CHAPTER IV

INTERRELATIONSHIPS BETWEEN HEAVY MINERAL PARAMETERS

4.1 Heavy Mineral Assemblages

4.1.1 Kathu Valley area

Considering the heavy mineral assemblages of 8 tin-mines within the Kathu Valley, it is apparent that the most abundant heavy mineral is cassiterite including cassiterite with manganese coat and cassiterite interlocking with quartz. Other heavy minerals which are commonly and selectively present in almost all samples are garnet, ilmenite, manganese oxide, topaz, monazite, xenotime, micas, tourmaline, zircon. Heavy minerals which are considered to be relatively less frequent and always present in small amount in the assemblages are Fe-oxide, rutile, spinel, wolframite, columbite-tantalite and mangan-tantalite. The last group of heavy minerals which are present in the very small amount in only a few localities are allanite, apalite, leucoxene, limonite, struverite, multiple oxide containing Nb-Ta and magnetite.

The overall heavy mineral assemblages of 8 tin-mines within the Kathu Valley are summarized and presented in Figure 4.1.1. In addition, the relative degree of abundance of heavy mineral assemblages from this area is summarized and tabulated in Table 4.1.1.

Evidences from direct field observation regarding the geology of heavy mineral deposits from these mines within the Kathu Valley reveal that they are of different, diversified, and complex in their origin. However, the total impression of heavy mineral assemblages exhibits only a slight variation on kinds of heavy mineral present. The differences in the amount and rank of abundance to these

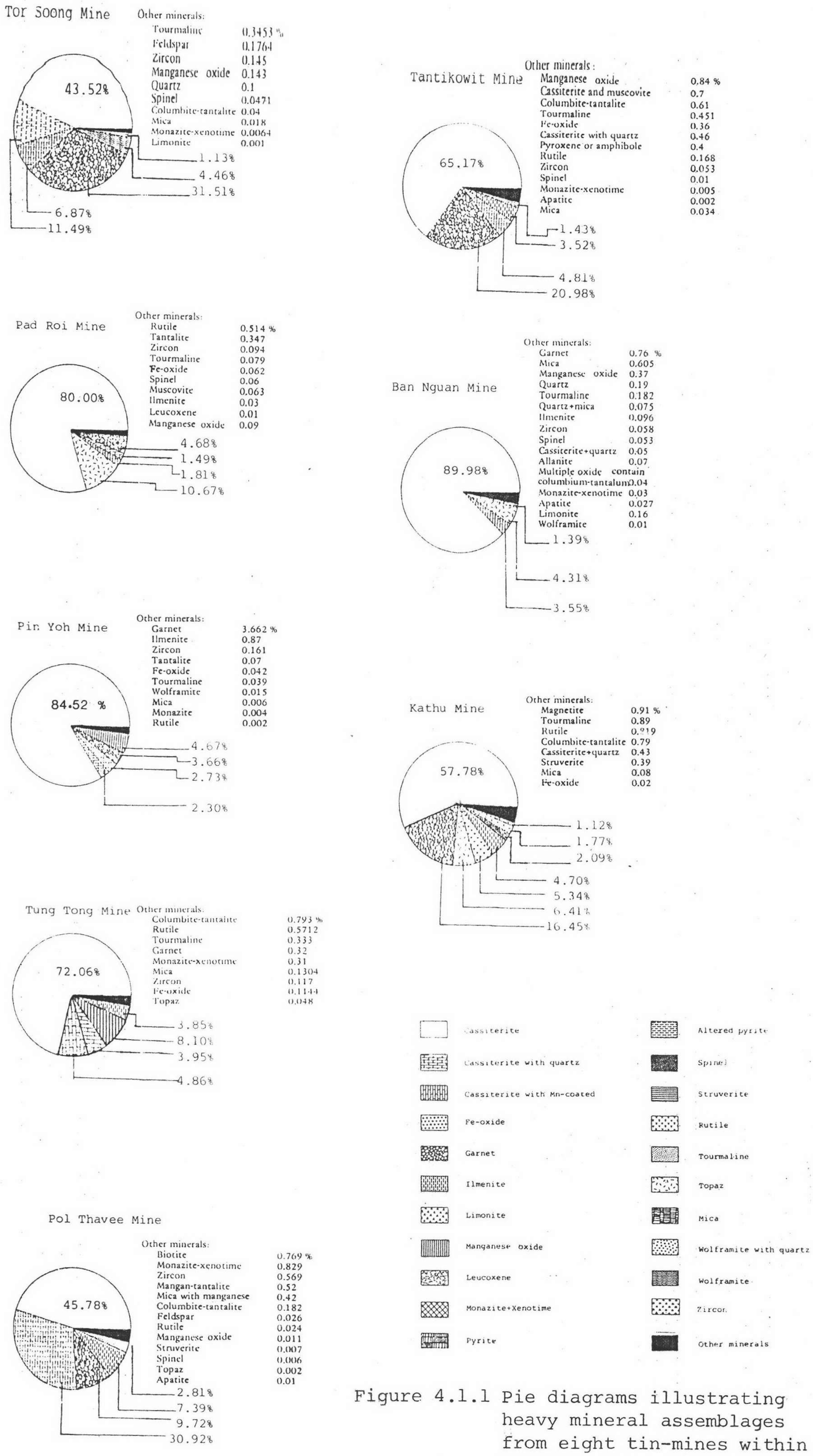


Figure 4.1.1 Pie diagrams illustrating heavy mineral assemblages from eight tin-mines within Kathu Valley

Table 4.1.1 The relative degree of abundance of heavy mineral assemblages from eight tin-mines within Kathu Valley

Mineral Name	Tor Soong Mine	Tantikowit Mine	Pad Roi Mine	Ban Nguan Mine	Pin Yoh Mine	Kathu Mine	Tung Tong Mine	Pol Tha-vee Mine
Allanite	-	-	-	X	-	-	-	-
Apatite	-	X	-	X	-	-	-	-
Arsenopyrite	-	-	-	-	-	-	-	-
Biotite	-	-	-	-	-	-	-	X
Cassiterite	A	D	F	F	F	D	D	A
Cassiterite with Fe, Qtz	C	-	R	X	R	X	R	-
Cassiterite with Manganese	P	R	R	R	R	-	R	A
Columbite-Tantalite	X	X	-	-	X	X	X	X
Fe-oxide	-	X	X	R	X	X	X	-
Fluorite	-	-	-	-	-	-	-	-
Garnet	A	C	R	-	R	C	X	P
Hematite	-	-	-	-	-	-	-	-
Ilmenite	-	R	X	X	X	R	R	P
Limonite	X	-	-	X	-	R	-	-
Manganese oxide	X	X	X	X	R	-	P	X
Mangan-Tantalite	X	-	X	-	X	-	-	X
Monazite-Xenotime	X	X	-	X	X	R	X	X
Magnetite	-	-	-	-	-	X	-	-
Multiple oxide contain Cb-Ta	-	-	-	X	-	-	-	-
Pyrite & Altered pyrite	-	-	-	-	-	-	-	-
Rutile	-	X	X	-	X	X	X	X
Scheelite	-	-	-	-	-	-	-	-
Siderite	-	-	-	-	-	-	-	-
Spinel	X	X	X	X	-	R	-	X
Struverite	-	-	-	-	-	X	-	X
Topaz	R	-	P	R	-	P	X	X
Tourmaline	X	X	X	X	X	R	X	R
Thorite	-	-	-	-	-	-	-	-
Wolframite and Huebnerite	R	R	-	X	X	-	-	-
Zircon	X	X	X	X	X	R	X	X

Remarks

Flood (F)	= 75-100 %
Dominant (D)	= 50-75 %
Abundance (A)	= 25-50 %
Common (C)	= 10-25 %
Present (P)	= 5-10 %
Rare (R)	= 1-5 %
Trace (X)	= less than 1 %

heavy mineral assemblages are, however, detectable. Besides, some minerals, notably, wolframite, extraordinary large amount of zircon, struverite which are present in only a few localities might be used as the indicator to the origin of those heavy mineral deposits. Considering extraordinary large amount of zircon in heavy mineral assemblages at Kathu mine, it obviously suggests the alluvial origin with probably additional human reworked condition or old tin-mine site. For wolframite and struverite, they certainly indicate specific genetic environment, but the present stage of knowledge on the genesis of these two minerals are not fully understood. Therefore, it is difficult to conclude specifically on the presence of these two minerals.

4.1.2 Area outside Kathu Valley

For the purpose of comparison, additional heavy mineral samples from 7 tin-mines outside the Kathu Valley have been studied. It is important to note that the origin of these heavy mineral deposits are more diversified as compared with those in the Valley. This factor is belived to be very influential on heavy mineral assemblages as well as on the relative degree of abundances of heavy minerals.

The most abundant of heavy mineral from seven tin-mines outside the Valley is obviously the cassiterite and cassiterite interlocking with other minerals. Other common heavy minerals are ilmenite, tourmaline, zircon, garnet, Mn-bearing mica and topaz. Those heavy minerals which rarely present are leucoxene, limonite, monazite, xenotime, pyrite, rutile, Fe-oxide, spinel, siderite, struverite, columbite-tantalite, mangan-tantalite, etc.

Considering the difference of heavy mineral assemblages between samples within and outside Kathu Valley, it is noticed that some minerals, namely, hematite, pyrite, siderite, thorite, fluorite, scheelite, arsenopyrite and altered pyrite are present only in some localities outside Kathu Valley. The only variety of cassiterite, cassiterite with manganese coat, is present only in tin-mines inside the Valley.

The overall heavy mineral assemblages of 7 tin-mines outside the Kathu Valley are summarized and presented in Figure 4.1.2. In addition, the relative degree of abundance of heavy mineral assemblages from this area is summarized and tabulated in Table 4.1.2.

The heavy mineral associations from 7 localities outside the Valley are partly governed by the difference in original source materials, namely, pegmatitic and pneumatolitic origins, and partly by the surface processes concerned, namely, mass-movement, fluvial and marine. The pneumatolitic origin is characterized by the abundance of tourmaline and cassiterite interlocking with quartz, and rare amounts of magnetite, fluorite, scheelite, arsenopyrite, ilmenite, hematite, and pyrite. The heavy mineral assemblages of pegmatitic origin are indicated by the presence of mangan-tantalite, ilmenite, pyrite, topaz and zircon in rare quantity. For heavy mineral associations of fluvial and marine types, it is noted that the ilmenite is most abundant, while garnet and pyrite are common, and altered pyrite is rare. The heavy mineral assemblages of colluvial deposit is characterized by the abundance of ilmenite, common amounts of spinel and rare amounts of thorite, multiple oxide containing Nb-Ta and siderite.

4.2 Relationships Between Grain Size Parameters of Detrital Heavy Minerals

In this investigation, an attempt has been made to determine the characteristics of grain size distribution of heavy mineral

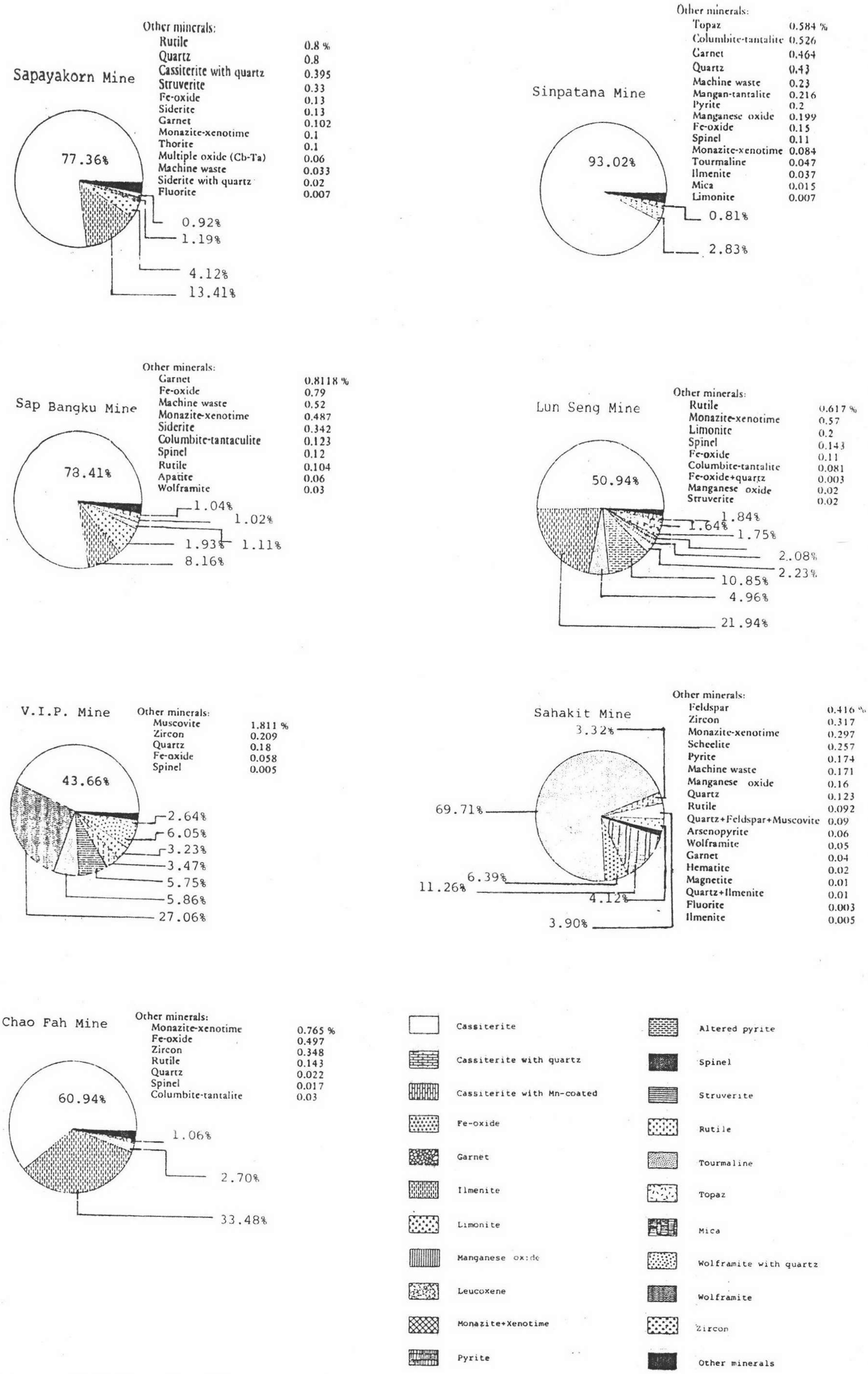


Figure 4.1.2 Pie diagrams illustrating heavy mineral assemblages from seven tin-mines outside Kathu Valley.

Table 4.1.2 The relative degree of abundance of heavy mineral assemblages from seven tin-mines outside Kathu Valley

Mineral Name	Sapayakorn Mine	Sinpatana Mine	Sap Bangku Mine	Lun Seng Mine	V.I.P. Mine	Sahakit Mine	Chao Fah Mine
Allanite	-	-	-	-	-	-	-
Apatite	-	-	-	-	-	-	-
Arsenopyrite	-	-	-	-	-	R	-
Biotite	-	-	-	-	-	-	-
Cassiterite	F	F	F	D	A	R	D
Cassiterite with Fe,Quartz	X	R	-	-	R	R	-
Cassiterite with Manganese	-	-	-	-	-	-	-
Columbite-Tantalite	-	X	X	X	-	-	X
Fe-oxide	X	X	X	X	X	P	X
Fluorite	X	-	-	-	-	X	-
Garnet	X	X	X	R	-	X	R
Hematite	-	-	-	-	-	X	-
Ilmenite	C	X	P	C	-	X	A
Limonite	-	X	P	X	-	R	-
Manganese oxide	-	X	-	-	-	-	-
Mangan-Tantalite	-	X	-	-	-	-	-
Monazite-Xenotime	X	X	X	X	R	X	X
Magnetite	-	-	-	-	-	X	-
Multiple Oxide contain Cb-Ta	X	-	-	-	-	-	-
Pyrite/Altered Pyrite	-	X	-	C	-	X	-
Rutile	X	X	X	X	R	X	X
Scheelite	-	-	-	-	-	X	-
Siderite	X	-	X	-	-	-	-
Spinel	R	X	X	X	X	-	X
Struverite	X	-	-	X	P	-	-
Topaz	-	X	R	R	-	-	-
Tourmaline	R	X	X	X	P	D	R
Thorite	X	-	-	-	-	-	-
Wolframite	-	-	X	-	A	X	-
Zircon	R	X	R	R	X	X	X

Remarks

Flood (F) = 75-100 %

Dominant (D) = 50-75 %

Abundance (A) = 25-50 %

Common (C) = 10-25 %

Present (P) = 5-10 %

Rare (R) = 1-5 %

Trace (X) = less than 1 %

suites and cassiterite of 8 samples within the Kathu Valley as well as additional 7 samples outside the Valley. Grain size parameters, namely, mean, median, including sorting have been determined from the standard cumulative curves of each sample. Besides, the relative abundances of total heavy minerals and cassiterite in each size fraction of every samples have been prepared and graphically illustrated as pie diagrams.

Considering the median diameter, it is apparent that almost all of the samples obtained from Kathu Valley show the value of coarse sand and very coarse sand except that from Kathu mine which falls in the range of fine sand. The mean diameter of heavy mineral suites from similar localities exhibit the similar pattern to those of median. The rather coarse to very coarse sand of mean and median values of heavy mineral suites can be explained in terms of their pegmatitic origin, whereas the fine sand value indicates the reworked alluvium origin.

With regard to the sorting characteristics of heavy mineral suites of Kathu Valley, all of them are considered poorly sorted. This indicates that the heavy mineral deposits in the Kathu Valley are essentially resulted from in situ weathering of pre-existing pegmatitic rocks. The transportation of these heavy mineral suites is negligible or insignificant.

For samples obtained from tin-mines outside the Kathu Valley, the median and mean diameters are assorted ranging from coarse sand to fine sand. This is probably due to the diversity of origin of these heavy mineral deposits, notably, pegmatite, pneumatolitic-hydrothermal, colluvial and alluvial deposits. Considering the sorting characteristics of heavy minerals from similar locality, it is noted that the pattern varies from moderately well to moderately to poorly sorted. This is attributed to the complexity of diversed origins including partial differential sorting of fluvial and other surface processes.

Concerning the grain size parameters of cassiterite, the mean and median grain sizes of samples obtained from Kathu Valley are coarse to very coarse sand similar to those of associated heavy mineral suites. For sorting characteristics of cassiterite from the same area, almost all of them are poorly sorted except that from Kathu Mine which is relatively better sorted. The nature and characteristics of grain size parameters of cassiterite, namely, mean, median, and sorting can be explained in terms of the original texture of parent materials without any diagnostic changes by surface processes except that of the Kathu Mine.

For cassiterite samples obtained from tin-mines outside Kathu Valley, the mean and median grain sizes vary from coarse to fine sand similar to those of associated heavy mineral suites. The sorting characteristics of cassiterite show only slight variation as compared with the associated heavy mineral suites. The explanation regarding these matters is probably due to the diversed origins as well as the influence of surface processes concerned.

The data and information concerning the grain size parameters and genesis of heavy minerals and cassiterite are summarized and presented in Table 4.2.

In addition,graphic representation of grain size distribution of heavy mineral suites and cassiterite of samples obtained from various mines within and outside Kathu Valley under the present in-

Table 4.2 Grain size parameters and genesis of cassiterite and heavy minerals from tin-mines within and outside Kathu Valley.

Locality name	Genesis	Median		Mean		Sorting	
		Heavy minerals	Cassiterite	Heavy minerals	Cassiterite	Heavy minerals	Cassi-terite
Kathu Valley Area							
Tor Soong Mine	Quartz-feldspar pegmatite	0.25 (cs)	0.23 (cs)	0.08 (cs)	0.32 (cs)	1.21 (ps)	1.02 (ps0
Tantikowit Mine	Tourmaline-mus-covite pegmatite	0.83 (cs)	0.65 (cs)	0.54 (cs)	0.53 (cs)	1.34 (ps)	1.31 (ps)
Pad Roi Mine	Tourmaline-mus-covite pegmatite	0.8 (cs)	0.8 (cs)	0.66 (cs)	0.69 (cs)	1.09 (ps)	1.09 (ps)
Ban Nguan Mine	Lepidolite pegmatite	0.25 (cs)	0.6 (cs)	0.35 (cs)	0.55 (cs)	1.23 (ps)	1.16 (ps)
Pin Yoh Mine	Muscovite pegmatite	0.75 (cs)	0.95 (cs)	0.62 (cs)	0.77 (cs)	1.23 (ps)	1.20 (ps)
Kathu Mine	Reworked/allu-vium	2.55 (fs)	2.73 (fs)	2.03 (fs)	2.61 (fs)	1.06 (ps)	0.44 (ws)
Tung Tong Mine	Colluvium/mus-covite pegmatite	-1 (vcs)	-0.5 (vcs)	-0.85 (vcs)	-0.46 (vcs)	2.00 (ps)	1.33 (ps)
Pol Thavee Mine	Quartz-feldspar-muscovite peg-matite	-0.7 (vcs)	-0.75 (vcs)	-0.32 (vcs)	-0.48 (vcs)	1.55 (ps)	1.25 (ps)
Area outside Kathu Valley							
Sapayakorn Mine	Colluvium	1.35 (ms)	1.2 (ms)	1.35 (ms)	1.13 (ms)	1.01 (ps)	0.96 (ms)
Sinpatana Mine	Quartz-feldspar pegmatite	1.17 (ms)	1.17 (ms)	1.42 (ms)	1.12 (ms)	0.91 (ms)	1.13 (ps)
Sap Bangku Mine	Colluvium	2.3 (fs)	1.2 (ms)	2.13 (fs)	1.32 (ms)	1.12 (ps)	0.93 (ms)
Lun Seng Mine	Fluvial/marine deposit	1.2 (ms)	2.37 (fs)	1.25 (ms)	2.27 (fs)	0.69 (mws)	0.54 (mws)
V.I.P. Mine	Pneumatolitic/ hydrothermal	0.45 (cs)	0.5 (cs)	0.47 (cs)	0.68 (cs)	1.65 (ps)	1.41 (ps)
Sahakit Mine	Pneumatolitic/ hydrothermal	2.03 (fs)	2.8 (fs)	1.91 (ms)	1.78 (ms)	0.71 (ms)	1.47 (ps)
Chao Fah Mine	Colluvium	0.5 (cs)	-0.7 (cs)	0.39 (cs)	-0.33 (cs)	1.39 (ps)	1.04 (ps)

Remarks: vcs = very coarse sand — ws = well sorted
cs = coarse sand — mws = moderately well sorted
ms = medium sand — ms = moderately sorted
fs = fine sand — ps = poorly sorted

vestigation have been presented as cumulative frequency curves and pie diagram in Figure 4.2.1 a, 4.2.1 b, 4.2.2 a, 4.2.2 b.

The determination of mean grain size of cassiterite and associated heavy mineral suites of sample within the Kathu Valley reveals that a strong positive linear relationship exists (Fig. 4.2.3). The increasing mean grain size of cassiterite corresponds with the increasing mean grain size of associated heavy minerals. In contrast, the relationships between mean grain size of cassiterite and associated heavy minerals outside the Kathu Valley does not exhibit a distinct pattern (Fig. 4.2.4).

Considering the relationships between mean grain size and sorting of heavy minerals within and outside the Valley, it is apparent that the negative linear relationships exists (Fig. 4.2.5). That is, the better sorted heavy minerals are found associated with relatively finer mean grain size. However, the relationships between mean grain size and sorting of cassiterite within and outside the Valley does not show any promising pattern (Fig. 4.2.6).

The sorting of heavy minerals against the sorting of cassiterite of samples within the Kathu Valley shows a relatively well defined cluster than that of outside Kathu Valley (Fig. 4.2.7). This can be explained in terms of the different degree of operation of surface processes on the deeply in situ weathered pre-existing parent materials. Those within the Kathu Valley are mainly the products of in situ weathering, whereas those outside the Valley are the products of combined in situ weathering and other surface processes.

4.3 Variation of Relative Abundance of Heavy Minerals According to Grain Size.

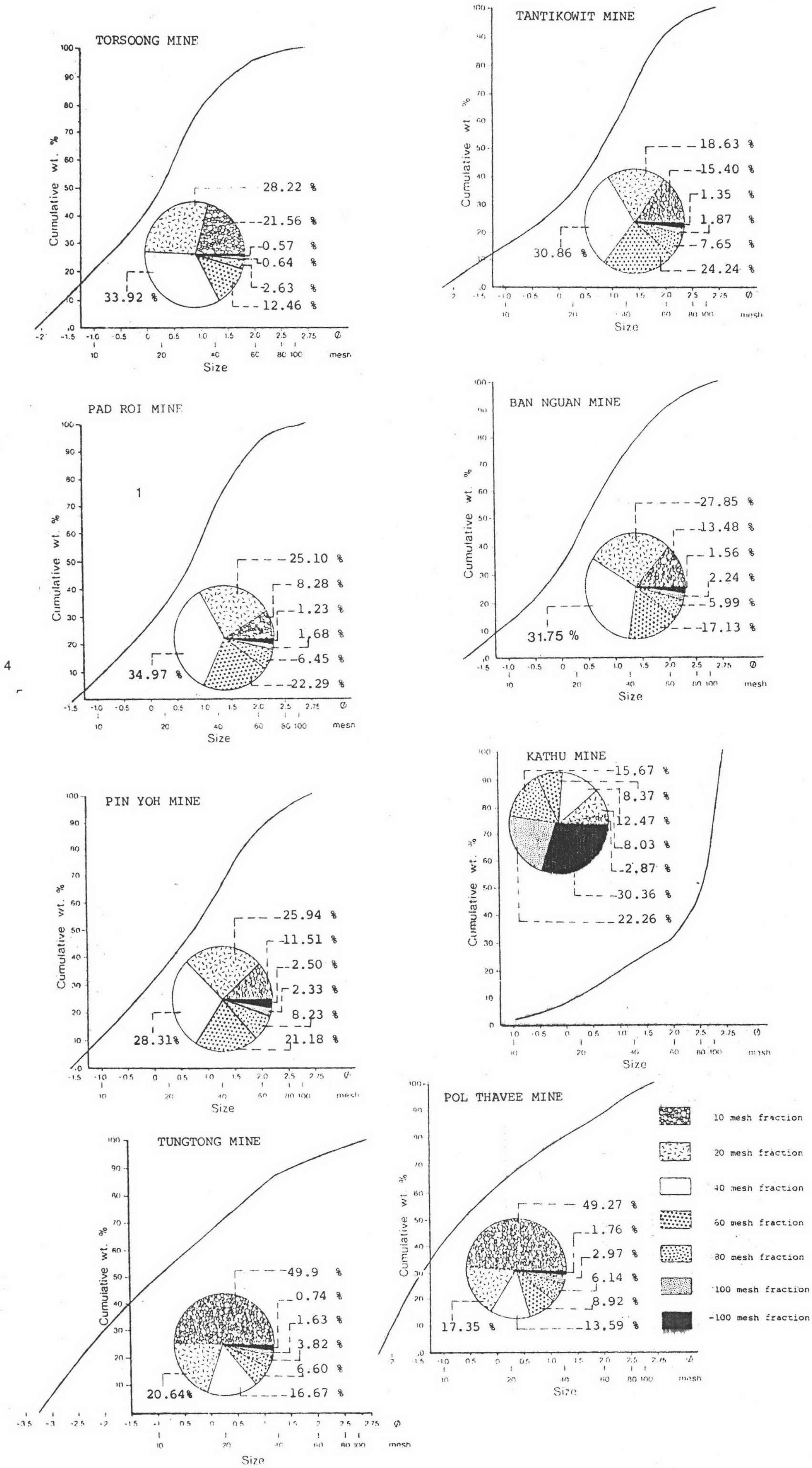


Figure 4.2.1a Cumulative frequency curves and pie diagrams of heavy mineral suites within Kathu Valley.

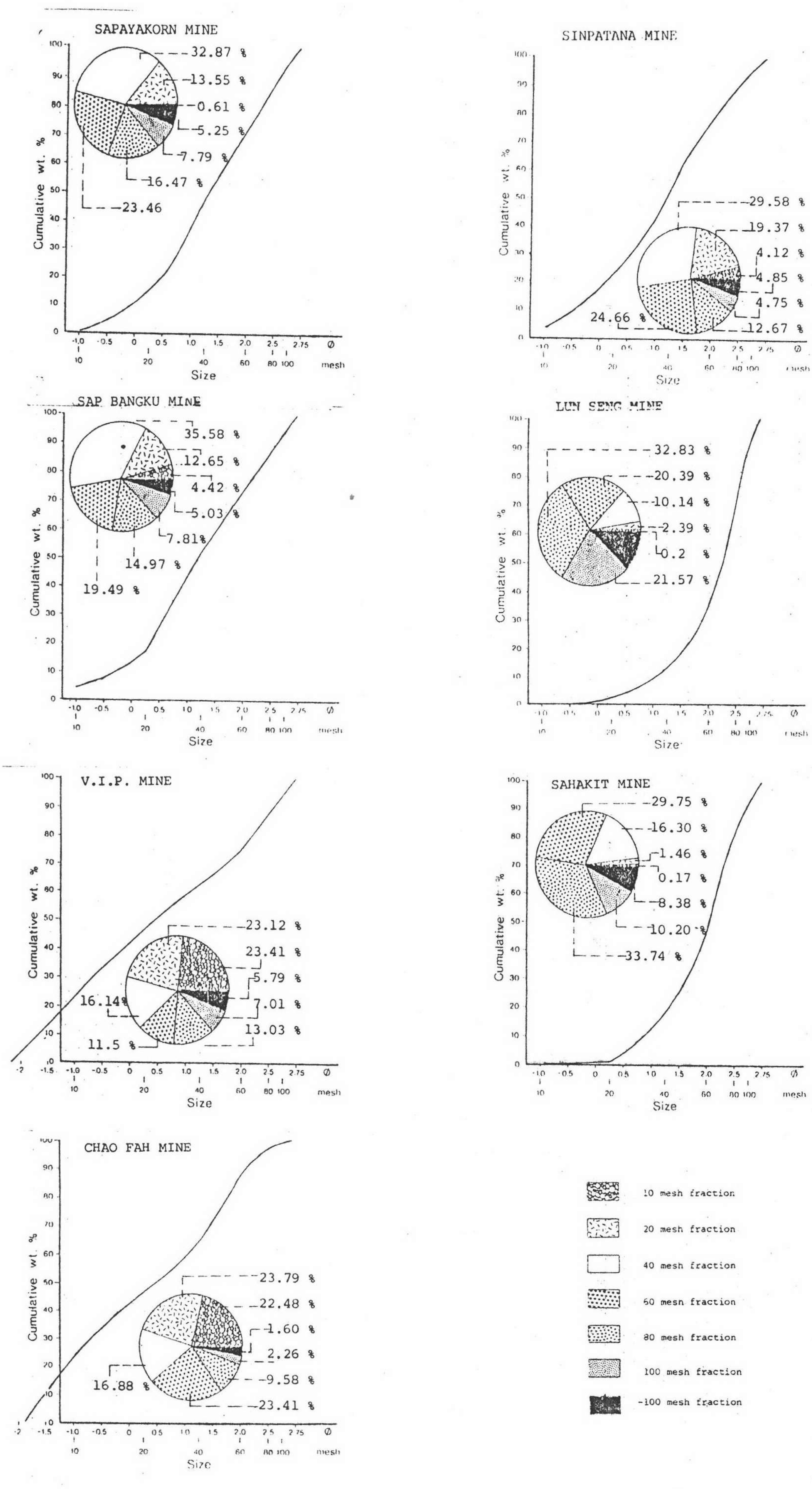


Figure 4.2.1b Cumulative frequency curves and pie diagrams of heavy mineral suites outside Kathu Valley.

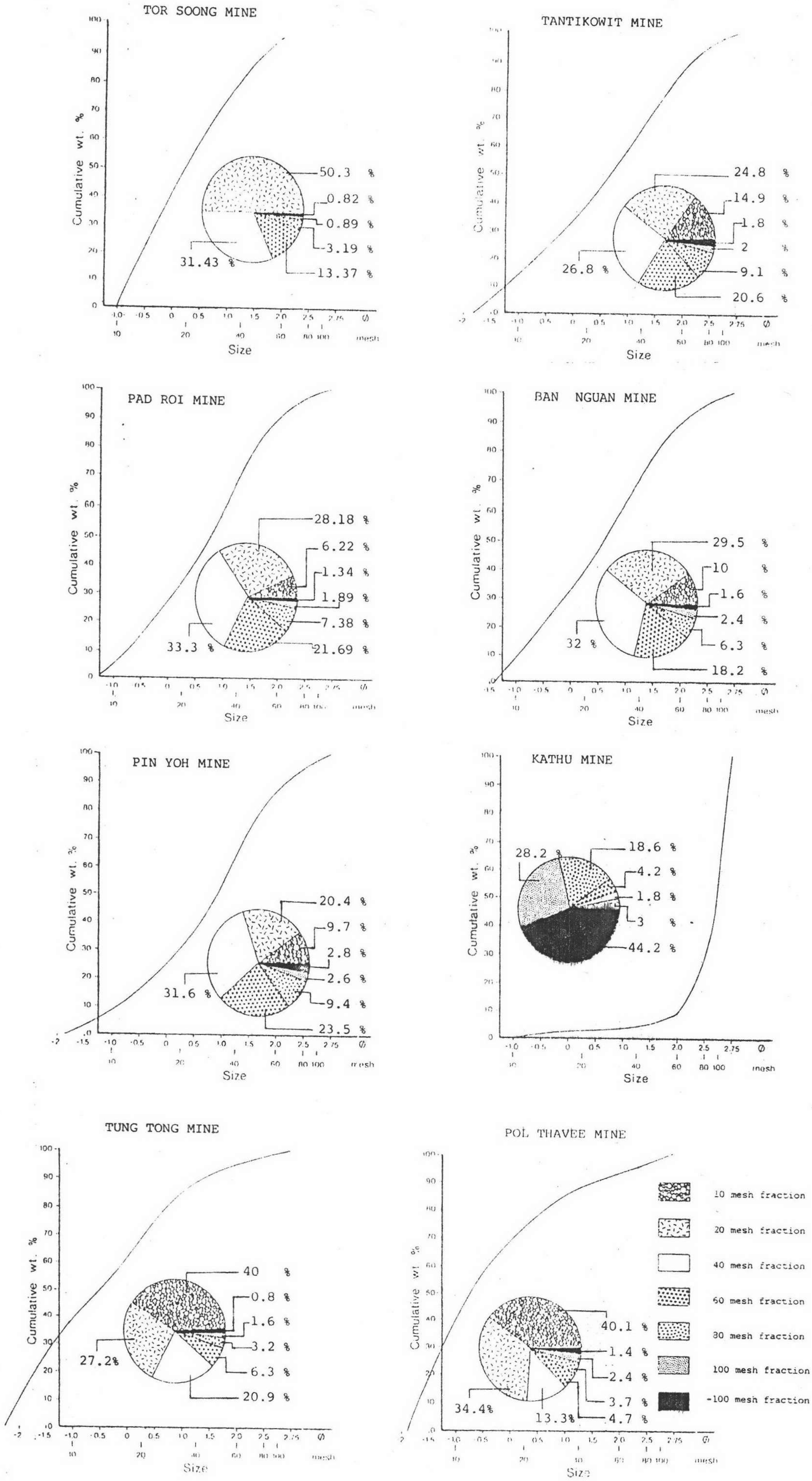


Figure 4.2.2a Cumulative frequency curves and pie diagrams of cassiterite within the Kathu Valley.

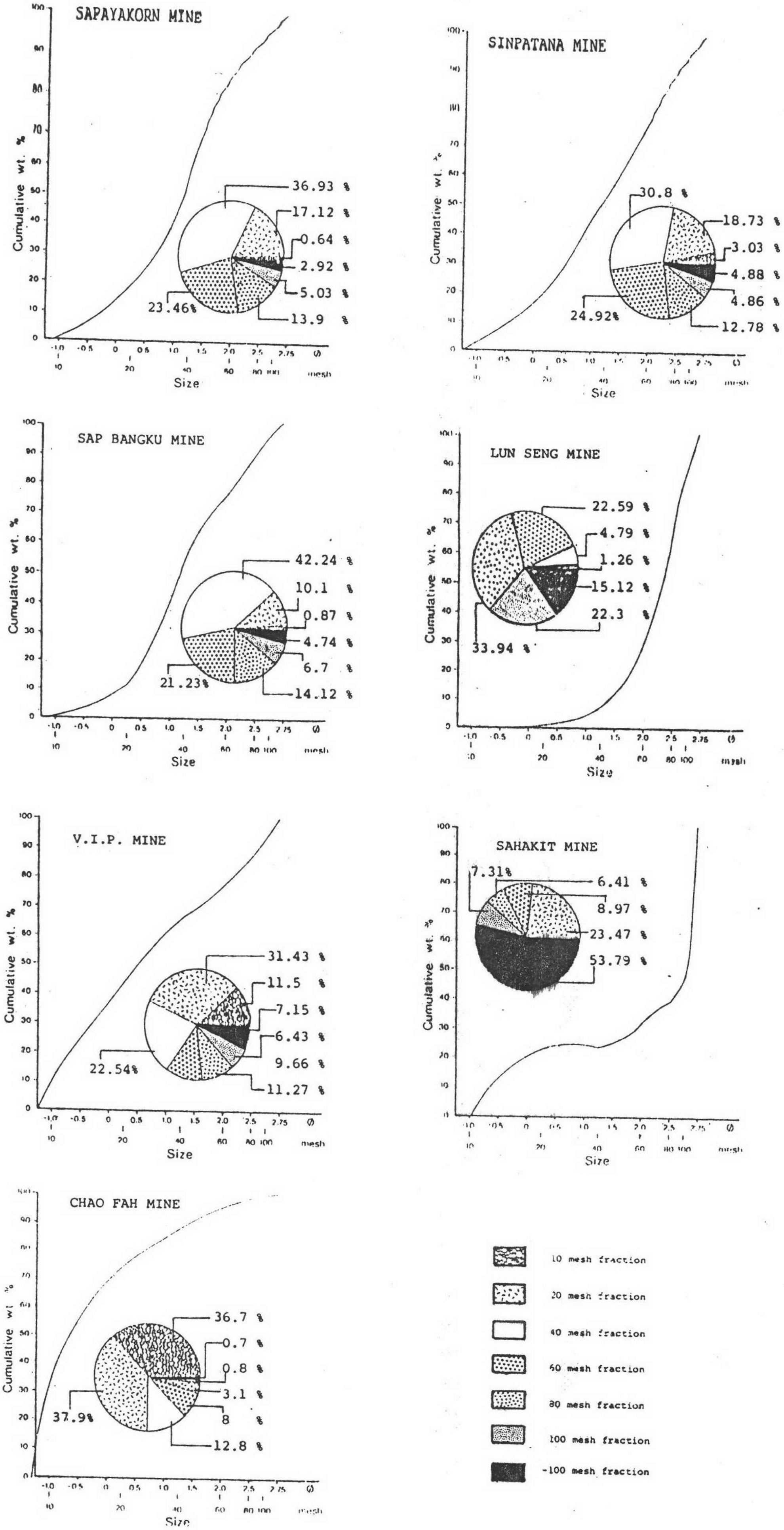


Figure 4.2.2b Cumulative frequency curves and pie diagrams of cassiterite outside Kathu Valley.

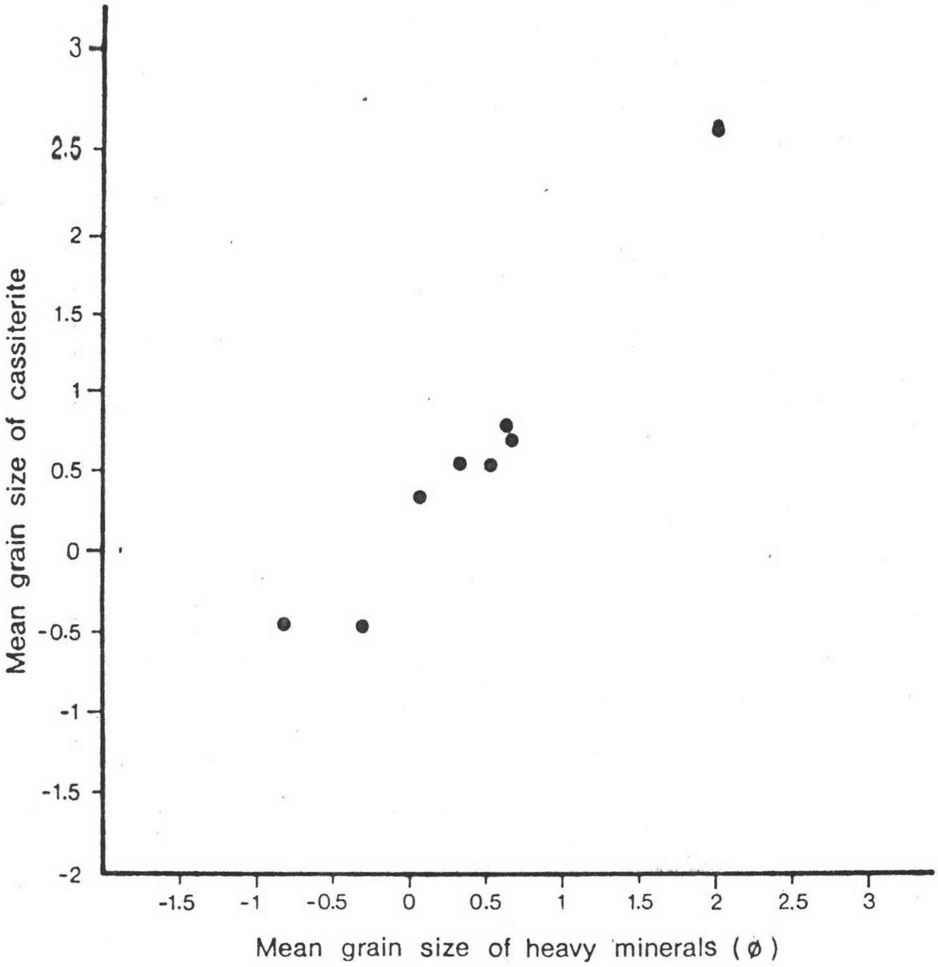


Figure 4.2.3 The relationship between mean grain size of cassiterite and heavy minerals of eight samples obtained from tin-mines within Kathu Valley.

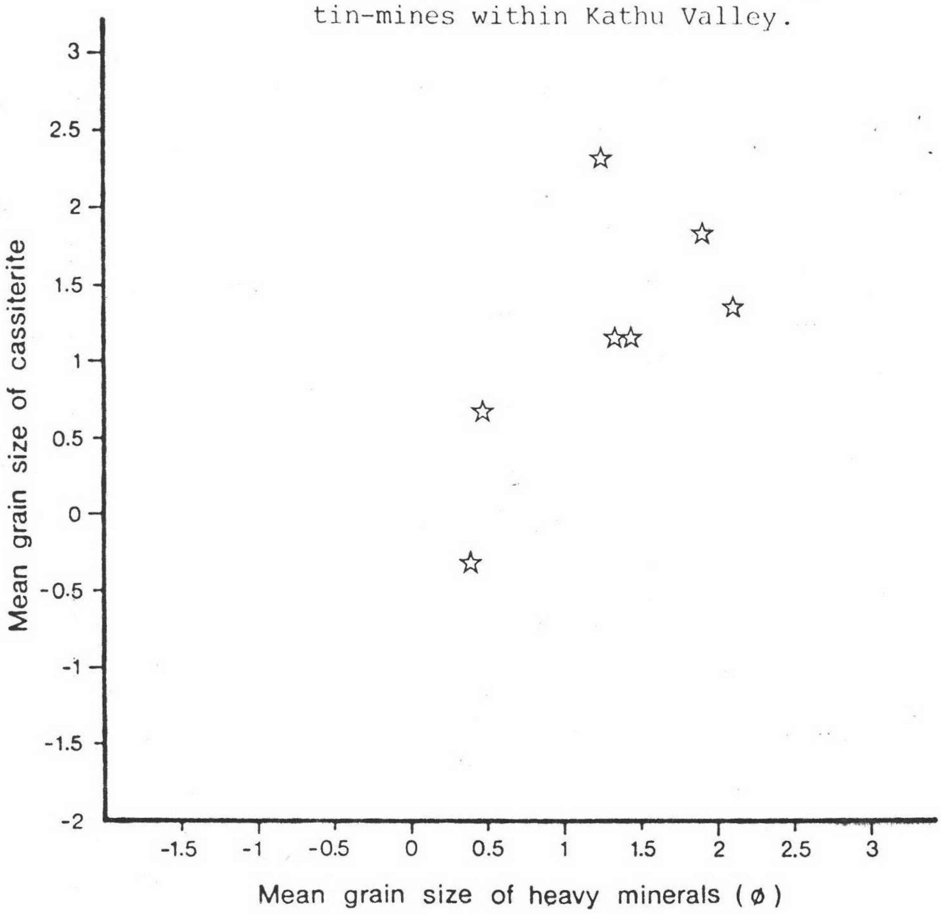


Figure 4.2.4 The relationship between mean grain size of cassiterite and heavy minerals of seven samples obtained from tin-mines outside Kathu Valley.

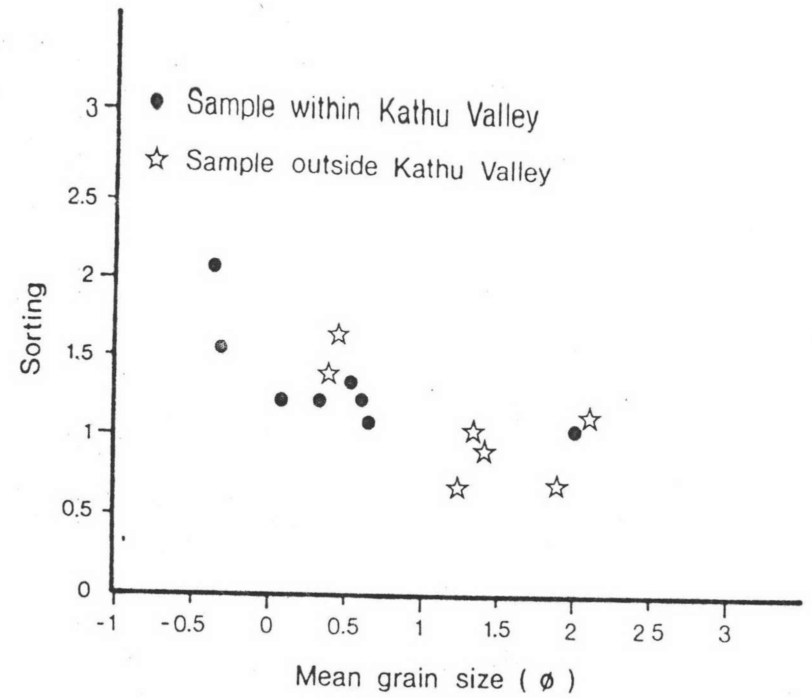


Figure 4.2.5 The relationship between sorting and mean grain size of heavy minerals from tin-mines within and outside Kathu Valley.

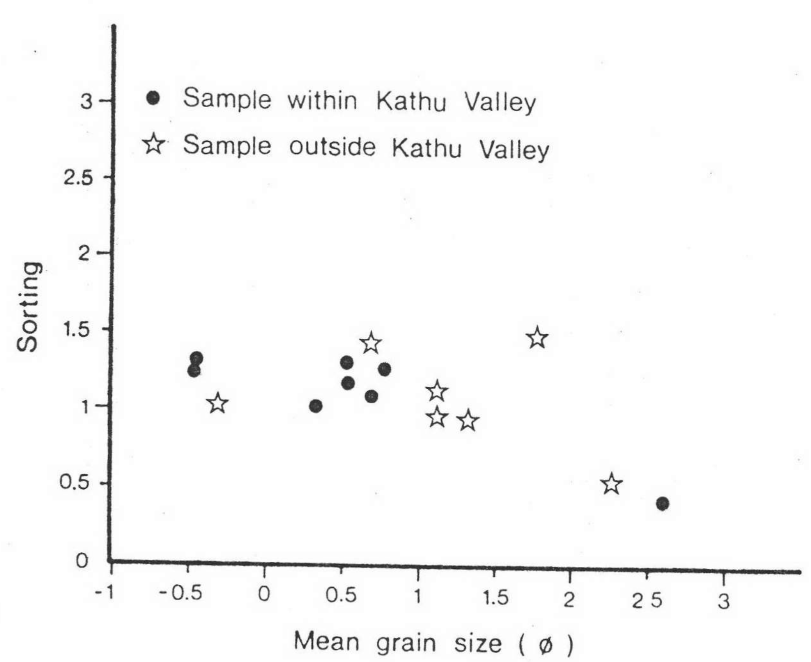


Figure 4.2.6 The relationship between sorting and mean grain size of cassiterite from tin-mines within and outside Kathu Valley.

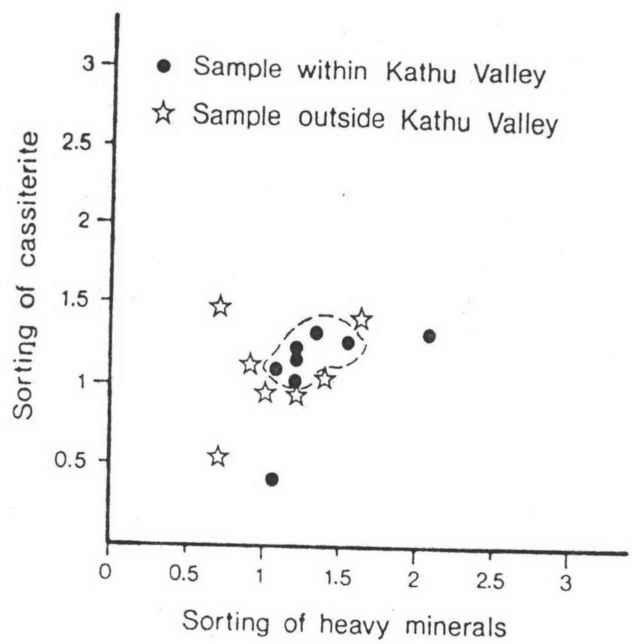


Figure 4.2.7 The relationship between sorting of cassiterite and sorting of heavy minerals from tin-mines within and outside Kathu Valley.

Analyses of the grain size and the degree of abundance of various types of heavy minerals in each size fraction show a significant pattern. Besides, relative degree of abundance of some minerals exhibit a distinct relationship with others. The following paragraph attempts to discuss these variations and relationships.

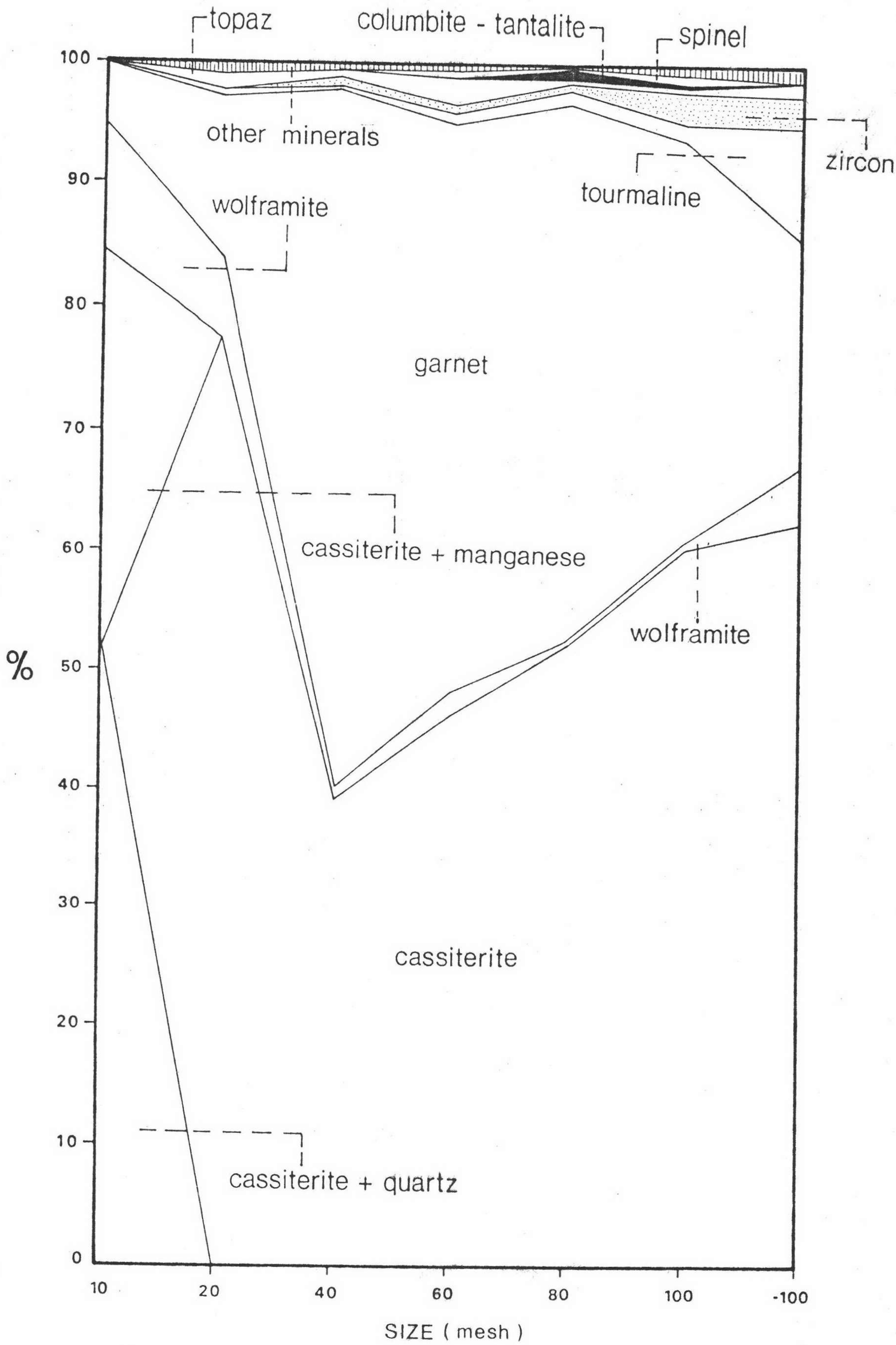
First, considering data regarding this matter from sampling obtained within the Kathu Valley,the most obvious finding is that the cassiterite of pegmatitic origin appears to be most abundant in the size fraction of 40 mesh (0.42 mm.) or medium sand. Other principal heavy minerals in this area are ilmenite, topaz, garnet, and wolframite. Ilmenite appears to be most abundant in the size fraction of 40-60 mesh (0.42-0.25 mm.) or medium sand, while topaz is most abundant in the size fraction of 20-40 mesh (0.841-0.42 mm.) or coarse to medium sand, and garnet is distinctively most abundant in the size fraction of 40 mesh (0.42 mm.) or medium sand. The abundance of wolframite, which is present only in three localities in the Valley, is not cleary defined in terms of grain size.

Other minor heavy minerals which are present in the samples obtained from Kathu Valley are tourmaline, rutile, zircon, columbite-tantalite, mangan-tantalite, spinel, monazite, xenotime, etc. Tourmaline is most abundant in the size fraction of 40-60 mesh (0.42-0.25 mm.) or medium sand, rutile in the size fraction of 20-40 mesh (0.841-0.42 mm.) or coarse to medium sand, zircon in the size fraction of 80 mesh to more than 100 mesh (0.177 mm. to less than 0.149 mm.) or fine to very fine sand, columbite-tantalite in the size fraction of 40 mesh (0.42 mm.) or medium sand, mangan-tantalite in the size fraction of 60 mesh (0.25 mm.) or medium sand, and spinel in the size fraction of 60 mesh (0.25 mm.) or medium sand.

The relative abundance of some important heavy minerals with respect to different grain size of 8 samples obtained from Kathu Valley are summarized and presented in Figure 4.3.1-4.3.8.

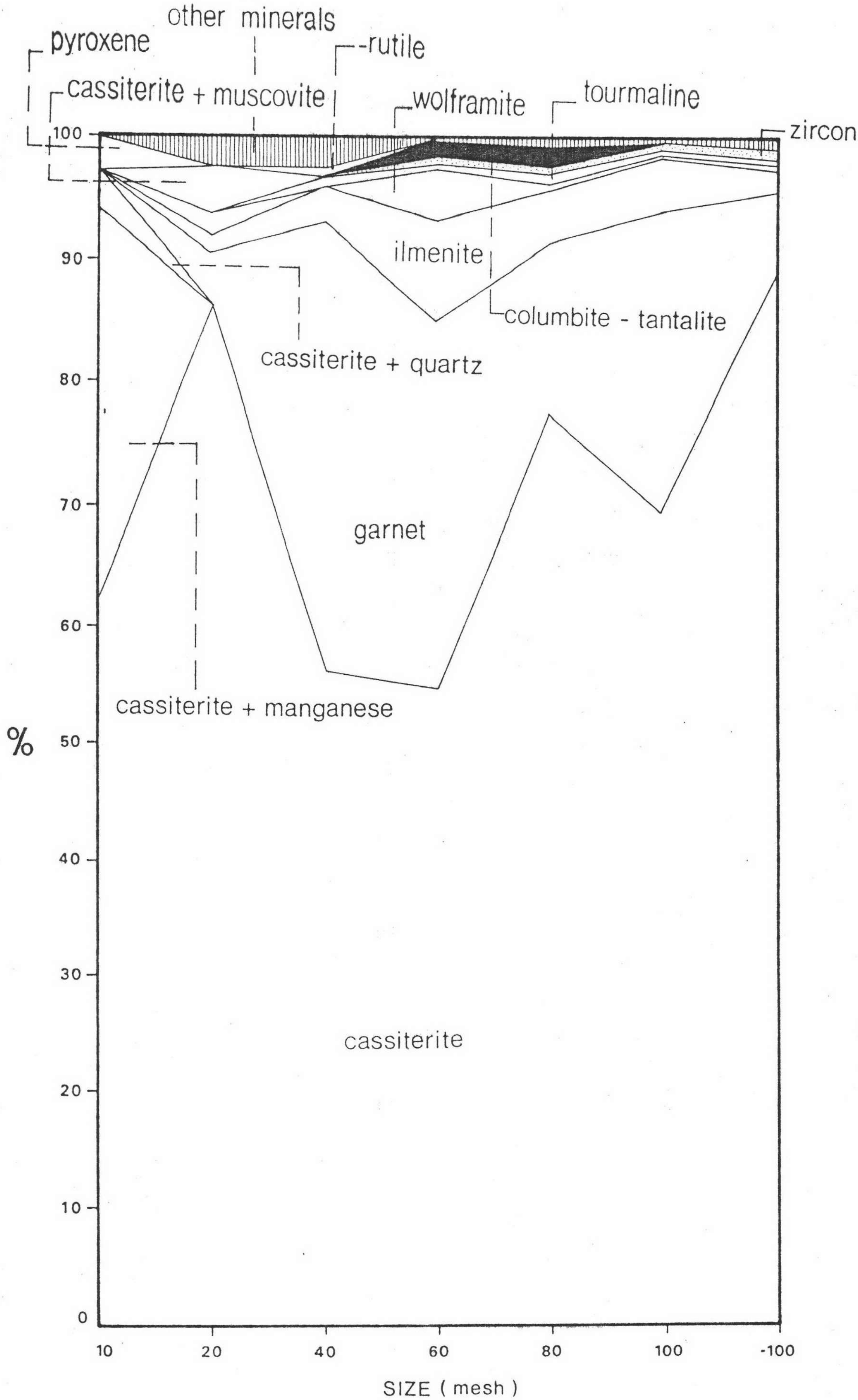
Concerning the degree of abundance of principal heavy minerals in relation to grain size of samples outside Kathu Valley, it is noted that the most dominant mineral is cassiterite of different origins which is most abundant in 20-40 mesh (0.841-0.42 mm.) or coarse to medium sand. Other principal heavy minerals in this area are garnet and ilmenite. Garnet is most abundant in the size fraction of 60 mesh (0.25 mm.) or medium sand, while ilmenite is most abundant in the size fraction of 60-80 mesh (0.25-0.177 mm.) or medium to fine sand. The abundance of wolframite which is present only in 2 localities is not cleary defined in terms of grain size.

Other minor heavy minerals which are present in the samples obtained outside Kathu Valley are tourmaline, rutile, zircon, columbite-tantalite, monazite, xenotime, spinel, struverite, siderite, etc. Tourmaline is most abundant in the size fraction of 40, 80 mesh (0.42, 0.177 mm.) or medium and fine sand, rutile in the size fraction of 60-80 mesh (0.25-0.177 mm.) or medium to fine sand, zircon in the size fraction of more than 100 mesh (less than 0.149 mm.) or very fine sand, columbite-tantalite in the size fraction of 40,80 mesh (0.42, 0.177 mm.) or medium and fine sand, monazite-xenotime in the size fraction of 80 mesh to more than 100 mesh (0.177 mm. to less than 0.149 mm.) or fine to very fine sand, spinel in the size fraction of 80 mesh to more than 100 mesh (0.177 mm. to less than 0.149 mm.) or fine to very fine sand, while struverite and siderite which are



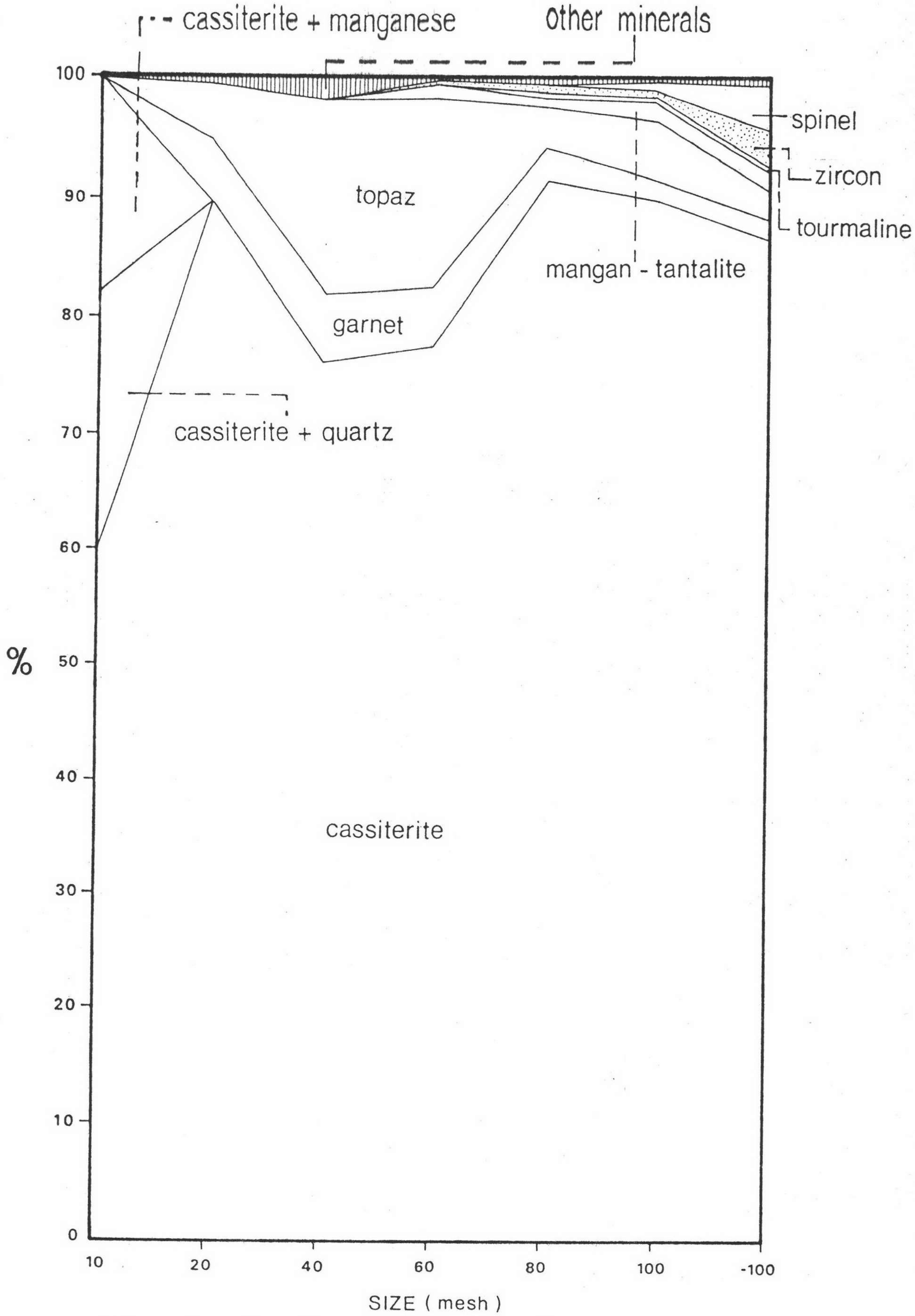
Other minerals: limonite, manganese oxide, monazite, xenotime, mica, and mangan-tantalite.

Figure 4.3.1 The relative abundance of some important heavy minerals with respect to different grain size of Tor Soong mine (within Kathu Valley).



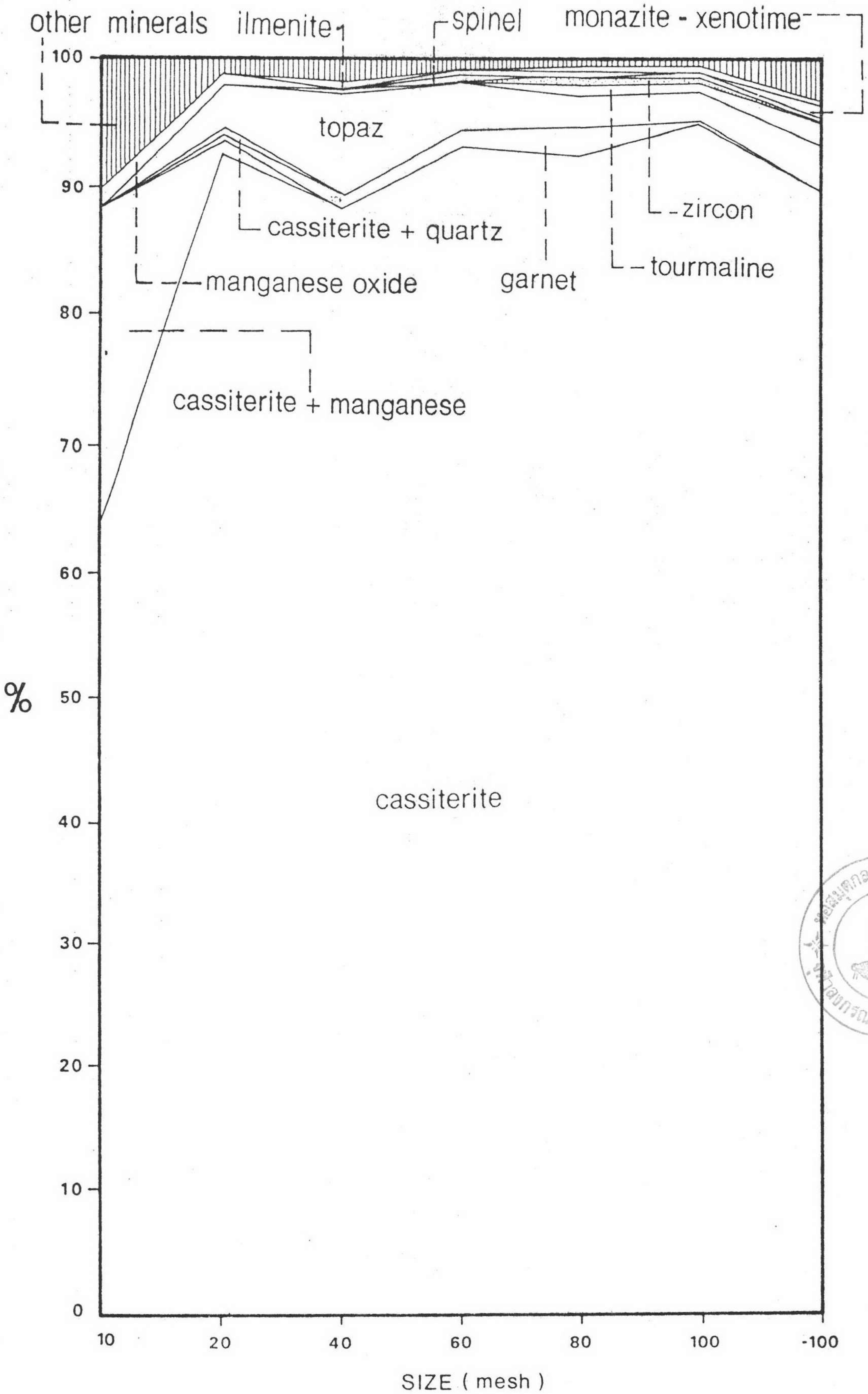
Other minerals: apatite, Fe-oxide, manganese oxide, mica, monazite, xenotime, and spinel.

Figure 4.3.2 The relative abundance of some important heavy minerals with respect to different grain size of Tantikowit mine (within Kathu Valley).



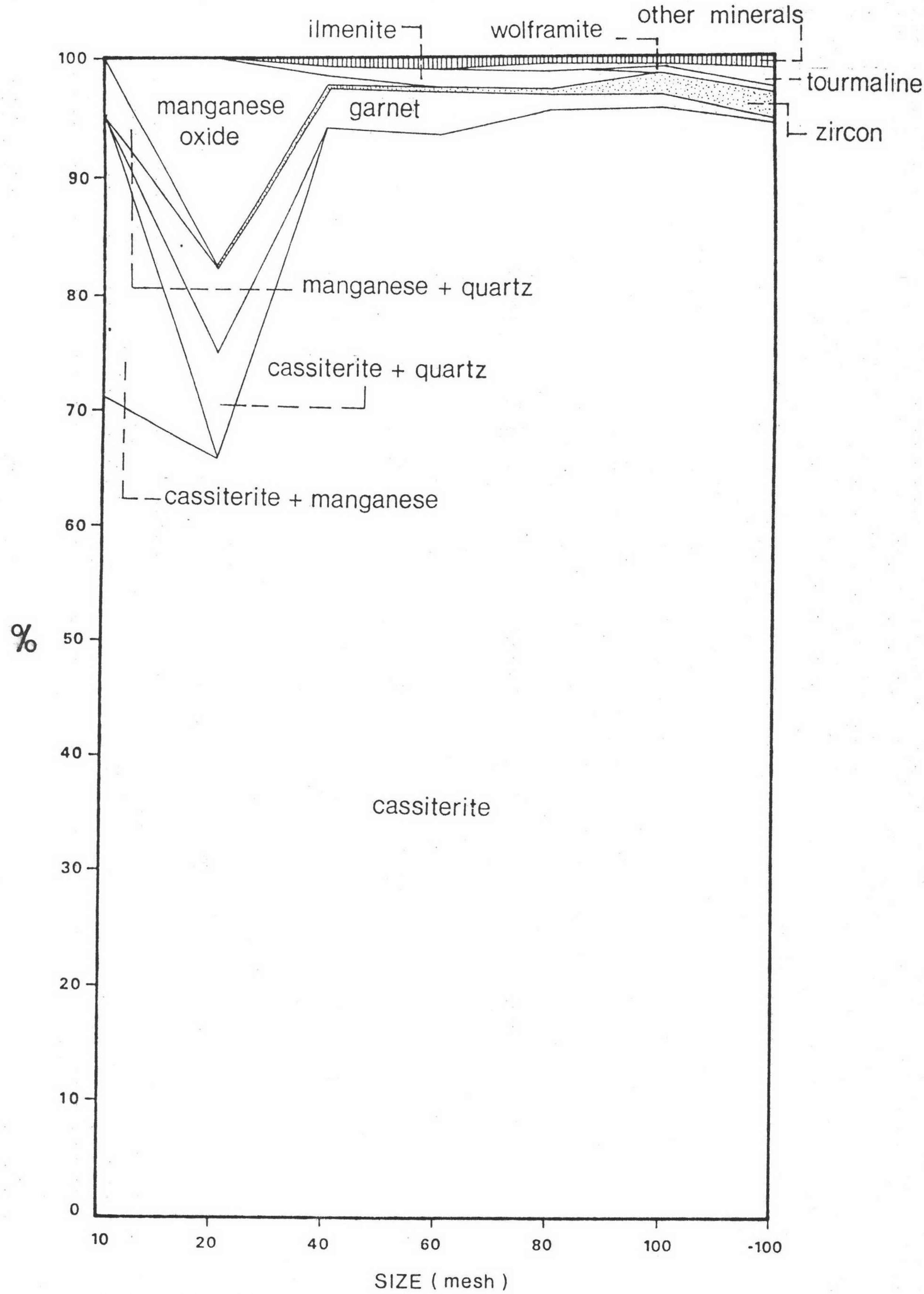
Other minerals: Fe-oxide, ilmenite, leucoxene, manganese oxide, muscovite, and rutile.

Figure 4.3.3 The relative abundance of some important heavy minerals with respect to different grain size of Pad Roi mine (within Kathu Valley).



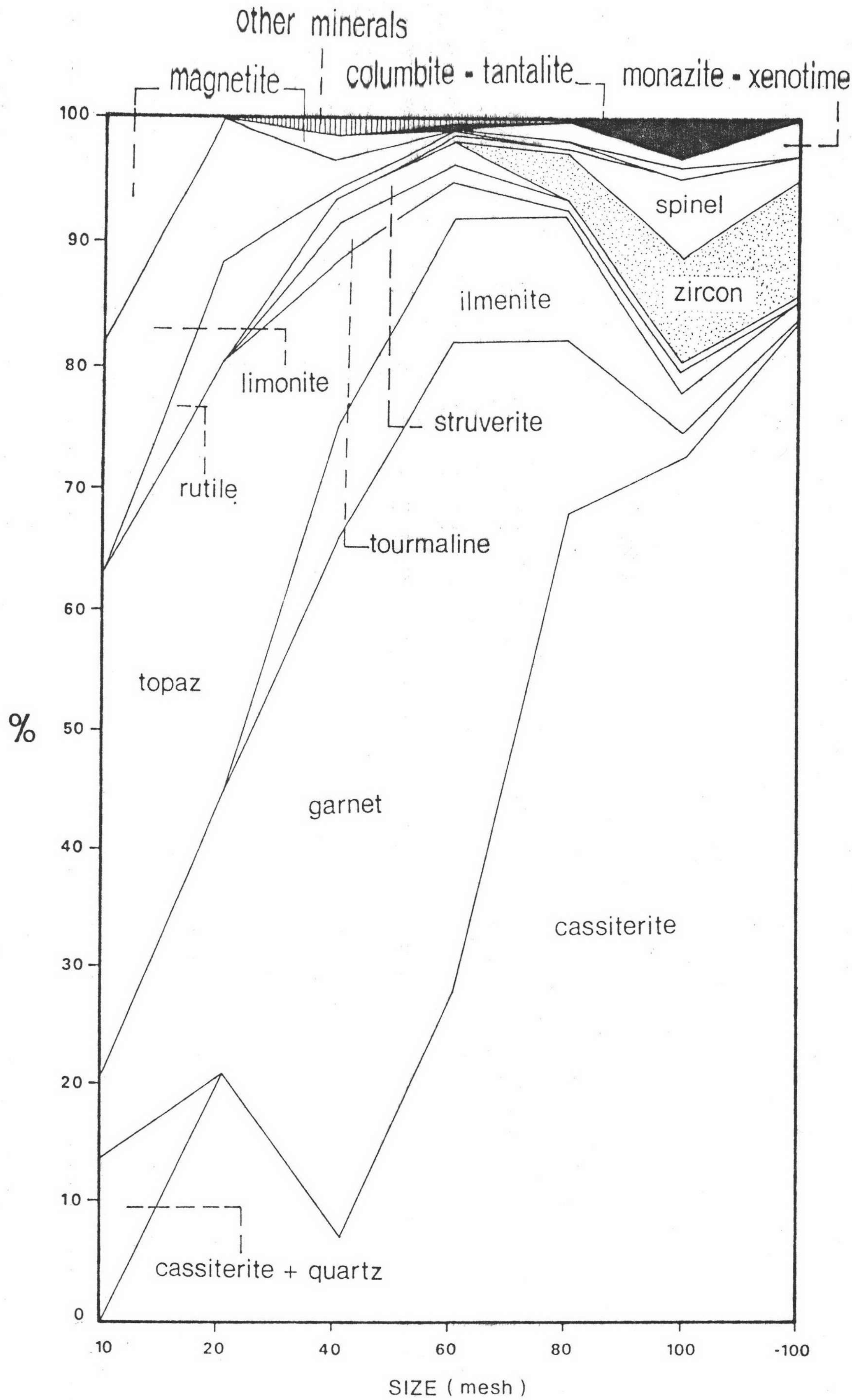
Other minerals: allanite, apatite, Fe-oxide, limonite, mica, multiple oxide contain Cb-Ta, and wolframite.

Figure 4.3.4 The relative abundance of some important heavy minerals with respect to different grain size of Ban Nguan mine (within Kathu Valley).



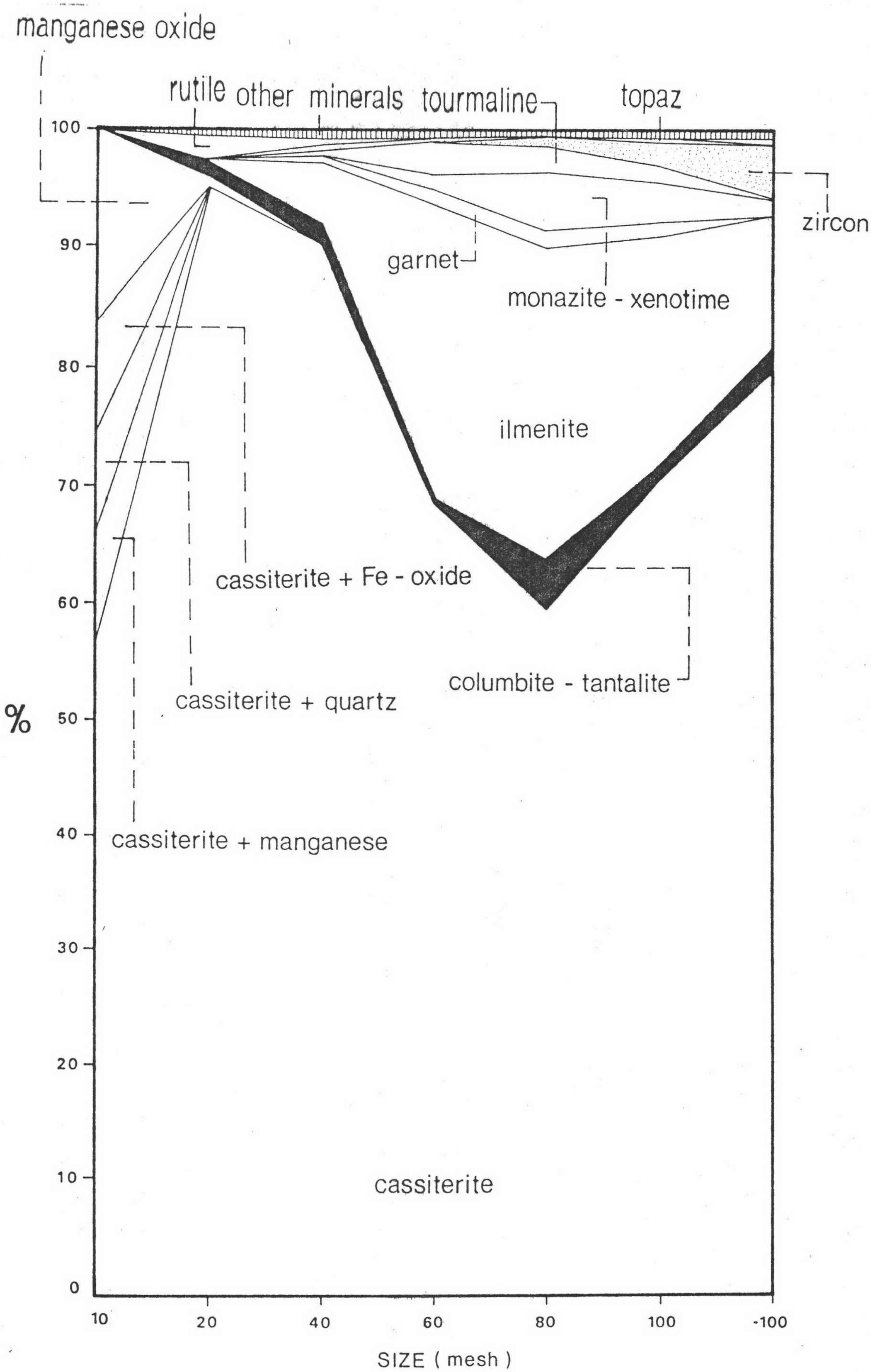
Other minerals: columbite-tantalite, Fe-oxide, mica, monazite, xenotime, rutile, and mangan-tantalite.

Figure 4.3.5 The relative abundance of some important heavy minerals with respect to different grain size of Pin Yoh mine (within Kathu Valley).



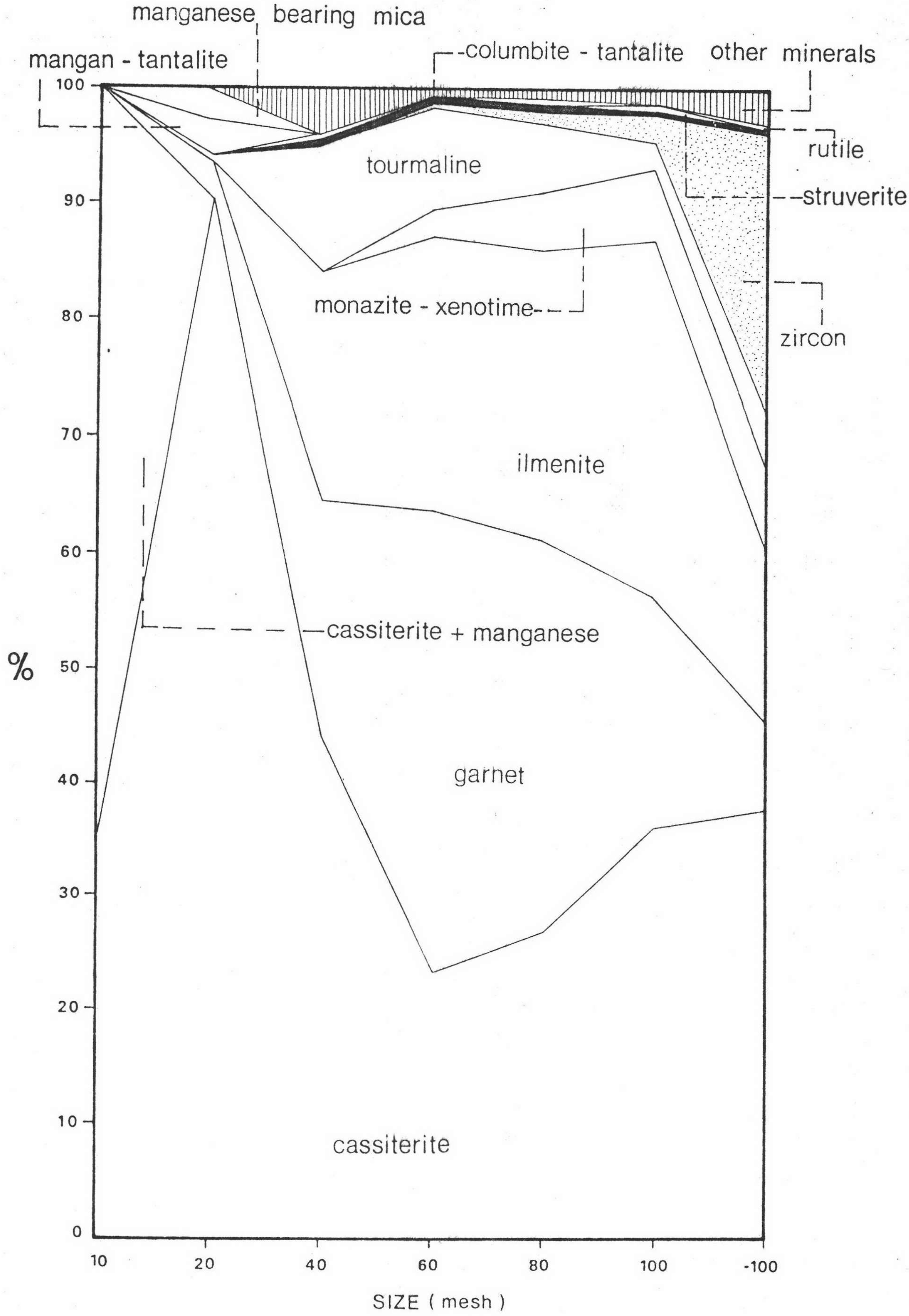
Other minerals: Fe-oxide, and mica.

Figure 4.3.6 The relative abundance of some important heavy minerals with respect to different grain size of Kathu mine (within Kathu Valley).



Other minerals: Fe-oxide, and mica.

Figure 4.3.7 The relative abundance of some important heavy minerals with respect to different grain size of Tung Tong mine (within Kathu Valley).



Other minerals: apatite, biotite, manganese oxide, spinel, and topaz.

Figure 4.3.8 The relative abundance of some important heavy minerals with respect to different grain size of Pol Thavee mine (within Kathu Valley).

present only in 2 localities have no distinct grain size distribution patterns.

The relative abundance of some important heavy minerals with respect to different grain size of seven samples obtained outside Kathu Valley are summarized and presented in Figure 4.3.9-4.3.15

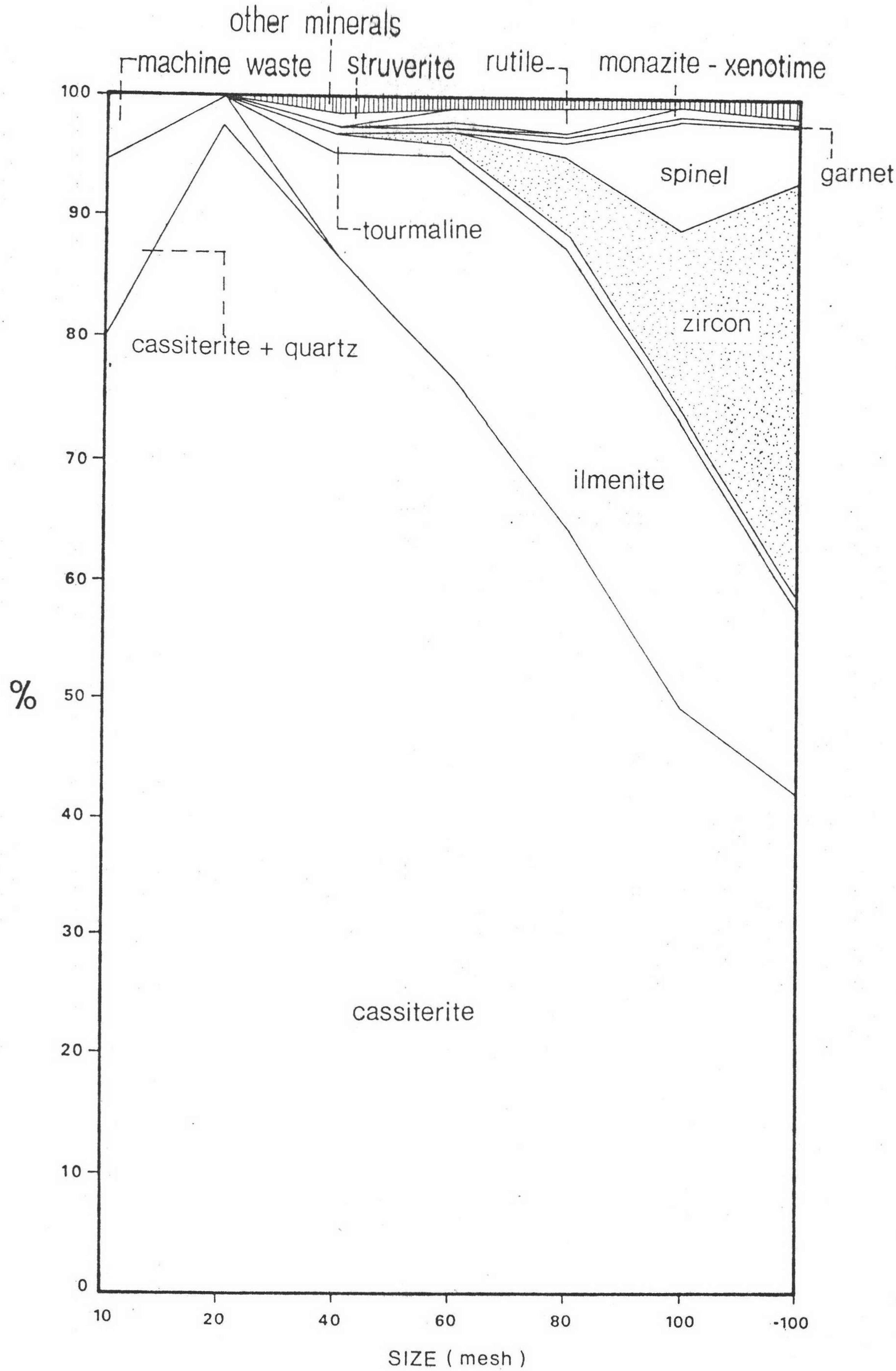
4.4 Distribution and Abundance of some Economically Important Heavy Minerals

Among economic detrital heavy minerals produced in Thailand, the following mineral, cassiterites,columbite-tantalite,columbium-tantalum (struverite), zircon, monazite, xenotime, ilmenite are considered to be important. The actual production statistics of these minerals for the whole country are summarized in Table 4.4.1. However, these figures are not really a representation of the potential reserves. This is basically due to many factors, notably, the world market demand, the fluctuation of price, the export restriction, etc. Nevertheless, the production statistics of these minerals for Thailand indicates the economic importance as well as the potential reserves.

Considering the production statistics of some detrital heavy minerals from Phuket Island, the same reasoning is also applicable (Table 4.4.2). It is anticipated that the role of these minerals will be increasing in the future with respect to the production and value.

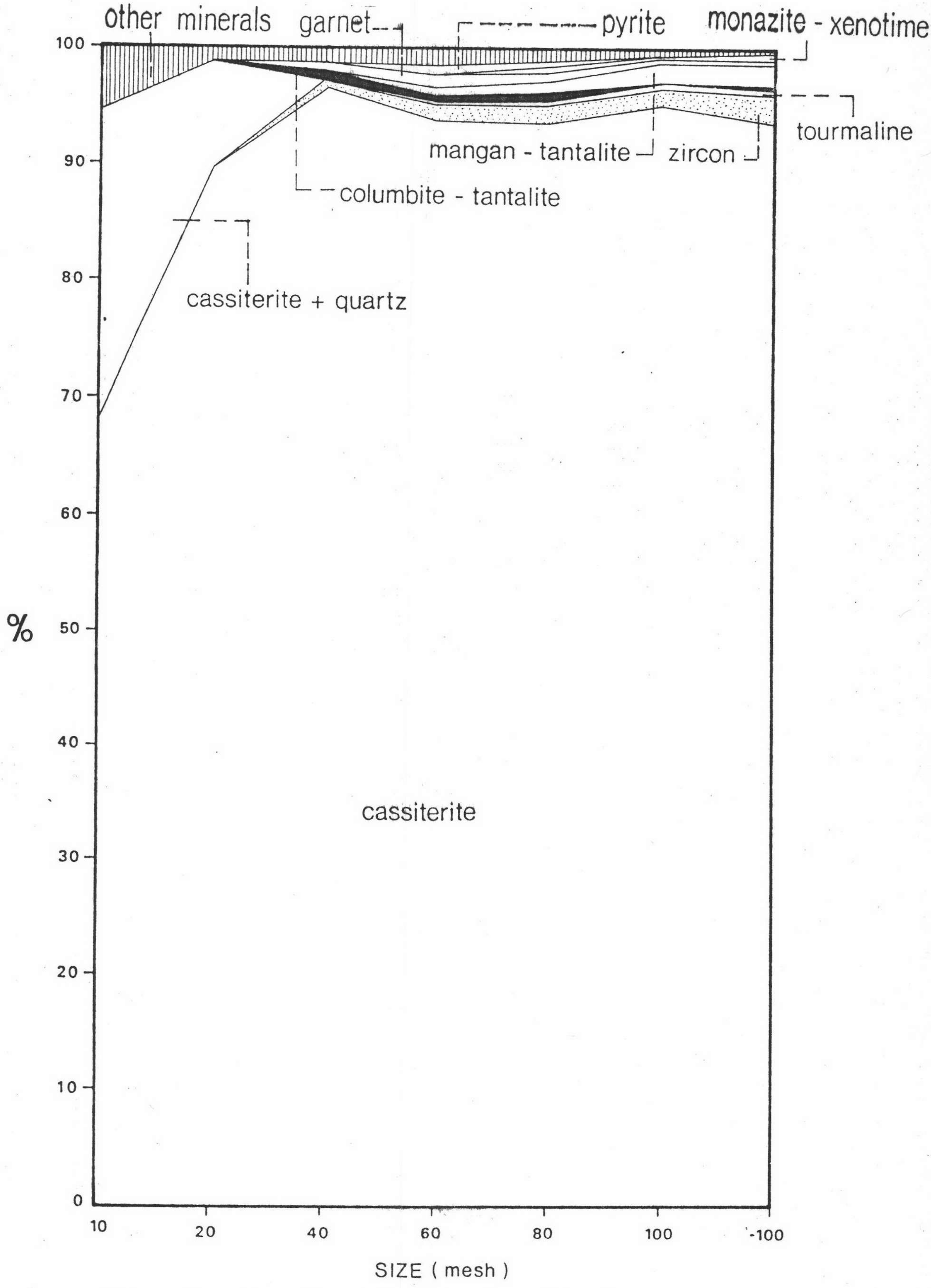
4.4.1 Cassiterite

Analyses of cassiterite content in heavy mineral suites of eight samples obtained from tin-mines in Kathu Valley against grain size reveal that they are mostly abundant in the size range of 10-40 mesh (2.00-0.42 mm.) or very coarse to medium sand with a general tendency of decreasing abundance respective to the decreasing grain size



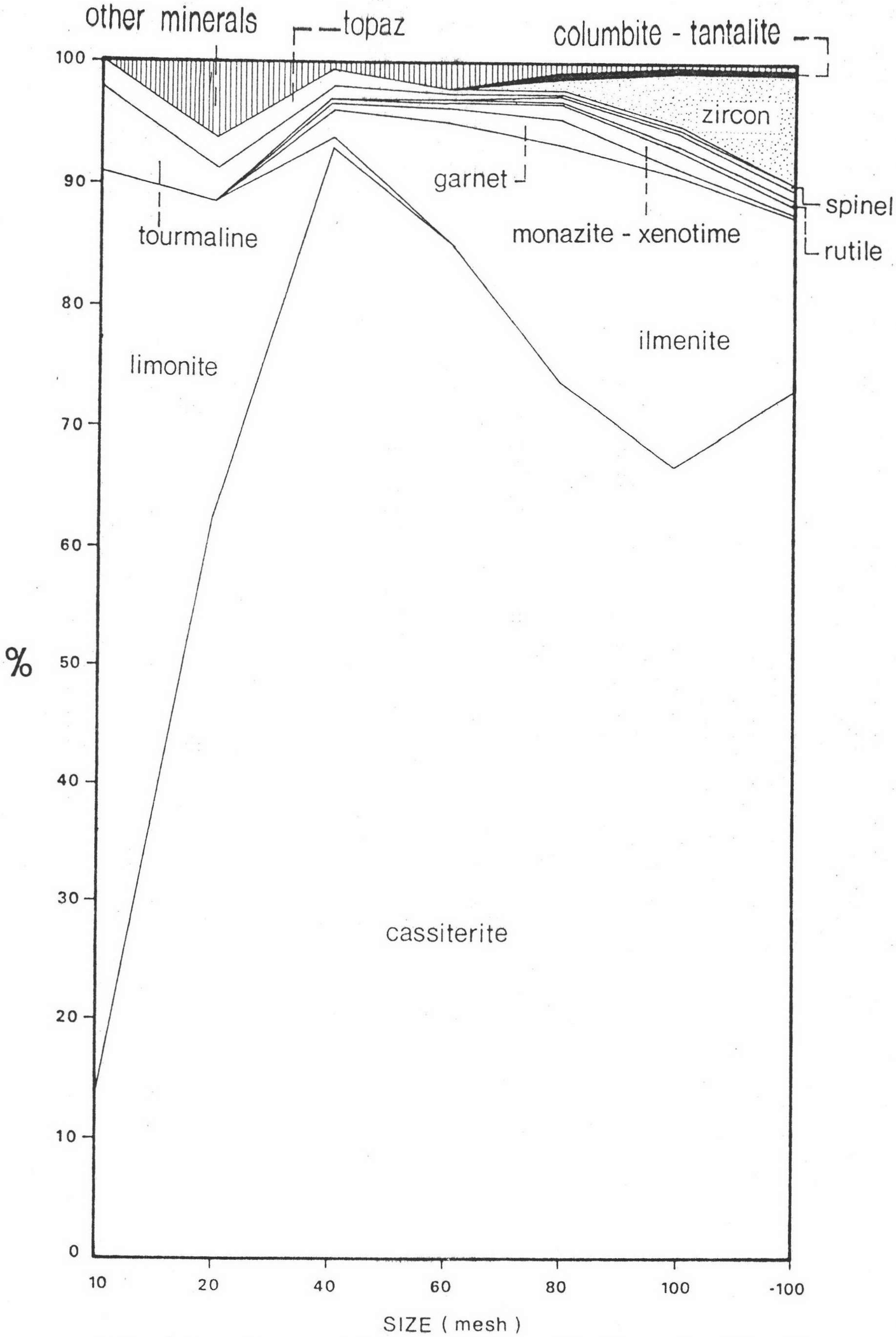
Other minerals: Fe-oxide, fluorite, multiple oxide contain Cb-Ta, siderite, siderite+quartz, and thorite.

Figure 4.3.9 The relative abundance of some important heavy minerals with respect to different grain size of Sapayakorn mine (outside Kathu Valley).



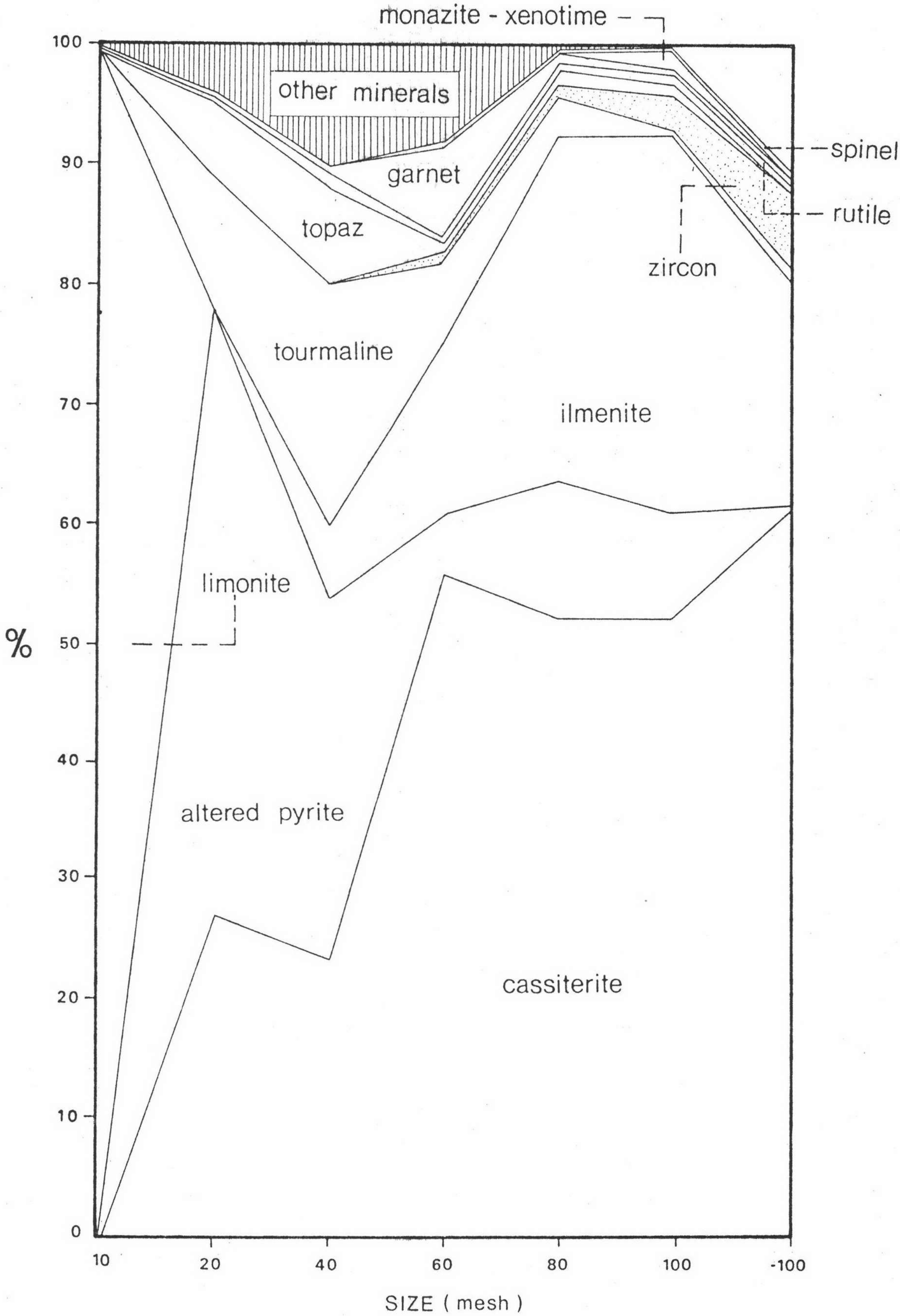
Other minerals: Fe-oxide, ilmenite, limonite, manganese oxide, mica, and topaz.

Figure 4.3.10 The relative abundance of some important heavy minerals with respect to different grain size of Sinpatana mine (outside Kathu Valley).



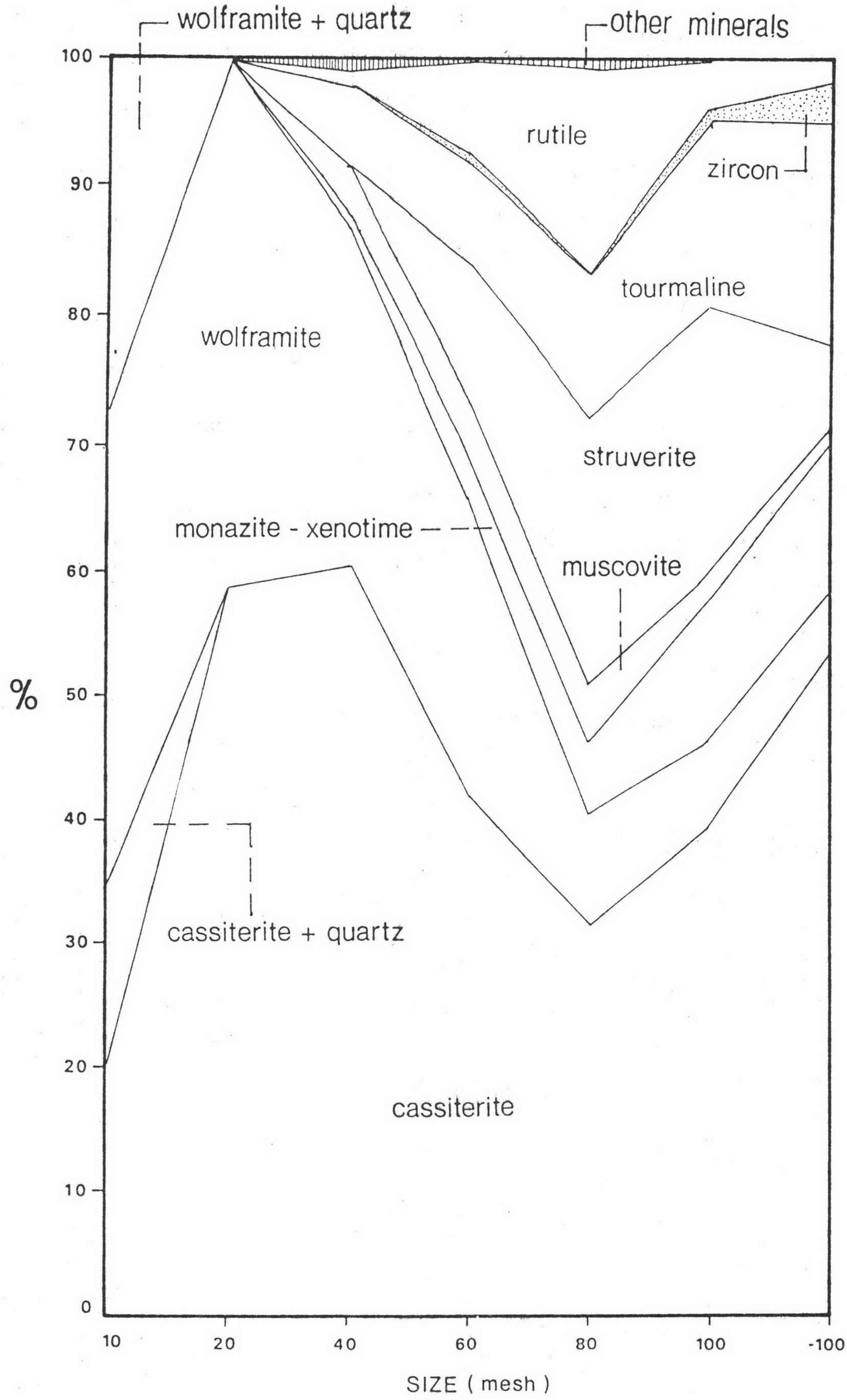
Other minerals: apatite, Fe-oxide, siderite, and wolframite.

Figure 4.3.11 The relative abundance of some important heavy mineral with respect to different grain size of Sap Bangku mine (outside Kathu Valley).



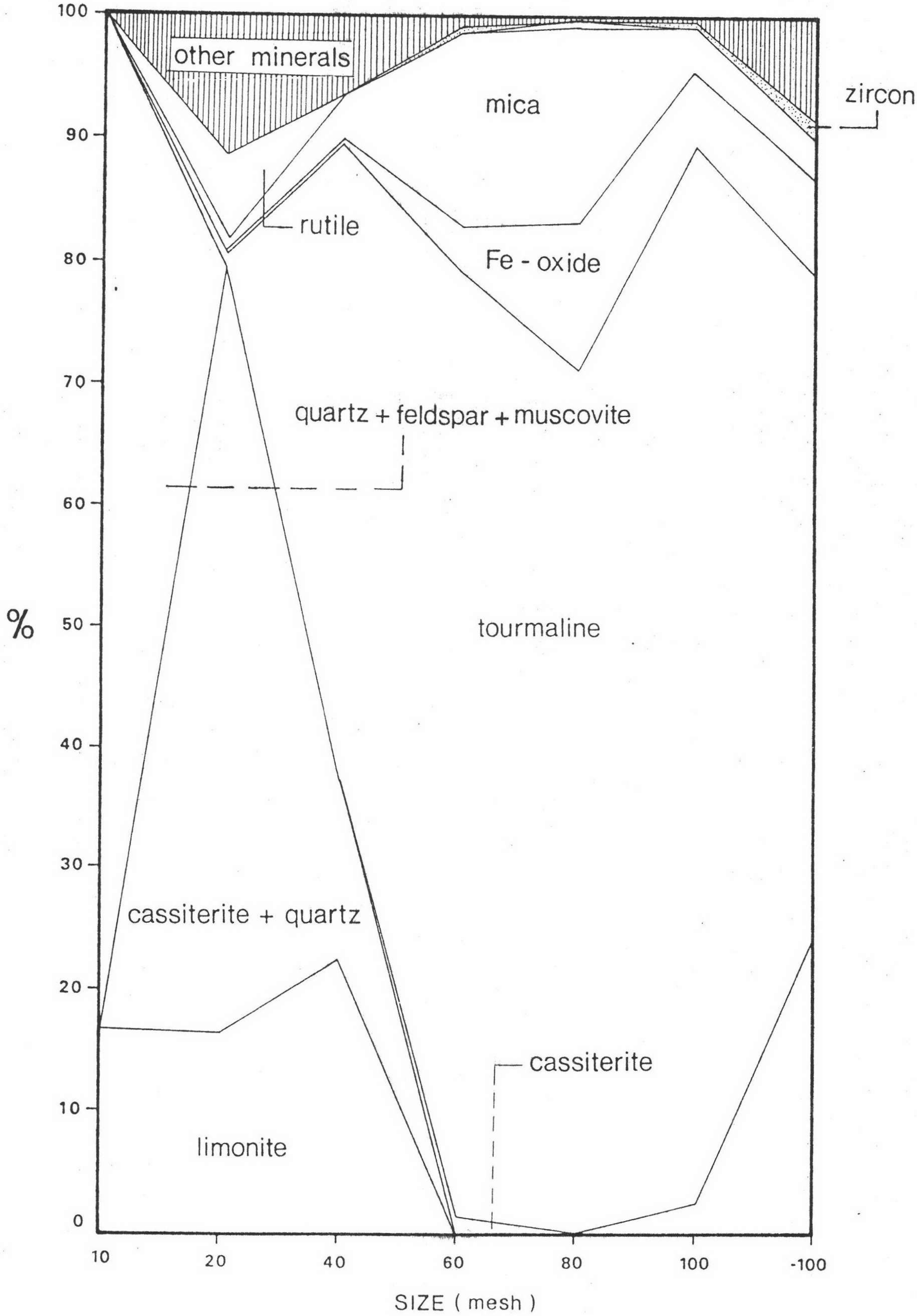
Other minerals: columbite-tantalite, Fe-oxide, Fe-oxide+quartz, leucoxene, manganese oxide, pyrite, and struverite.

Figure 4.3.12 The relative abundance of some important heavy minerals with respect to different grain size of Lun Seng mine (outside Kathu Valley).



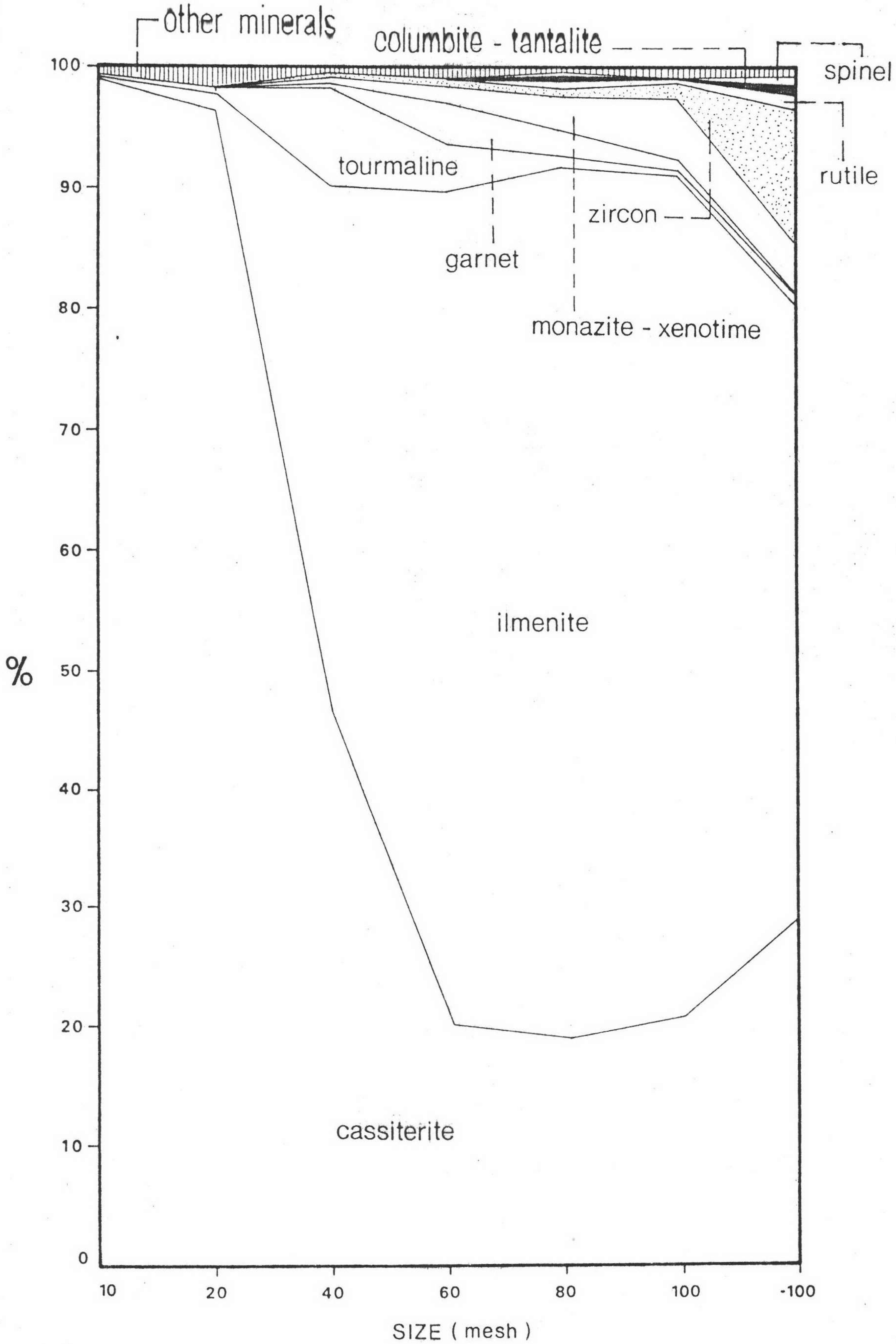
Other minerals: Fe-oxide, and spinel.

Figure 4.3.13 The relative abundance of some important heavy minerals with respect to different grain size of V.I.P. mine (outside Kathu Valley).



Other minerals: arsenopyrite, fluorite, garnet, hematite, ilmenite, magnetite, manganese oxide, monazite, xenotime, pyrite, wolframite and scheelite

Figure 4.3.14 The relative abundance of some important heavy minerals with respect to different grain size of Sahakit mine (outside Kathu Valley).



Other minerals: Fe-oxide

Figure 4.3.15 The relative abundance of some important heavy minerals with respect to different grain size of Chao Fah mine (outside Kathu Valley)

Table 4.4.1 Production statistics of some important economic heavy minerals of Thailand.

Mineral	Production (Tons)				
	1978	1979	1980	1981	1982
Cassiterite	41,210	46,364	45,986	42,968	35,644
Columbite-tantalite	64	407	356	49	39
Columbium-tantalum (Struverite)	-	231	301	44 R	10
Zircon	25	116	61	104	196
Monazite	-	32	152	107	162
Xenotime	-	6	52	45	46
Ilmenite	482	780	-	37	18

R - revised

Source: Department of Mineral Resource (1982)

Table 4.4.2 Production statistics of some important economic heavy minerals of Phuket.

Mineral	Production (Tons)				
	1978	1979	1980	1981	1982
Cassiterite	3,853	4,145	3,771	3,944	3,749
Columbite-tantalite	-	76	125	-	-
Columbium-tantalum (Struverite)	-	177	80	-	-
Zircon*	-	-	-	-	-
Monazite*	-	-	66	62	-
Xenotime*	-	-	-	-	-
Ilmenite*	-	-	-	-	-

* by-products from tin mine, production statistics is not available

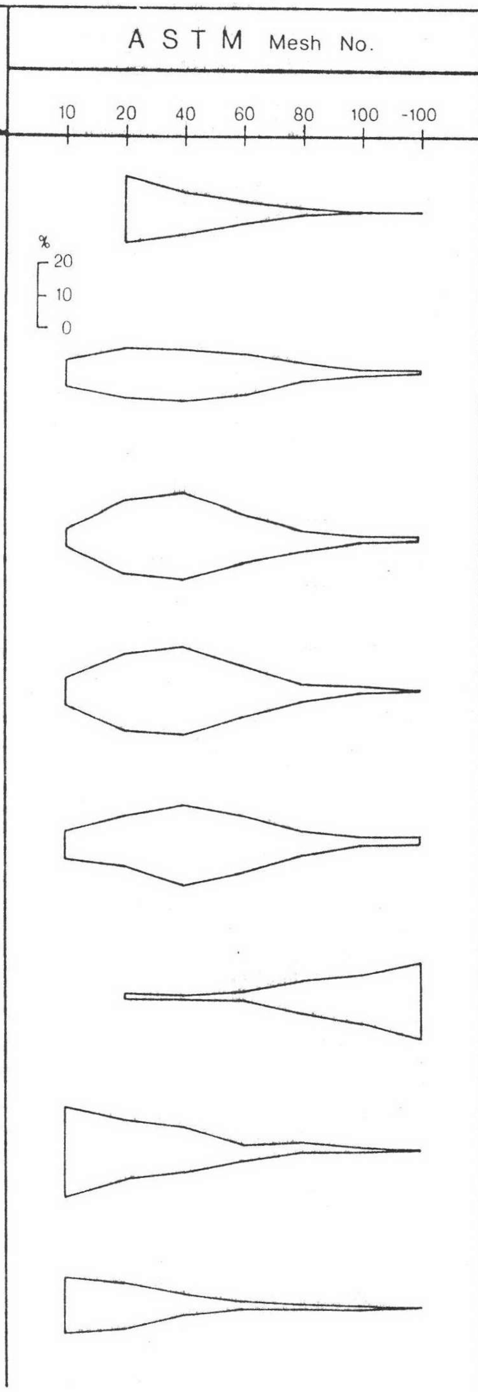
Source: Department of Mineral Resource. (1982)

(Fig. 4.4.1a). This pattern is, however, reversible for Kathu mine which is essentially due to the reworked type of deposit. The cassiterite distribution patterns which are most abundant in the size range of 10-40 mesh (2.00-0.42 mm.) or very coarse to medium sand can be explained in terms of their relatively coarser original size of pegmatitic origin.

The distribution patterns of cassiterite contents in heavy mineral suites obtained from seven tin-mines outside Kathu Valley show similar uniformity with most abundant contents distributed within the size range of 10-40 mesh (2.00-0.42 mm.) or very coarse to medium sand. Besides, there is also a general trend of decreasing cassiterite contents with respect to decreasing grain size. Exception appears at Lun Seng mine with reversible pattern (Fig. 4.4.1 b). This is due to the nature of deposit with fluvial and marine influences. Besides, it is noted that cassiterite contents in Sahakit mine is relatively less abundant than others. These distribution pattern of almost all samples, with cassiterite present in the size range of 10-40 mesh (2.00-0.42 mm.) or very coarse to medium sand, can be explained in terms of their original pegmatitic and pegmatitic/colluvial types of deposit.

4.4.2 Niobium/Tantalum-bearing minerals

With respect to another group of economically important heavy minerals containing niobium or columbium and tantalum, they include columbite-tantalite, struverite, mangan-tantalite, and other multiple-oxide minerals. Within the Kathu Valley, columbite-tantalite is present in almost all tin-mines except Ban Nguan mine. It is most abundant in the size range of 20-60 mesh (0.841-0.25 mm.) or coarse to



Grain size / Locality	Remarks genesis
Tor Soong Mine	Quartz-feldspar pegmatite
Tantikowit Mine	Tourmaline-muscovite pegmatite associated with lepidolite pegmatite.
Pad Roi Mine	Tourmaline-muscovite pegmatite associated with lepidolite pegmatite and quartz-muscovite pegmatite.
Ban Nguan Mine	Lepidolite pegmatite associated with quartz-muscovite pegmatite and quartz-feldspar pegmatite.
Pin Yoh Mine	Muscovite pegmatite associated with quartz-feldspar-muscovite pegmatite.
Kathu Mine	Reworked/alluvial deposit.
Tung Tong Mine	Colluvium/muscovite pegmatite.
Pol Thavee Mine	Quartz-feldspar-muscovite pegmatite associated with tourmaline muscovite pegmatite.

Figure 4.4.1a Distribution pattern of cassiterite contents with respect to grain-size of samples obtained from tin-mines within the Kathu Valley.

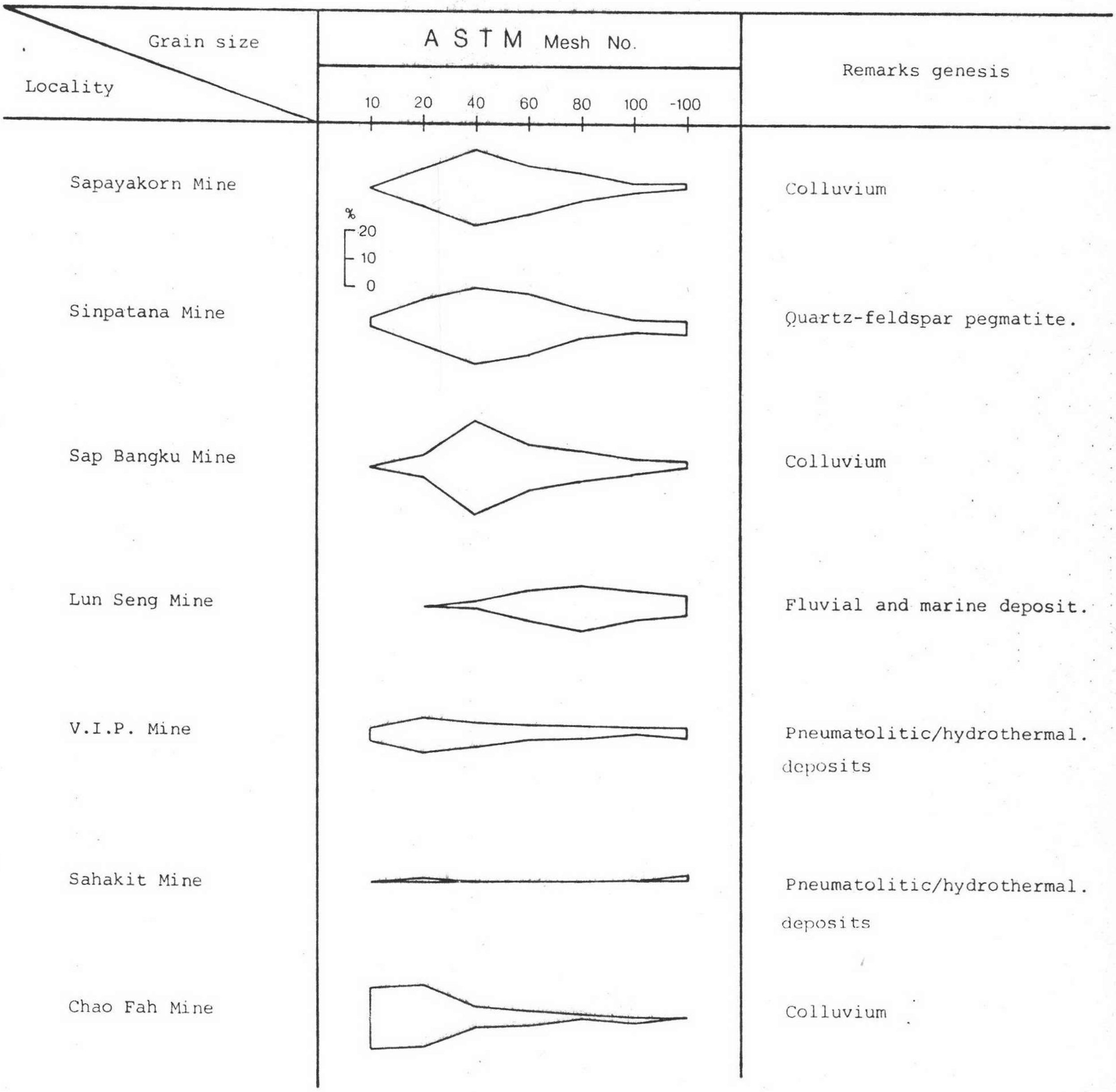


Figure 4.4.1b Distribution pattern of cassiterite contents with respect to grain-size of samples obtained from tin-mines outside Kathu Valley.

medium sand with a tendency to decrease in contents respective to decreasing grain size. This pattern is most distinctive in only 5 tin-mines, namely, Tantikowit mine, Pad Roi mine, Pin Yoh mine, Tung Tong mine, Pol Thavee mine. The mangan-tantalite is present at Pol Thavee mine and Pad Roi mine with maximum content in the 20 mesh and 60 mesh (0.841 mm. and 0.25 mm.) or coarse and medium sand. Besides, this mineral appears as trace in Tor Soong and Pin Yoh mines. For struverite, it is most abundant in the very limited size range of 40-60 mesh (0.42-0.25 mm.) or medium sand at Kathu mine, whereas at Pol Thavee mine this mineral is present as trace. The multiple-oxide minerals are present only at Ban Nguan mine. The distribution pattern of these minerals are summarized and presented in Figure 4.4.2 a.

Outside the Valley, struverite is extraordinary abundant in the size range of 60-100 mesh (0.25-0.149 mm.) or medium to fine sand at V.I.P. mine. However, at Sapayakorn and Lun Seng mine, it is present as trace. For columbite-tantalite, it is present within the size range of 40-80 mesh (0.42-0.177 mm.) or medium to fine sand and 80 mesh to more than 100 mesh (0.177 mm. to less than 0.149 mm.) or fine to very fine sand at Sinpatana mine and Sap Bangku, Chao Fah mines, respectively. Other minerals which appear as trace are mangan-tantalite at Sinpatana mine, and multiple-oxide minerals at Sapayakorn mine. The distribution pattern of these minerals are summarized and presented in Figure 4.4.2 b.

4.4.3 Zircon

The distribution pattern of zircon contents with respect to grain size reveals that it is mainly present in a size range of

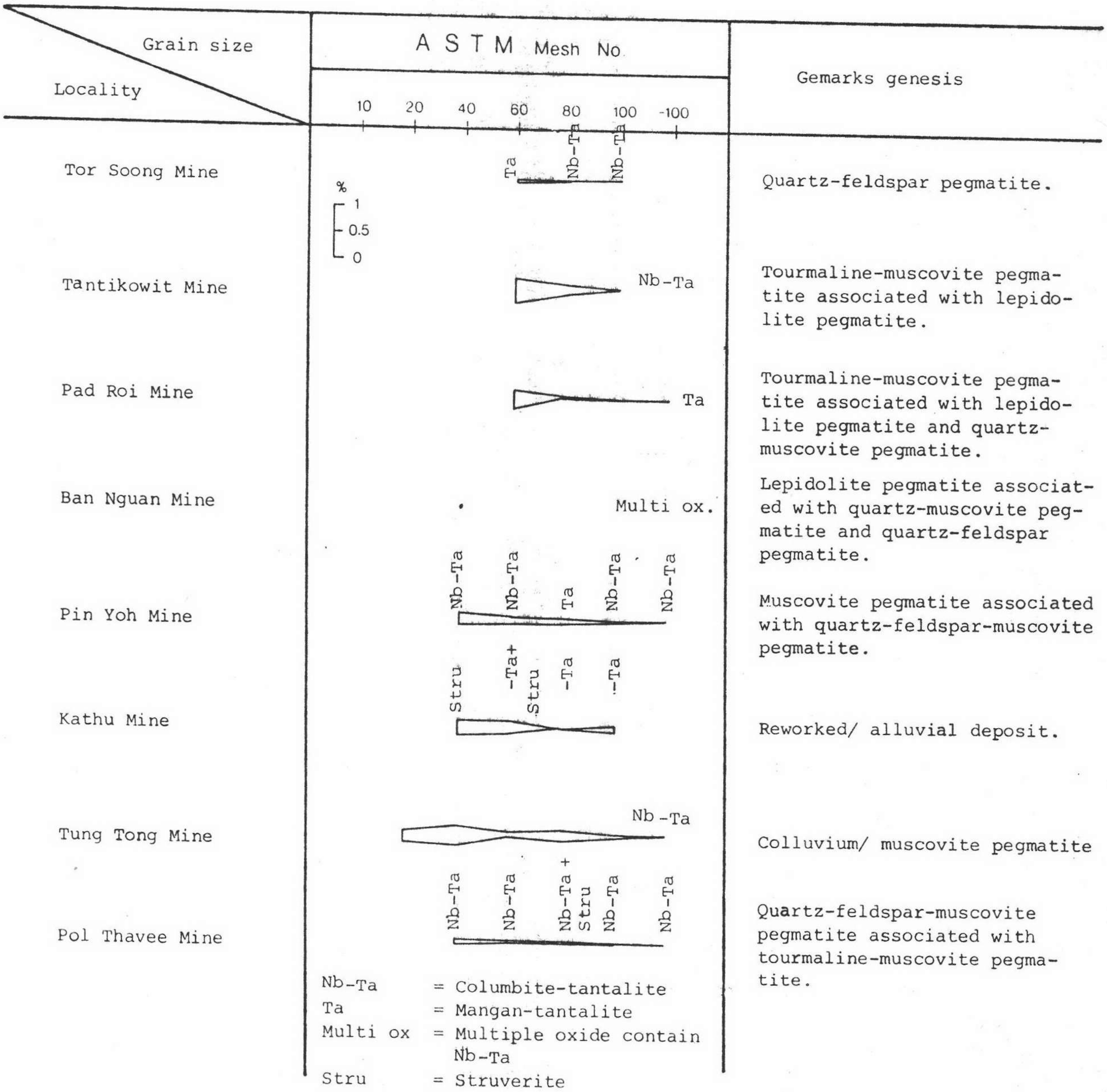


Figure 4.4.2a Distribution Pattern of columbite-tantalite, mangan tantalite, multiple oxide contain Nb-Ta, and struverite contents with respect to grain-size of samples obtained from tin-mines within Kathu Valley.

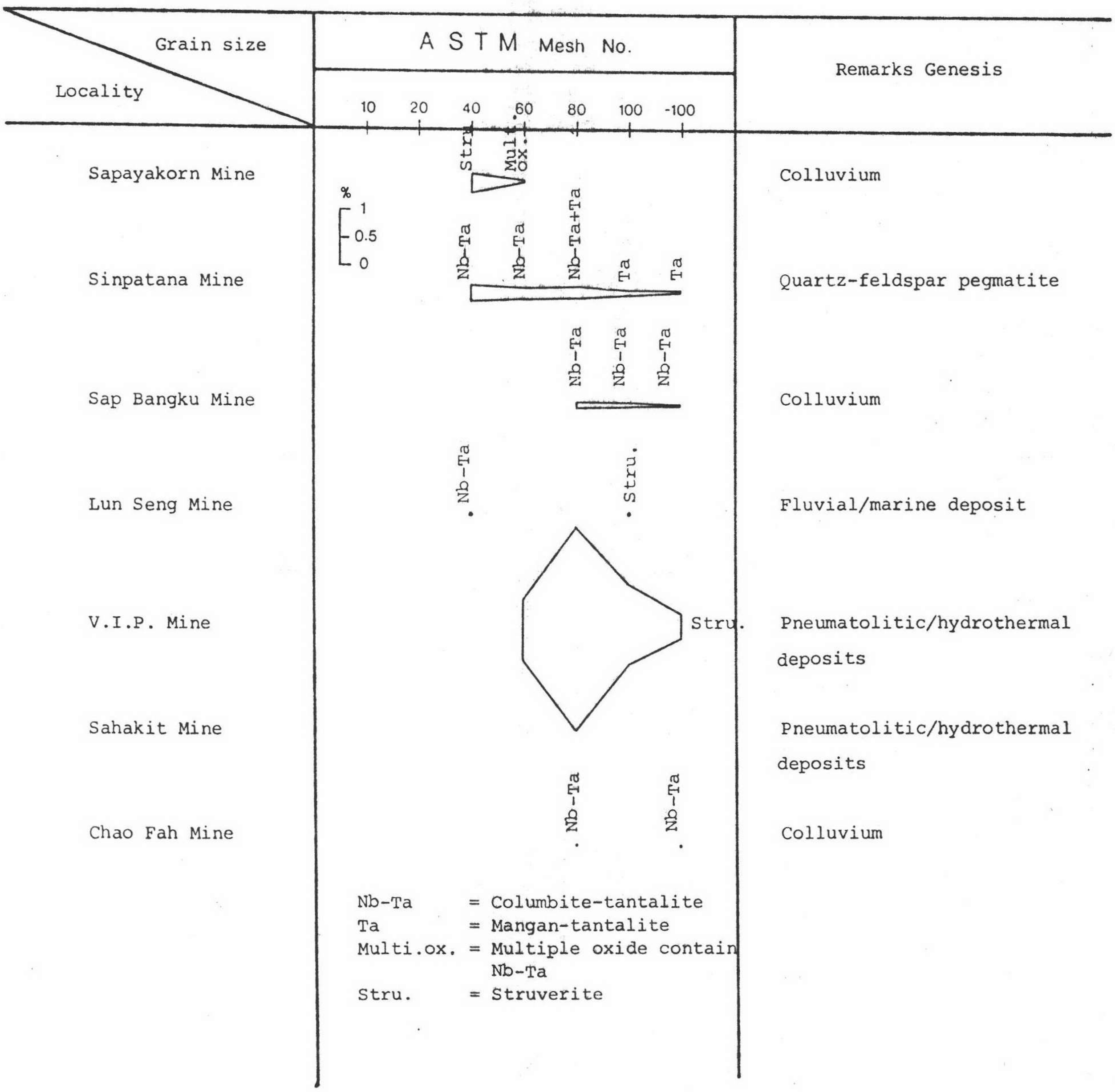


Figure 4.4.2b Distribution pattern of columbite-tantalite, mangan-tantalite, multiple oxide contain Nb-Ta and struverite contents with respect to grain-size of samples obtained from tin-mines outside Kathu Valley.

40 mesh to more than 100 mesh (0.42 mm. to less than 0.149 mm.) or medium to very fine sand for both Kathu Valley and neighbouring area outside the Valley. Within the Valley, it is noted that the degree of abundances of this mineral is fairly uniform for almost all size fractions except those of Kathu and Pol Thavee mines which exhibit the increasing degree of abundances respective to the decreasing grain size. The relatively fairly uniform distribution patterns of zircon in most cases is attributed to the uniform size of original mineral in the primary deposit and the ultra stable nature. However, the exceptional pattern of zircon of Kathu mine can be explained in terms of the reworked origin. Besides, the difference distribution patterns of zircon at Pol Thavee mine, of pegmatitic origin, can probably be interpreted on the basis of different pegmatitic original material as compared with those from Tor Soong, Tantikowit, Ban Nguan, Pad Roi, Pin Yoh, Tung Tong mines (Fig. 4.4.3 a).

For the distribution pattern of zircon from tin-mines outside the Valley, it is generally increasing in its abundance with respect to decreasing grain size except those from Sinpatana, and Sahakit mines. This is obviously due to the reworked condition of primary deposit by some surface processes. The zircon distribution patterns of Sinpatana and Sahakit mines reflect the in situ weathering of original pegmatitic and pneumatolitic origins. It is also noted that the distribution pattern of in situ weathering of original pneumatolitic materials of V.I.P. mine shows the increasing in abundance with respect to decreasing grain size (Fig. 4.4.3 b).

4.4.4 Monazite/Xenotime

Due to the fact that monazite and xenotime have

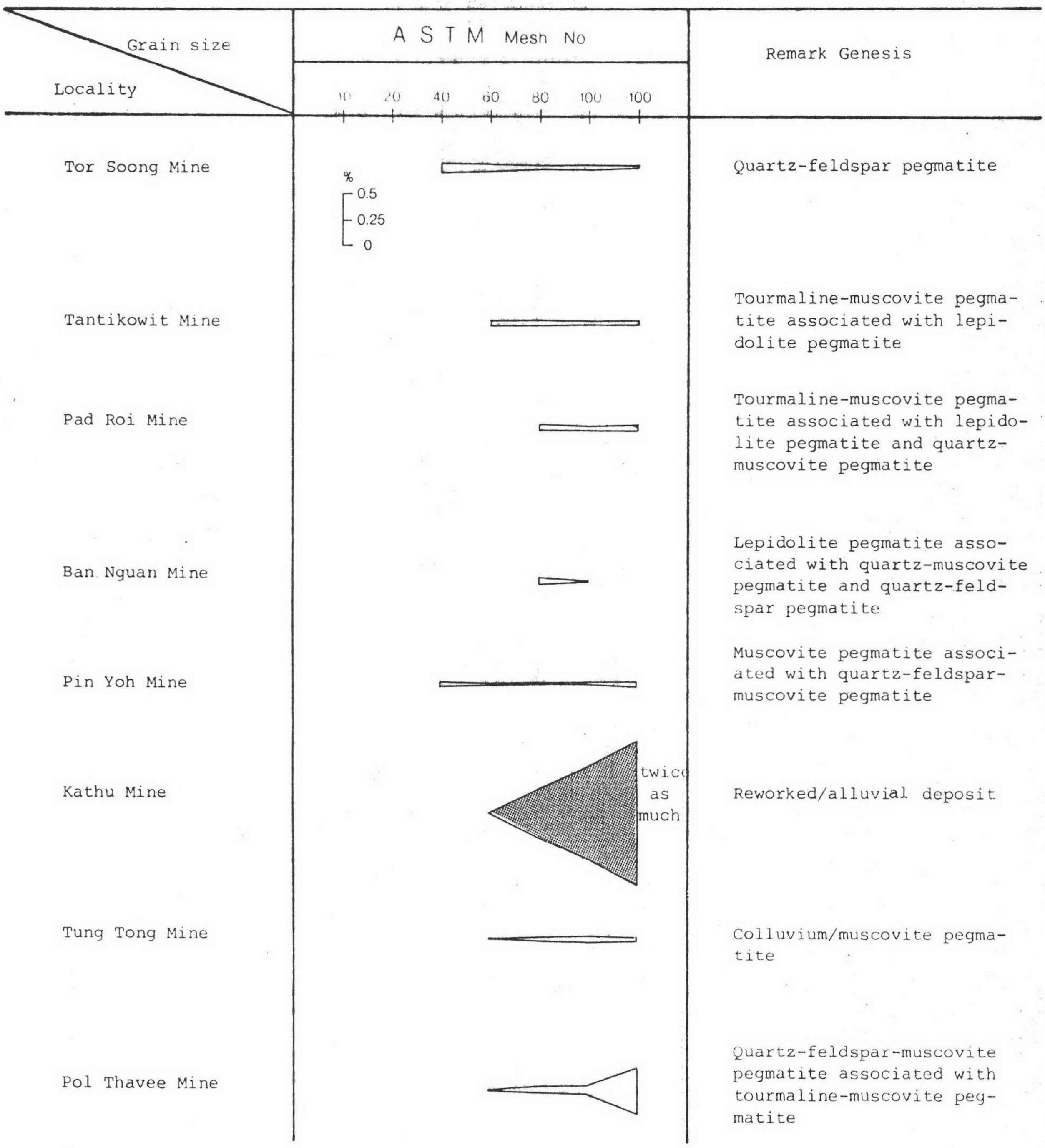


Figure 4.4.3a Distribution pattern of zircon contents with respect to grain-size of samples obtained from tin-mines within Kathu Valley.

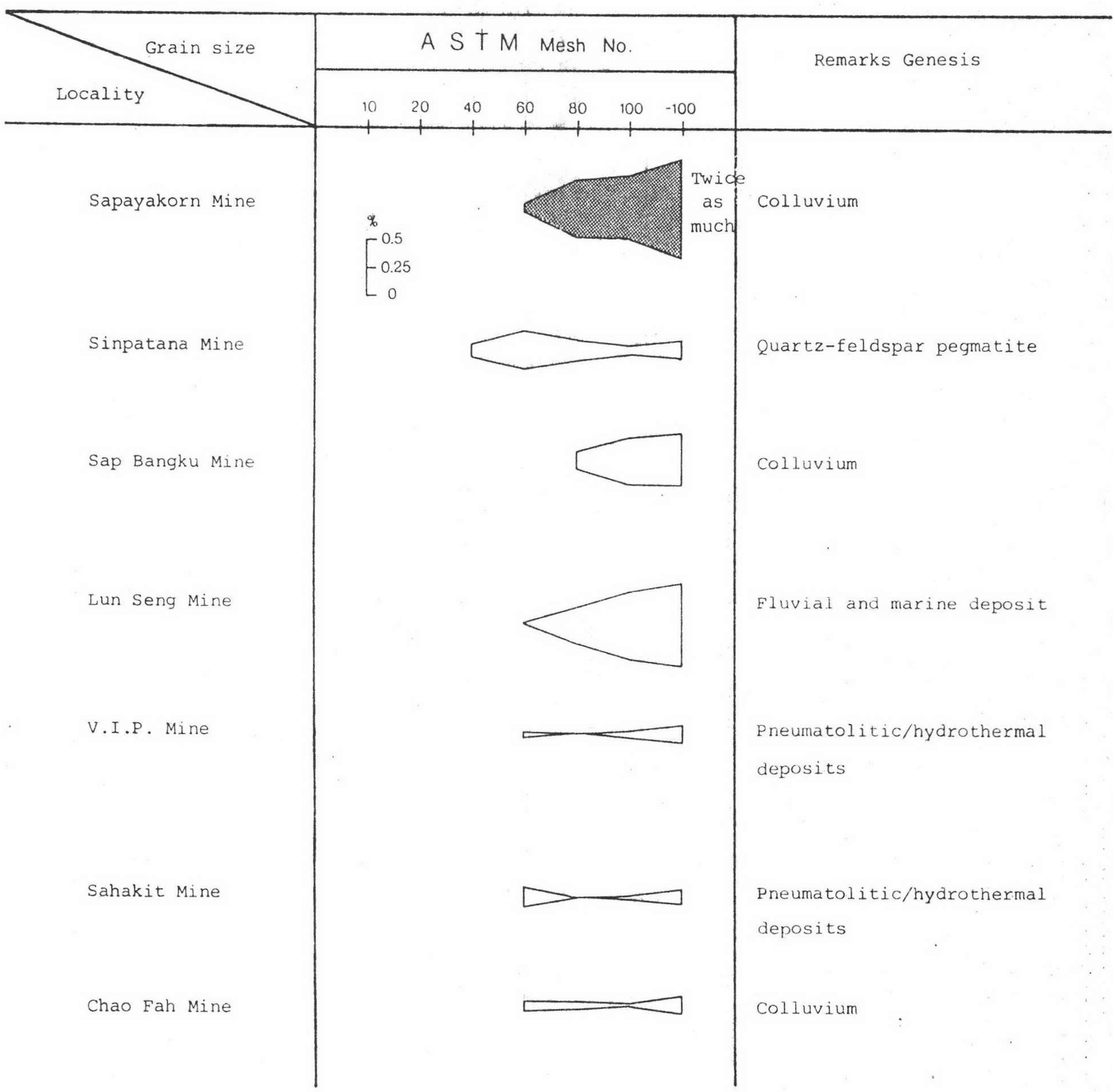


Figure 4.4.3b Distribution Pattern of zircon contents with respect to grain-size of samples obtained from tin-mines outside Kathu Valley.

fairly similar properties and they are also present in relatively abundant, These 2 minerals are therefore grouped together for convenient study. Generally, the distribution pattern of these two minerals in the in situ weathered primary deposit of pegmatitic origin is indistinctive.

The distribution pattern of Tung Tong and Pol Thavee mines which are of colluvium/pegmatitic and pegmatitic origin, respectively have exceptionally high degree of abundance and relatively uniform characteristics with respect to grain size. This is probably due to the extraordinary rich monazite-xenotime of pegmatitic origins. For Kathu mine, the distribution pattern of these minerals increase in abundance with respect to decreasing grain size. This is obviously due to the stable nature in reworked condition and alluvial origin. The distribution pattern of monazite-xenotime is illustrated in Figure 4.4.4 a.

Considering the distribution pattern of monazite-xenotime (Fig. 4.4.4 b) outside the Valley area, the most diagnostic feature is the extraordinary high content of these minerals at V.I.P. mine with the increasing in degree of abundance respective to decreasing grain size. However, these two minerals are most abundant in the size range of 80 mesh to more than 100 mesh(0.177 mm. to less than 0.149 mm.) or fine to very fine sand except that of from Chao Fah mine which is most abundant in a relatively coarser fraction. The general distribution pattern of almost all sampling stations in this area shows a relatively more abundant of monazite-xenotime as compare with that of inside the Valley.

The relative degree of abundance and the distribution

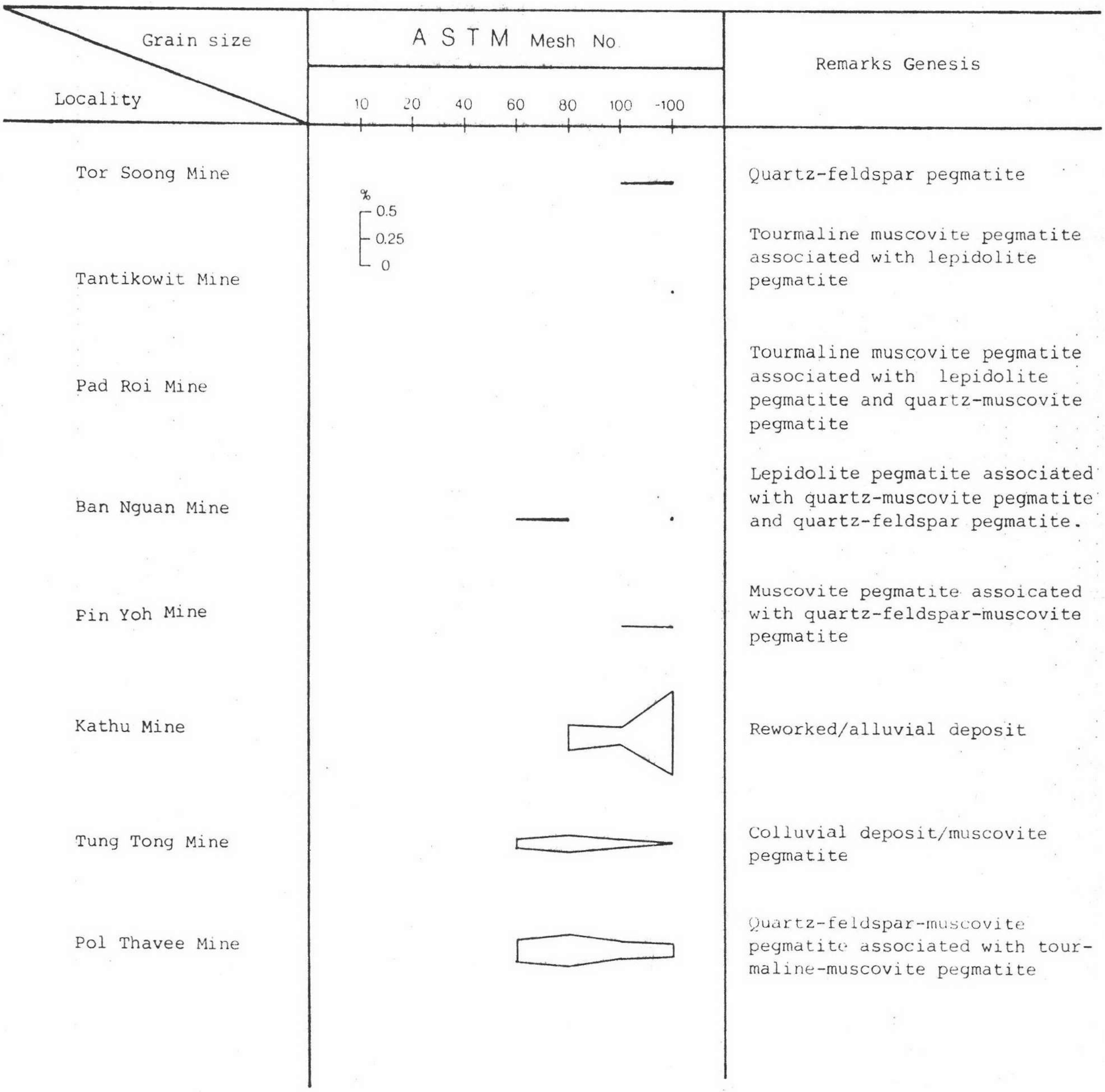


Figure 4.4.4a Distribution pattern of monazite-xenotime contents with respect to grain-size of samples obtained from tin-mines within Kathu Valley.

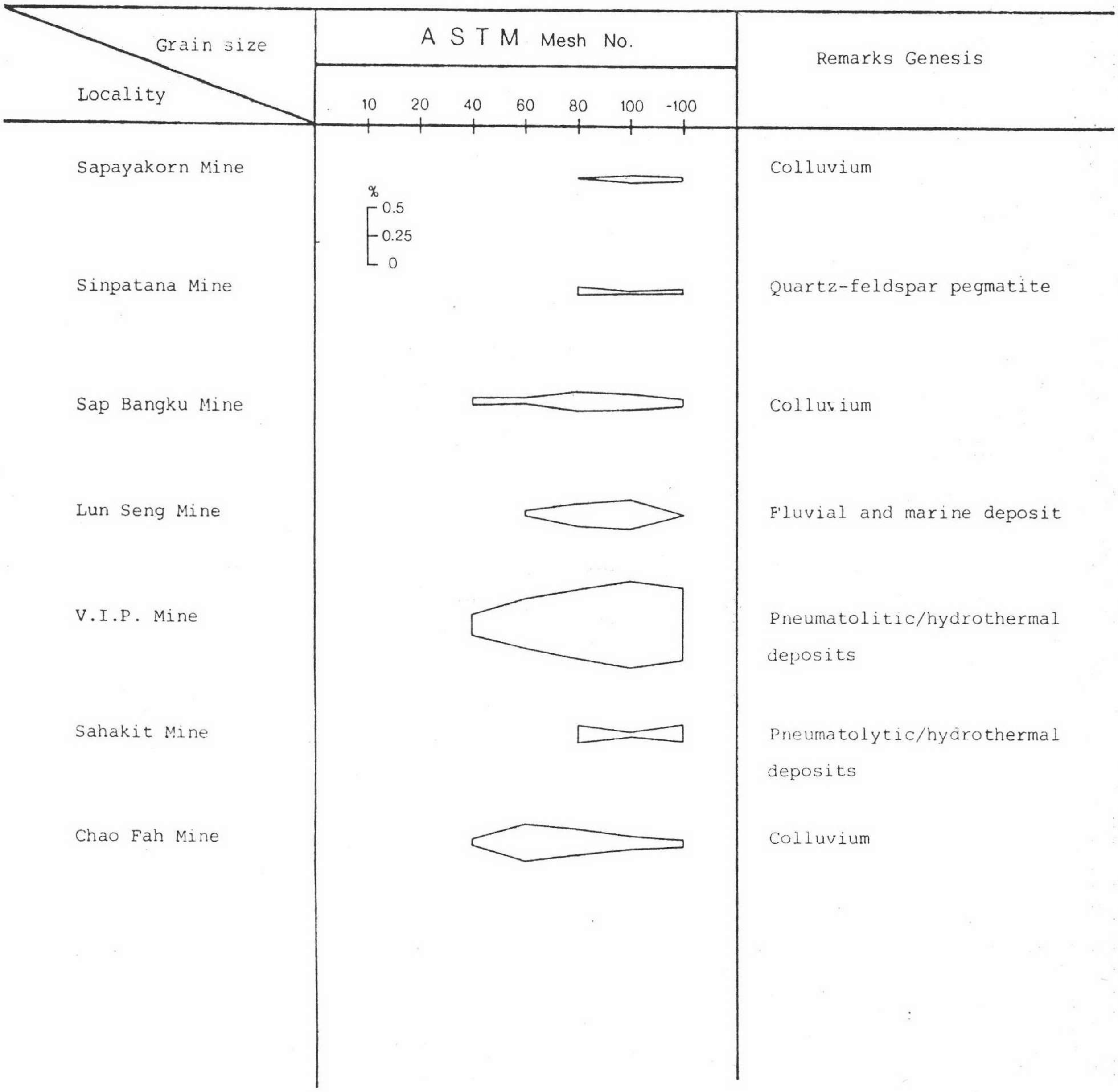


Figure 4.4.4b Distribution pattern of monazite-xenotime contents with respect to grain-size of samples obtained from tin-mines outside Kathu Valley.

pattern of monazite and xenotime are suggested to be probably controlled by the tin tungsten-bearing granitic country rocks rather than the mineralization, i.e. pneumatolitic, pegmatite, hydrothermal.

4.4.5 Ilmenite

The general distribution pattern of ilmenite of 8 sampling stations within Kathu Valley (Fig. 4.4.5 a) shows a relatively low degree of abundance within the grain size range of 40 mesh to more than 100 mesh (0.42 mm. to less than 0.149 mm.) or medium to very fine sand. However, there is a tendency of decreasing in degree of abundance with decreasing grain size.

In contrast, the distribution pattern of this mineral obtained from 7 mines outside the Valley (Fig. 4.4.5 b) obviously shows a higher degree of abundance in a similar grain size range. Ilmenite is considered to be rather stable heavy mineral. The abundance of this mineral in the area outside the Valley which have been reworked by surface processes more intensively than that of the Kathu Valley is therefore justified by the concentrating mechanism of not only in situ weathering but also other surface processes both marine and fluvial natures. The degree of abundance of this mineral, ilmenite, can be used as an indicator of the influence of surface processes other than mass-wasting and the time duration of reworking. That is the more intense fluvial and marine action operating on the deeply weather ilmenite-bearing source materials, the higher ilmenite content in the secondary deposit will be obtained. Besides, the longer time for fluvial and marine processes to operate, the higher amount of ilmenite will be left over at the secondary deposit concerned.

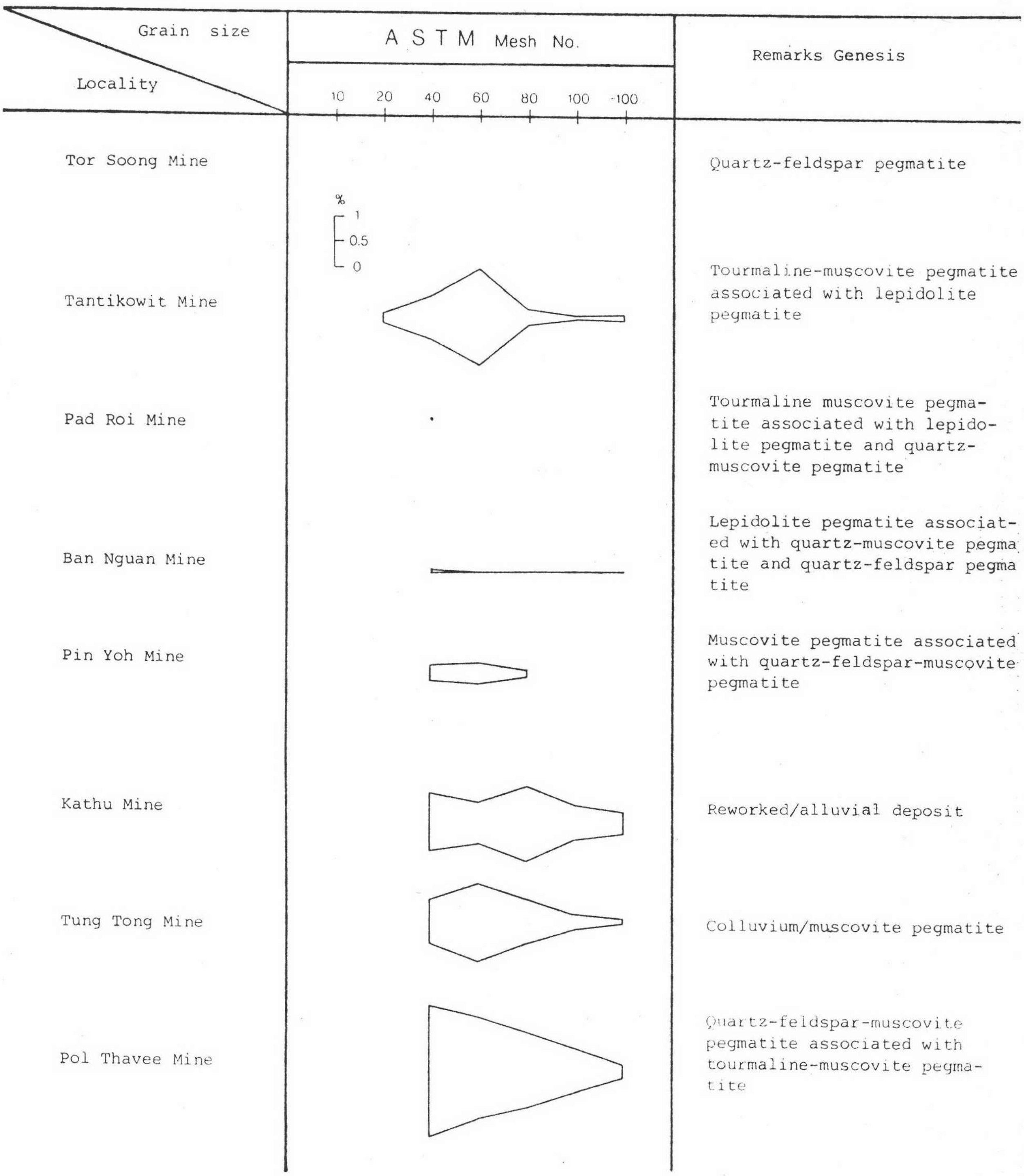


Figure 4.4.5a Distribution pattern of ilmenite contents with respect to grain - size of samples obtained from tin-mines within Kathu Valley.

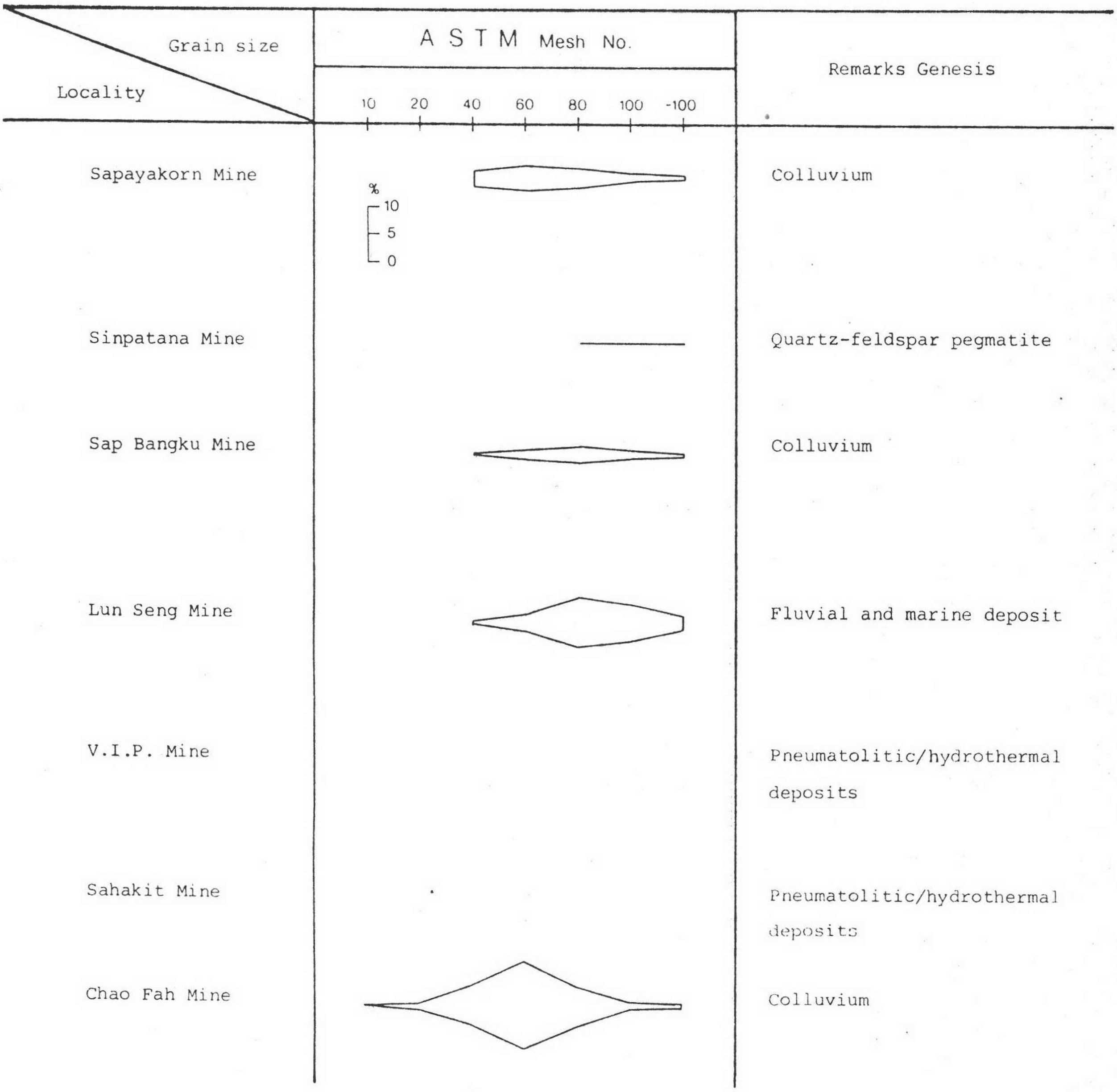


Figure 4.4. 5b Distribution pattern of ilmenite contents with respect to grain-size of samples obtained from tin-mines outside Kathu Valley.