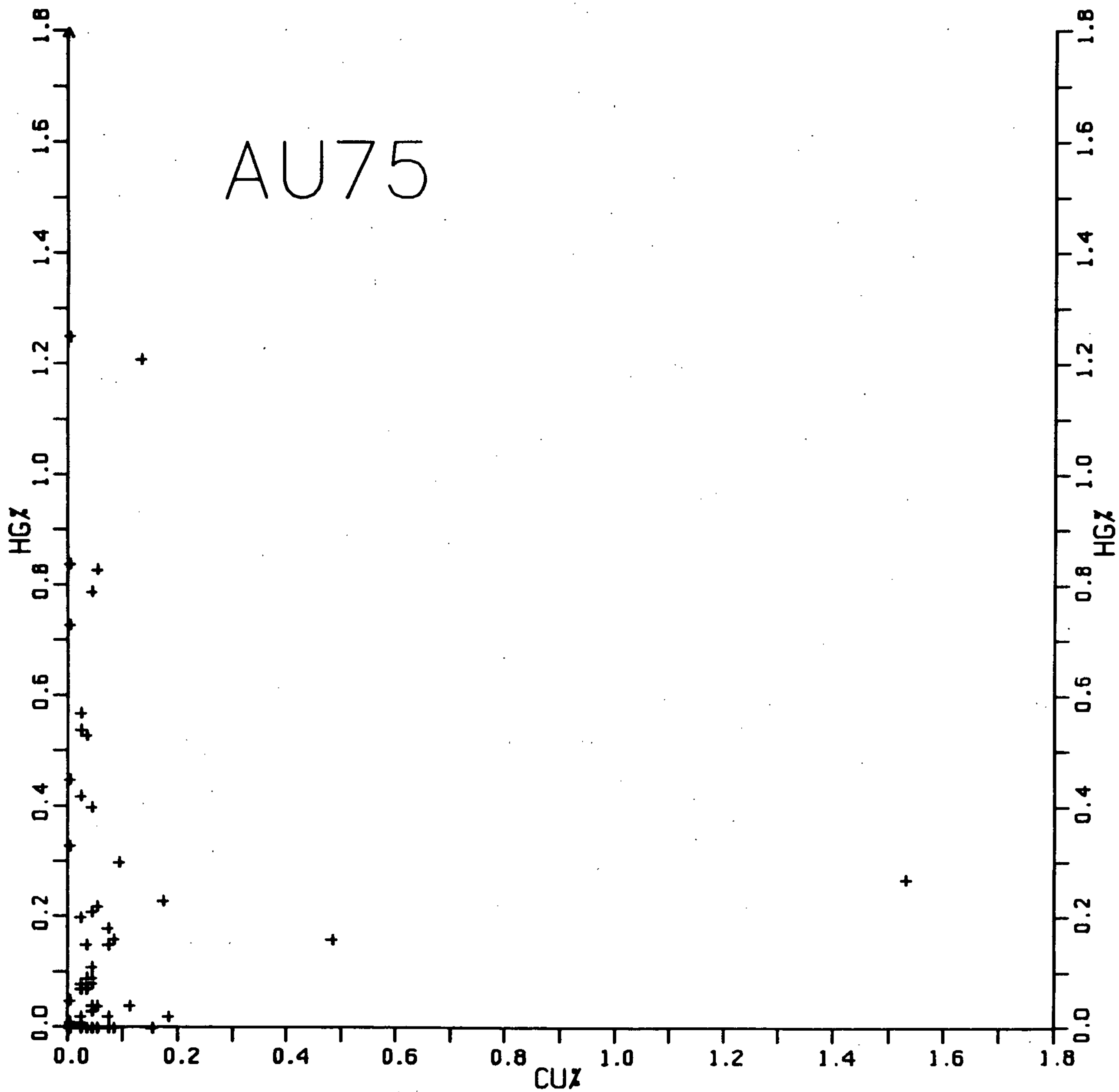


Figure 29d:
Hope

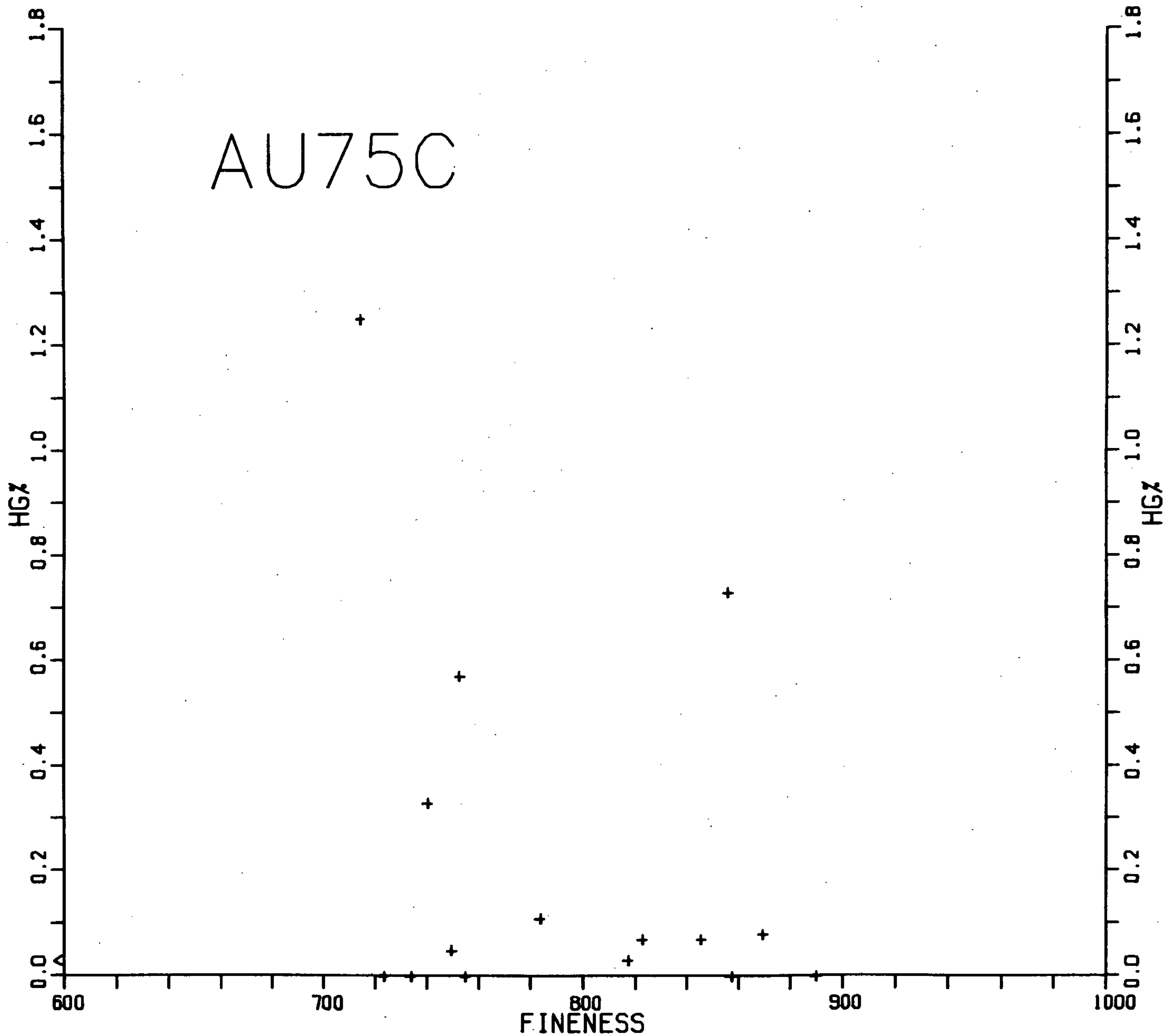


Figure 29e:

Hope (Rimmed)

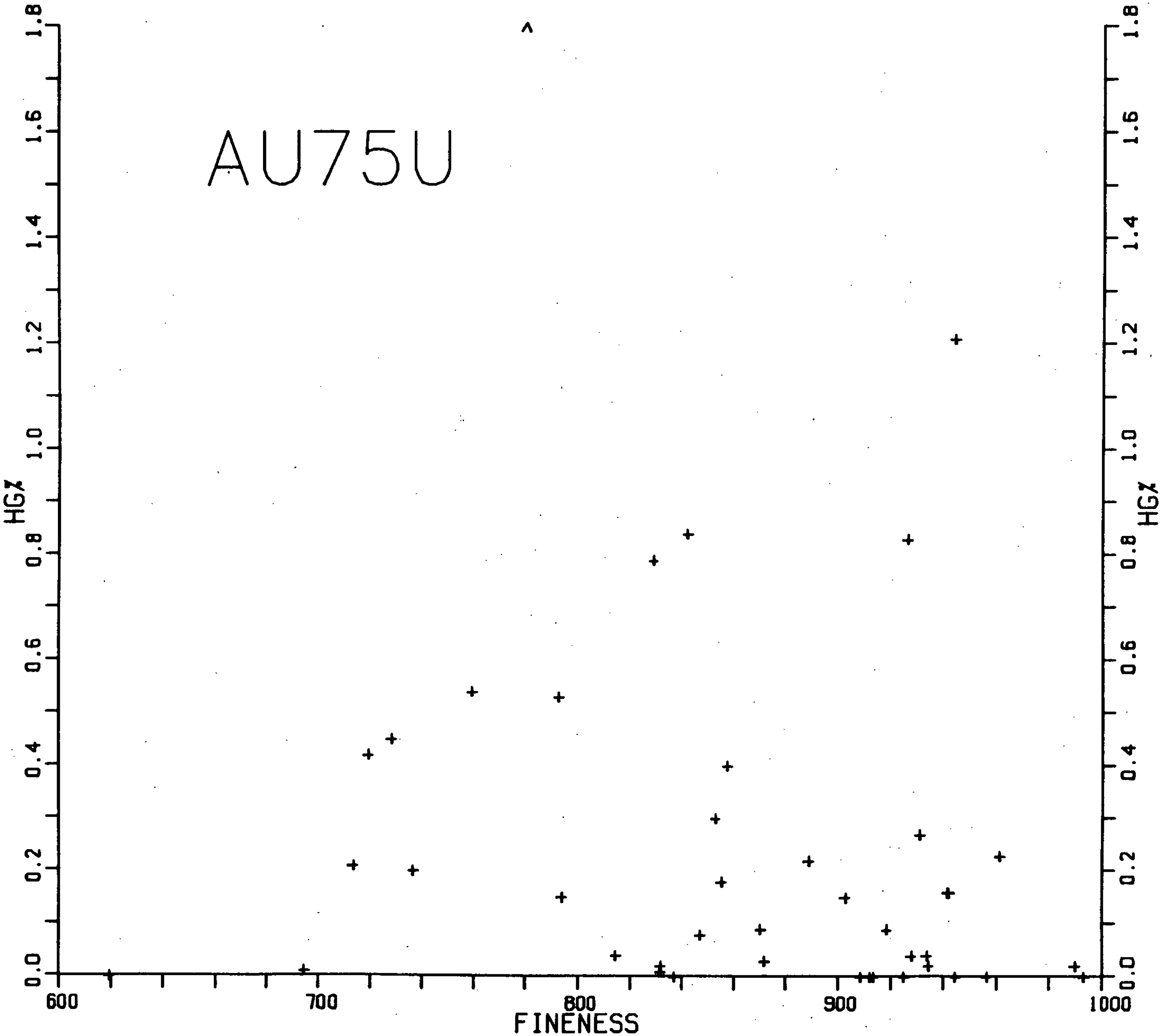


Figure 29f:

Hope (Unrimmed)