

6. The geochemistry of the Lebowa Granite Suite.

6.1. Introduction.

A detailed geochemical study of the Nebo Granite and Klipkloof Granite was undertaken with the aim to determine the relationship between these rock types, to study the differentiation of the Nebo Granite magma, to compare the Lebowa Granite Suite of the study area with that of the Potgietersrust area and to investigate the geochemical specialization of the Klipkloof Granite with respect to mineralization.

6.2. Major element geochemistry.

The Nebo Granite, comprising a sheet-like body, is characterized by an upward increase in SiO_2 and K_2O with increasing D.I.; TiO_2 , Al_2O_3 , FeO , MnO , MgO , CaO and P_2O_5 decrease with increasing D.I., whilst Na_2O shows no variation. The Nebo Granite displays a fairly large differentiation trend, ranging from a D.I. of 84 to 95 (see Appendix 2 for major element analyses).

In contrast, the Klipkloof Granite evidently crystallized from a highly fractionated liquid and displays no differentiation trend. The different rock types, viz. porphyritic, medium- to coarse-grained, fine- to medium-grained and albitized granites, plot randomly in the vicinity of the most differentiated Nebo Granite.

The concentration of MgO is very low and only the very first differentiates of the Nebo Granite contain values of about 0,05 per cent. The MgO content decreases to below the lower limit of detection for the differentiated Nebo Granite and the Klipkloof Granite. The low concentration of MgO in the rocks is apparent from the ferromagnesian minerals, hornblende and biotite, which contain at the most only one per cent MgO (Appendix 1).

A large range in SiO_2 concentration, from 69 to 76 per cent, was found from bottom to top in the Nebo Granite sheet. The Klipkloof Granite ranges between 74 and 77 per cent SiO_2 (Fig.6.1).

TiO_2 was found to decrease from 0,4 to 0,1 per cent with differentiation in the Nebo Granite. Of interest here is the fact that the Klipkloof Granite does not plot exactly at the end of the Nebo Granite trend, as seen on the plot of TiO_2 against SiO_2 (Fig.6.2).

A well defined trend results for the Nebo Granite if Al_2O_3 is plotted against the D.I. (Fig.6.3). It is not understood why the analyses of the Klipkloof Granite do not conform to this trend. The Al_2O_3 values are generally higher than those of the corresponding Nebo Granite and only the medium- to coarse-grained Klipkloof Granite plot towards the end of the Nebo Granite trend.

The decrease in FeO from five to two per cent is ascribed to the increasingly leucocratic nature of the upper parts of the Nebo Granite sheet. The bulk of the Klipkloof Granite samples contain between two and three per cent FeO , with the exception of the albitized varieties, which contain between one and two per cent.

The CaO content changes from 0,4 to 1,5 per cent from top to bottom in the Nebo Granite sheet, because the anorthite content of early crystallizing plagioclase is higher at the base of the sheet. The high fluorite content of the differentiated Nebo Granite also contributes to the total CaO content. This is also the case with the Klipkloof Granite, which contains between 0,3 and 0,8 per cent CaO .

The amount of sodium (3,8 per cent Na_2O) in the Nebo Granite stays constant with changing D.I. The majority of Klipkloof Granites plot towards the end of the differentiation trend (this plot is not presented here), except for the

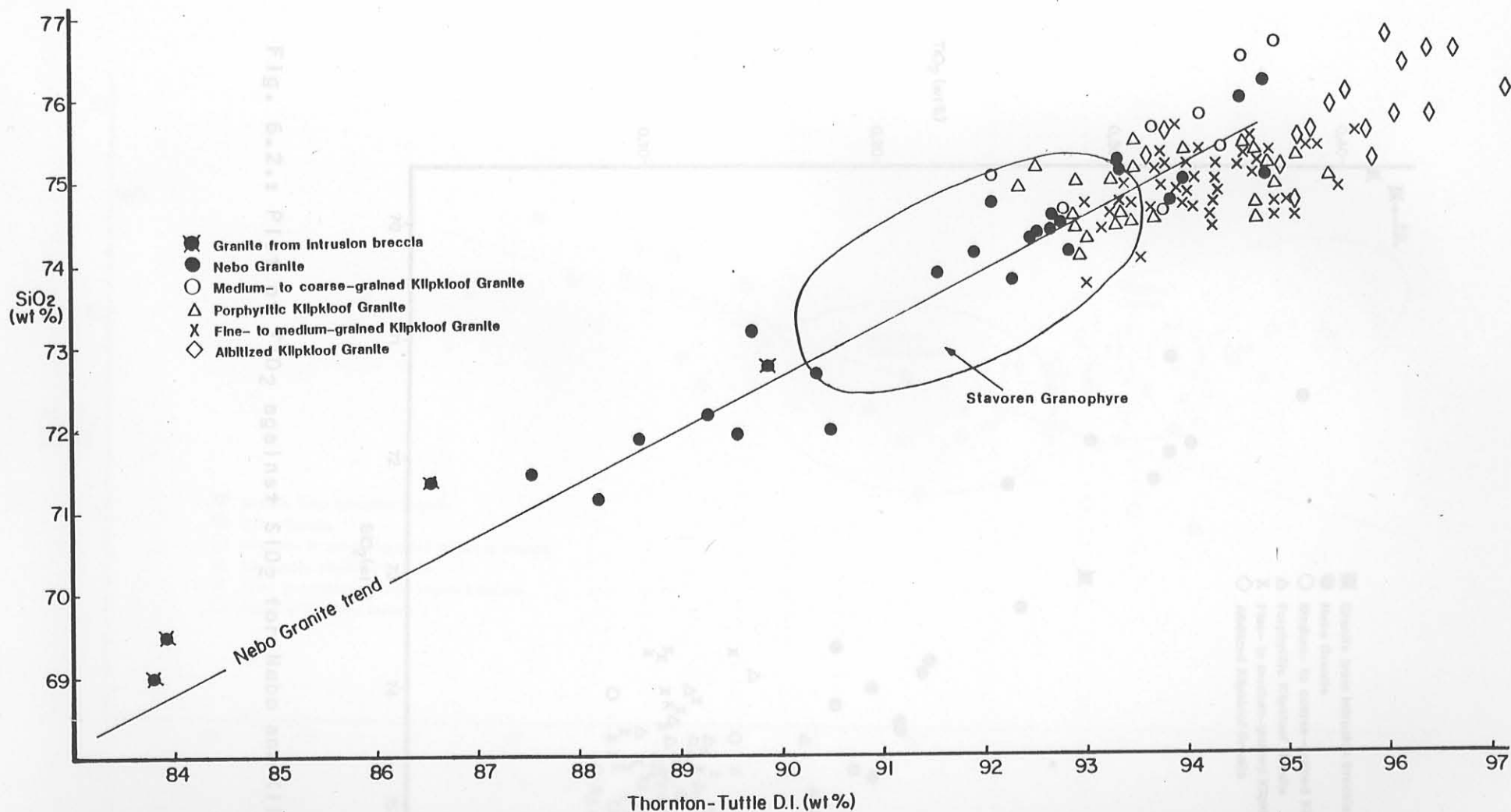


Fig. 6.1.: Plot of SiO₂ against the Thornton-Tuttle D.I. for Nebo and Klipkloof Granite. The field for Stavoren Granophyre is also indicated.

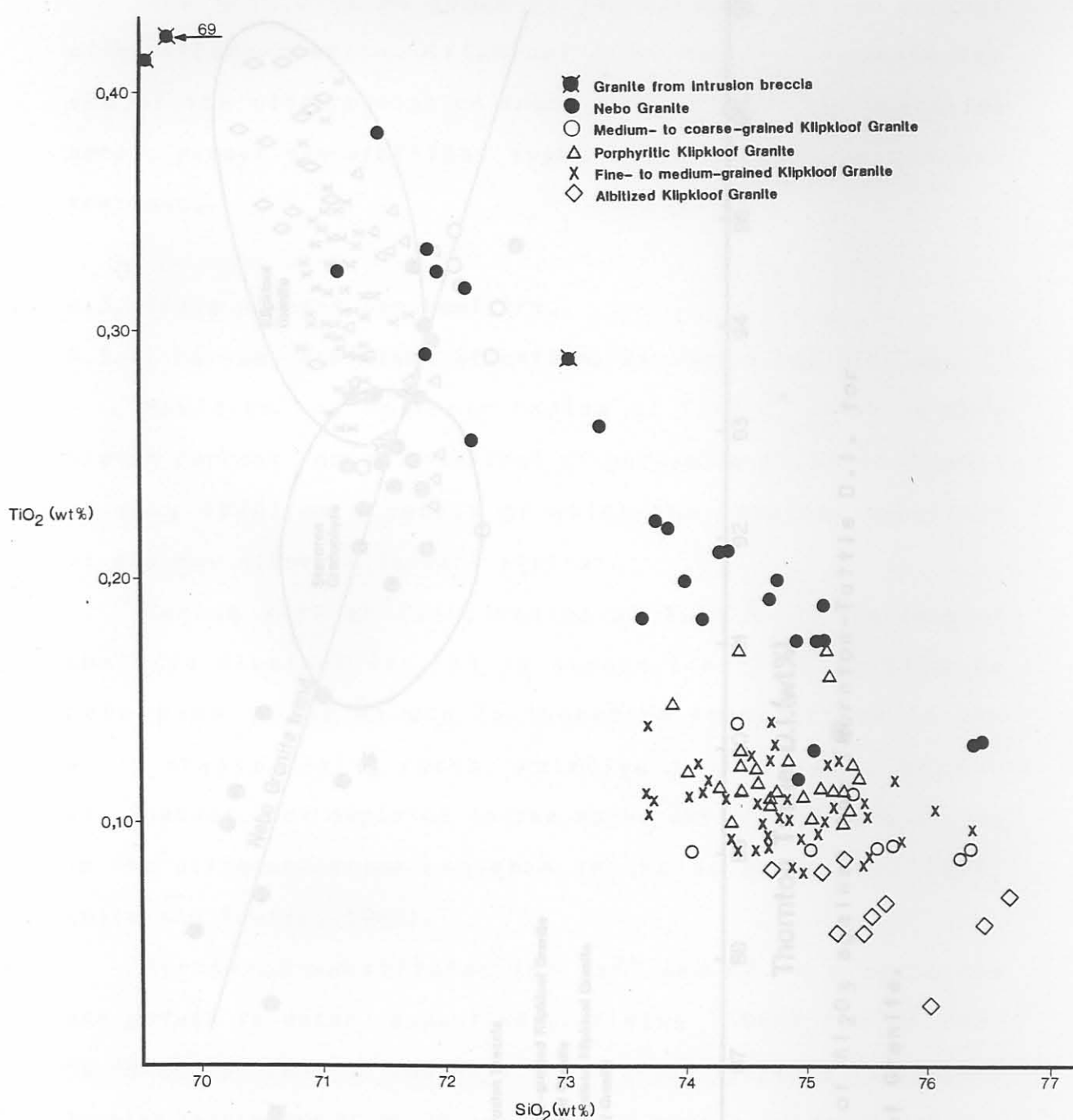


Fig. 6.2.: Plot of TiO_2 against SiO_2 for Nebo and Klipkloof Granite.

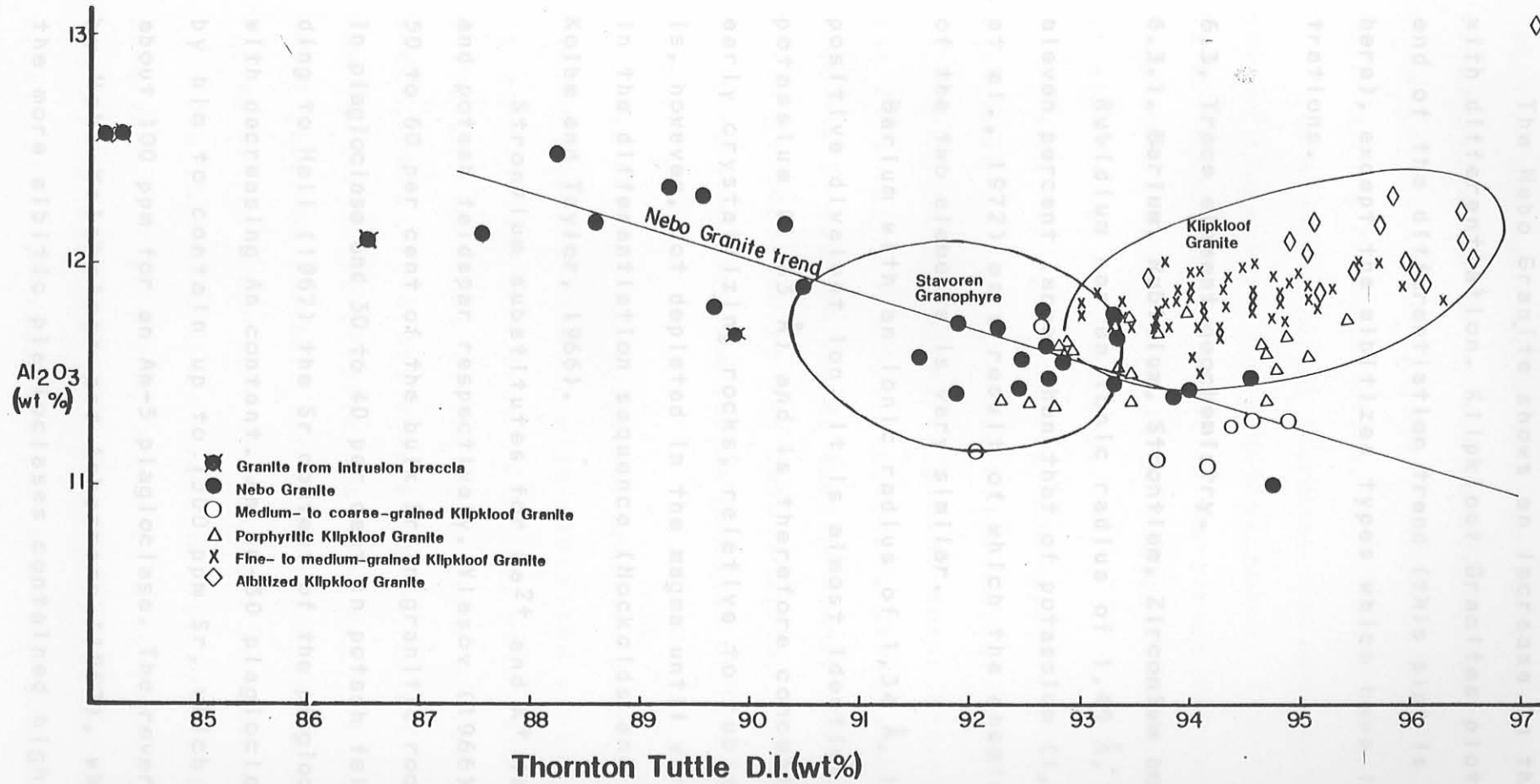


Fig. 6.3.: Plot of Al_2O_3 against the Thornton-Tuttle D.I. for Nebo and Klipkloof Granite.

albitized varieties, which have much higher values due to the large amount of albite in the rock.

The Nebo Granite shows an increase in the K_2O content with differentiation. Klipkloof Granites plot towards the end of the differentiation trend (this plot is not presented here), except the albitized types which have lower concentrations.

6.3. Trace element geochemistry.

6.3.1. Barium, Rubidium, Strontium, Zirconium and Niobium.

Rubidium has an ionic radius of $1,49 \text{ \AA}$, which is only eleven percent larger than that of potassium ($1,33 \text{ \AA}$) (Cocco et al., 1972) as a result of which the chemical behaviour of the two elements is very similar.

Barium with an ionic radius of $1,34 \text{ \AA}$, is the largest positive divalent ion. It is almost identical in size to potassium ($1,33 \text{ \AA}$) and is therefore concentrated in the early crystallizing rocks, relative to rubidium. Barium is, however, not depleted in the magma until very late stages in the differentiation sequence (Nockolds and Allen, 1953; Kolbe and Taylor, 1966).

Strontium substitutes for Ca^{2+} and K^+ in plagioclase and potash feldspar respectively. Vlasov (1966) claims that 50 to 60 per cent of the bulk Sr in granitic rocks is present in plagioclase and 30 to 40 per cent in potash feldspar. According to Hall (1967) the Sr content of the plagioclase decreases with decreasing An content. An An-30 plagioclase was shown by him to contain up to 1500 ppm Sr, which decreases to about 100 ppm for an An-5 plagioclase. The reverse was noted by Hahn-Weinheimer and Ackermann (1967), who found that the more albitic plagioclases contained higher Sr values than the earlier plagioclases.

The average granite contains 175 ppm Zr (Degenhardt,

1957), which is far below the concentration found in the Lebowa Granite Suite. Zirconium may either increase (Kolbe, 1966) or decrease during differentiation of a granitic magma. Crystallization of zircon is suppressed if the magma is peralkaline (Watson, 1979), which results in an increase of Zr during differentiation.

The abundance of Nb increases from early to later intrusive phases (Mogarovskiy and Mel'nichenko, 1968), because it is an incompatible element in the common rock-forming minerals. Niobium may also serve as an indicator of mineralization, if high values are recorded.

If Ba, Rb and Sr values (see Appendix 3 for trace element analyses) of the Nebo and Klipkloof Granite are plotted on the ternary diagram (Fig.6.4) described by El Bouseily and El Sokkary (1975), a complete differentiation trend from the Ba apex to the Rb apex is found. The "normal granite" field is occupied by the Nebo Granite, which in turn can be correlated with the low-Ca granites of Turekian and Wedepohl (1961).

The bulk of the Klipkloof Granites plot in the "differentiated granite" field, with albitized varieties near the Rb apex. Klipkloof Granite sills, which are developed at different horizons in the upper part of the Nebo Granite sheet, have different compositions. The sill which occupies the lowest stratigraphic position has the lowest Rb and the highest Ba content. Sills therefore become more differentiated as the upper part of the sheet is approached.

The characteristic trend of the Nebo Granite is also developed in Figure 6.5, where data of Lenthall and Hunter (1977) is used to define the granites of the Zaaipplaats area. Point "B" represents a starting composition of 40 ppm Sr and 240 ppm Rb and the line "pure solid composition" represents the compositions of solids formed during perfect

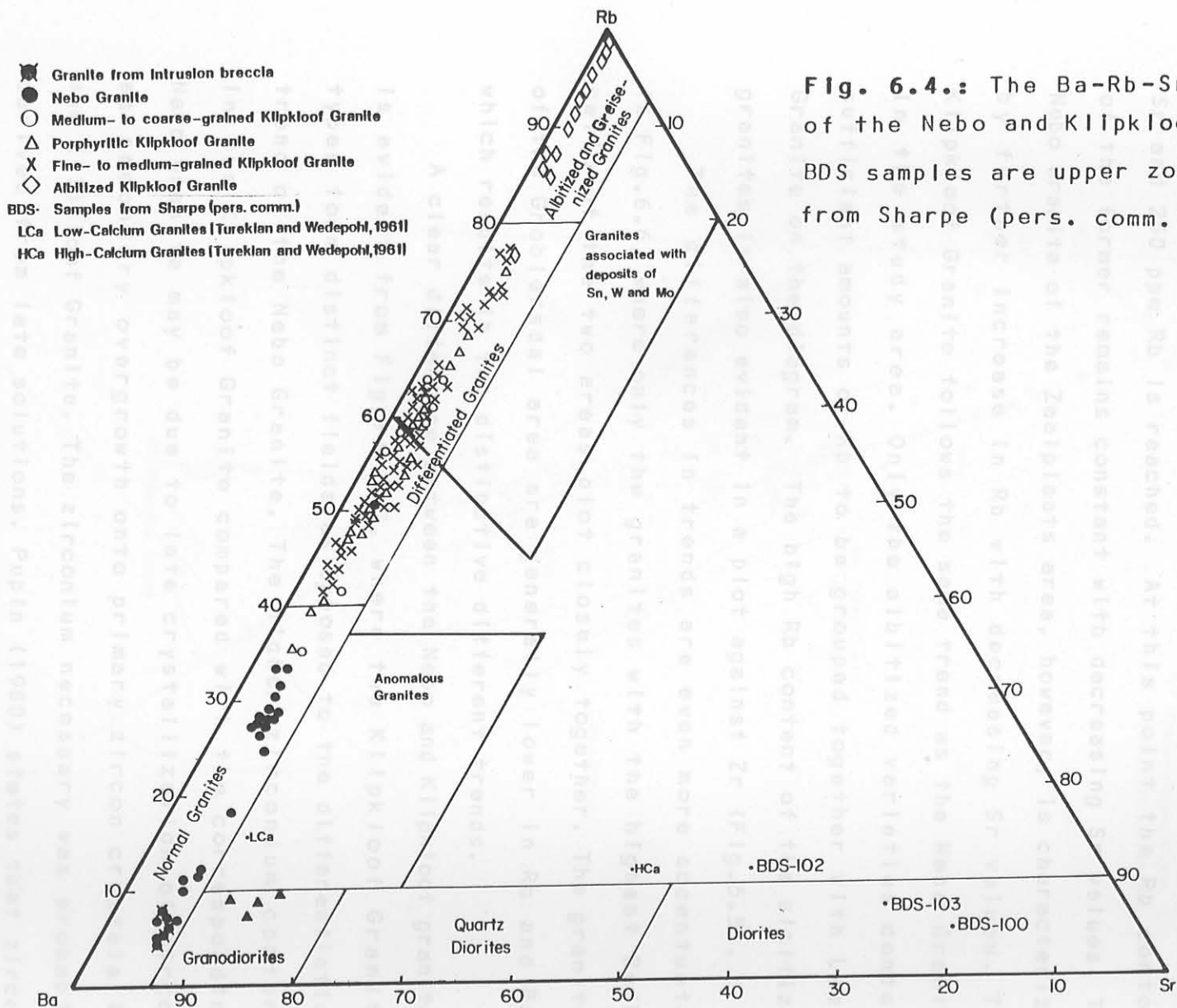


Fig. 6.4.: The Ba-Rb-Sr distribution of the Nebo and Klipkloof Granite. BDS samples are upper zone diorites from Sharpe (pers. comm.).

fractional crystallization of melt "B". The line "melt composition" connects the compositions of the equilibrium melts.

From Figure 6.5 it is evident that the Nebo Granite of the study area follows the same trend as its counterpart from the Zaaiplaats area, until a concentration of 30 ppm Sr and 250 ppm Rb is reached. At this point the Rb content of the former remains constant with decreasing Sr values. The Nebo Granite of the Zaaiplaats area, however, is characterized by further increase in Rb with decreasing Sr values. The Klipkloof Granite follows the same trend as the Nebo Granite in the study area. Only the albitized varieties contain sufficient amounts of Rb to be grouped together with Lease Granite on the diagram. The high Rb content of the albitized granites is also evident in a plot against Zr (Fig. 5.5).

The differences in trends are even more accentuated in Fig. 6.6, where only the granites with the highest Ba/Rb ratio of the two areas plot closely together. The granites of the Groblersdal area are generally lower in Rb and Ba, which results in two distinctive different trends.

A clear difference between the Nebo and Klipkloof granites is evident from Figure 6.7, where the Klipkloof Granite types form distinct fields as opposed to the differentiation trend of the Nebo Granite. The higher zirconium content in the Klipkloof Granite compared with the corresponding Nebo Granite may be due to late crystallization of zircon as secondary overgrowth onto primary zircon crystals in the Klipkloof Granite. The zirconium necessary was probably derived from late solutions. Pupin (1980) states that zircon growth is possible in the hydrothermal stage.

The Nb concentration of the Nebo Granite remains constant with differentiation as opposed to the Klipkloof Granite, which shows some enrichment, with values of up to 85 ppm (Appendix 3).

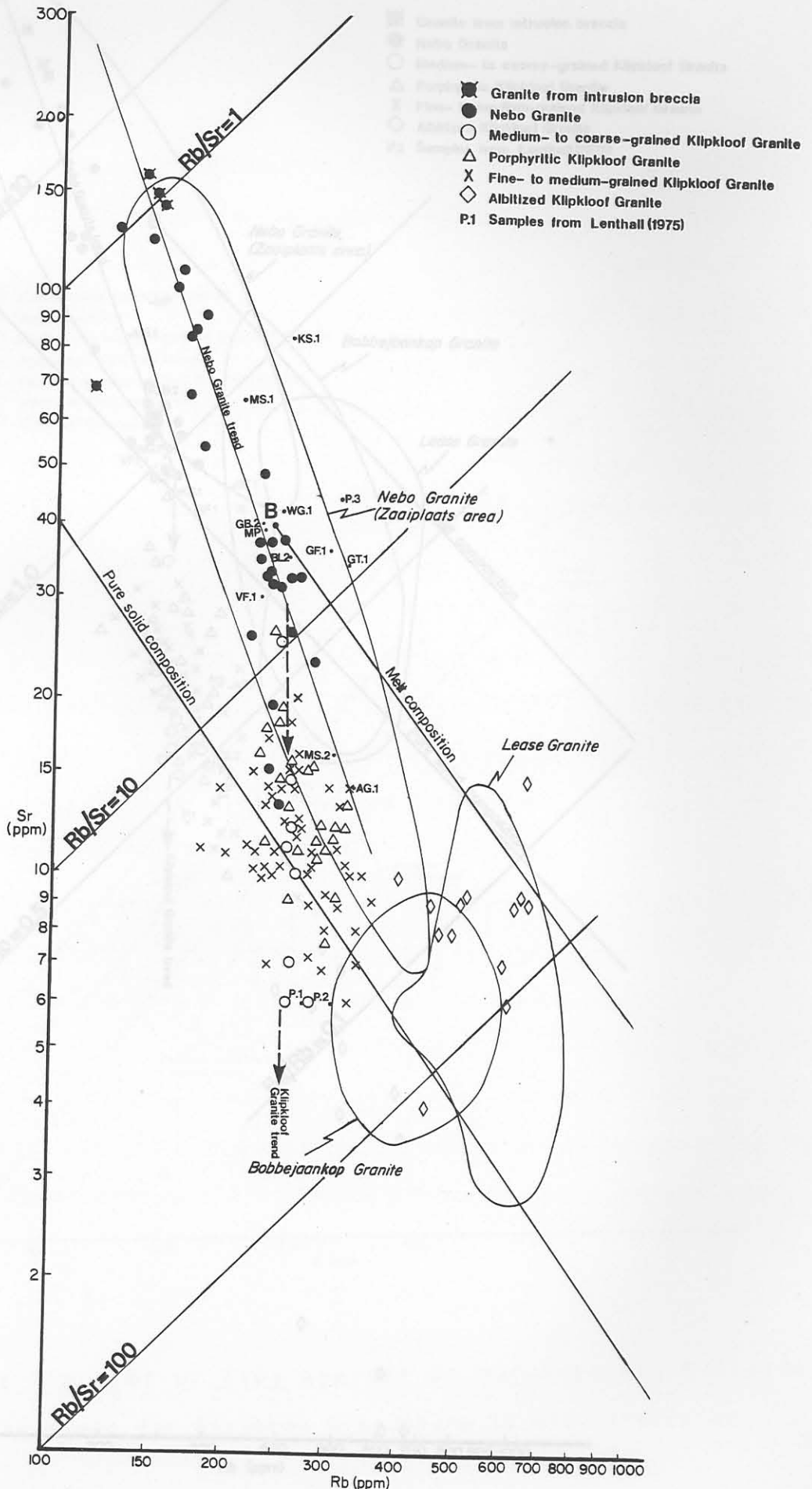


Fig. 6.6.: A log-log plot of Sr against Rb for Nebo and Klipkloof Granite.

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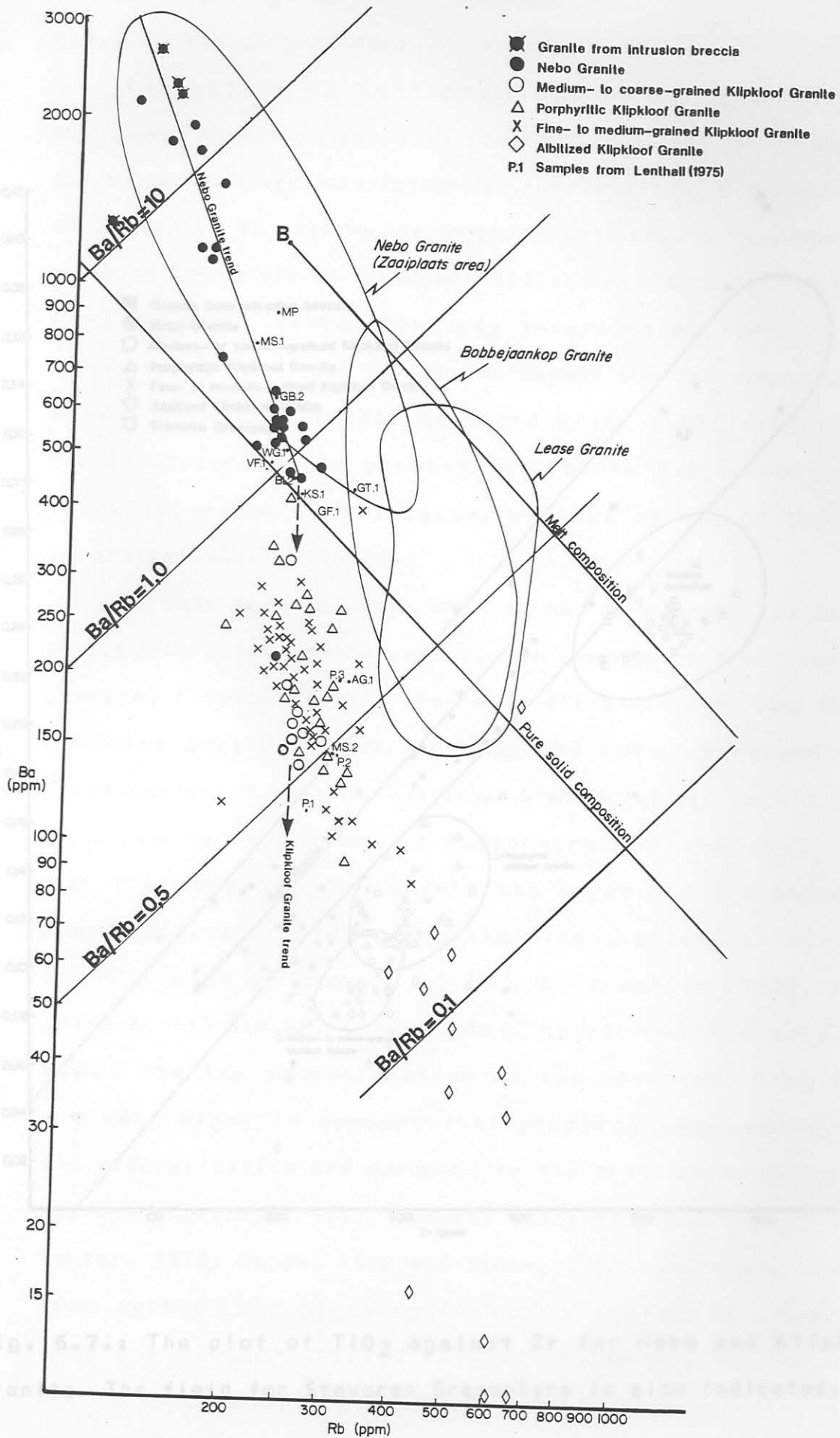


Fig. 6.7.: The plot of TiO_2 against Zr for Nebo and Klipkloof Granite. The field for S-type granites is also indicated.

Fig. 6.6.: A log-log plot of Ba against Rb for Nebo and Klipkloof Granite.

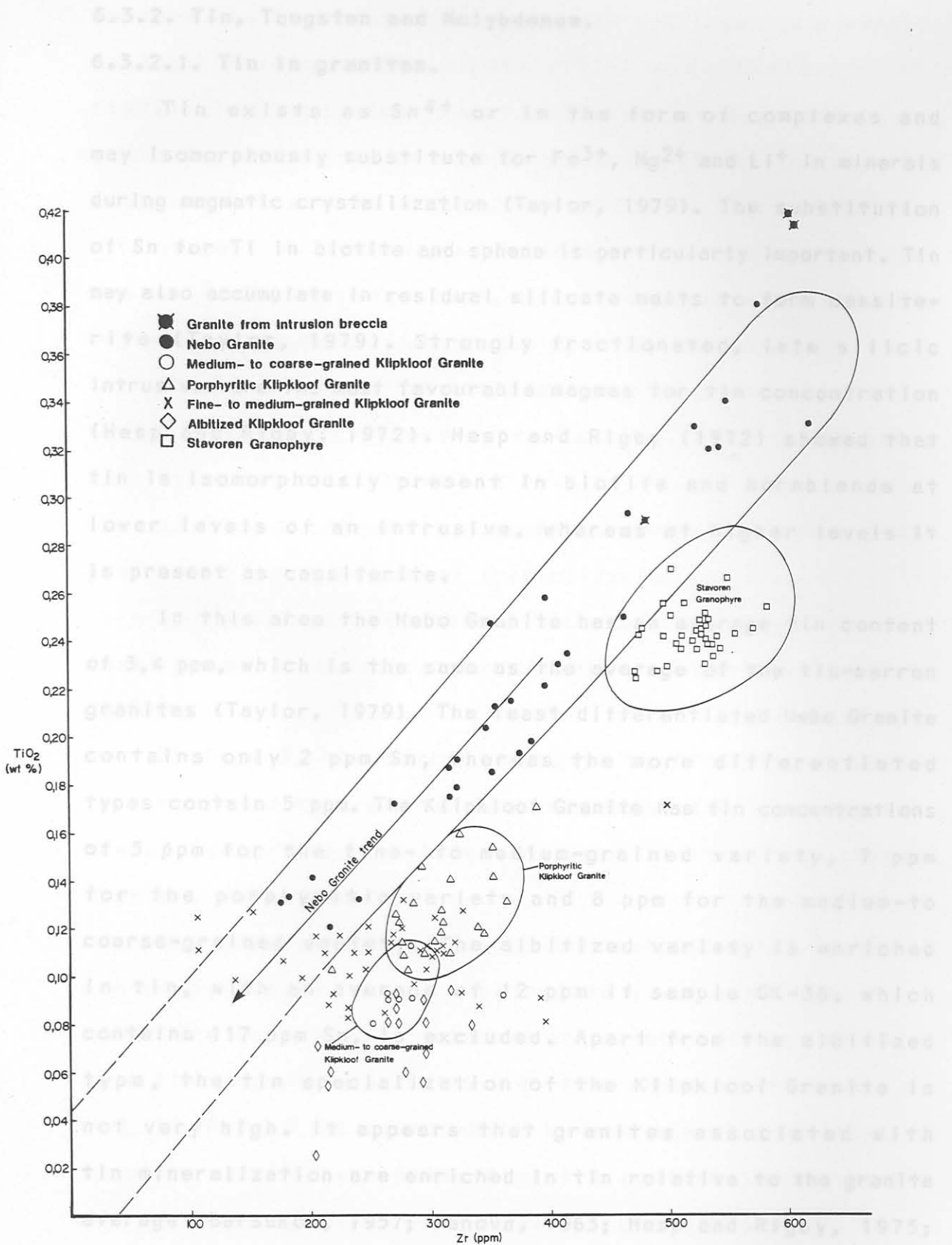


Fig. 6.7.: The plot of TiO_2 against Zr for Nebo and Klipkloof Granite. The field for Stavoren Granophyre is also indicated.

6.3.2. Tin, Tungsten and Molybdenum.

6.3.2.1. Tin in granites.

Tin exists as Sn^{4+} or in the form of complexes and may isomorphously substitute for Fe^{3+} , Mg^{2+} and Li^+ in minerals during magmatic crystallization (Taylor, 1979). The substitution of Sn for Ti in biotite and sphene is particularly important. Tin may also accumulate in residual silicate melts to form cassiterite (Taylor, 1979). Strongly fractionated, late silicic intrusives are the most favourable magmas for tin concentration (Hesp and Rigby, 1972). Hesp and Rigby (1972) showed that tin is isomorphously present in biotite and hornblende at lower levels of an intrusive, whereas at higher levels it is present as cassiterite.

In this area the Nebo Granite has an average tin content of 3,4 ppm, which is the same as the average of the tin-barren granites (Taylor, 1979). The least differentiated Nebo Granite contains only 2 ppm Sn, whereas the more differentiated types contain 5 ppm. The Klipkloof Granite has tin concentrations of 5 ppm for the fine- to medium-grained variety, 7 ppm for the porphyritic variety and 8 ppm for the medium- to coarse-grained variety. The albitized variety is enriched in tin, with an average of 12 ppm if sample GK-36, which contains 117 ppm Sn, is excluded. Apart from the albitized type, the tin specialization of the Klipkloof Granite is not very high. It appears that granites associated with tin mineralization are enriched in tin relative to the granite average (Barsukov, 1957; Janova, 1963; Hesp and Rigby, 1975; Taylor, 1979; Olade, 1980 and Stone, 1982). There are, however, some authors who argue against this statement (Hosking, 1968 and Flinter, 1971). Taylor (1979) states that there are very few examples of highly specialized granitoids which are not directly or indirectly associated with tin deposits. Hosking (1968), however, claims that there is no connection

between the tin content of a granite and possible mineralization. Flinter (1971), Hesp (1971) and Flinter et al. (1972) also state that the tin content of a granitoid has no bearing on the presence of mineralization. There is therefore a possibility that a granitoid which is not specialized with respect to tin can contain economic tin mineralization. Hunter (1973) states that, under favourable conditions, any granite is capable of producing a tin deposit.

Different types of tin distribution and concentration mechanisms exist. According to Taylor (1979, p 102) five such types may be defined:

1) The differentiation type, where the later phase granitoids show geochemical specialization for tin.

2) Type 2 occurs where tin content commences at a high level in more basic granitoids and then declines in acid rocks.

3) Type 3, the barren type, is typified by a decline in tin content towards the more acid members of an intrusive, where none of the granitoids are associated with tin concentration.

4) A complexity in trace element concentration is represented by Type 4, where a batholith has some intrusives which are specialized, whereas others are barren, but still have tin deposits associated with them (Hosking, 1968).

5) Type 5 is represented by the tin distribution in alkaline massifs, where the high tin content is due to the tin holding capacity of the alkaline rich minerals.

The tin specialization of a granitoid may be tested in many different ways, which include geochemical, mineralogical and petrological methods. According to Van de Pijpekamp (1982) the only tool necessary to establish the tin potential of a granitoid is the petrographic microscope. Later detailed geochemical surveys are performed on selected target areas. He

used the alteration of the rock to arrive at the "petrographical score", which is the sum of the different observations including texture, structure and newly formed minerals. A high petrographical score would therefore indicate the possible tin potential of a granitoid.

Following Van de Pijpekamp (1982), the Klipkloof Granite, especially the albitized variety, has a high petrographic score, because it contains newly formed minerals like chlorite, inclusions of fluorite in biotite and albitized perthite grains.

Flinter et al. (1972) used the Thornton-Tuttle D.I., the colour index (C.I) and the petrological index (P.I.) to identify a possible tin specialized granite. The color index represents the sum of the hornblende and biotite in the sample. The petrological index uses the initial letter of each of the granite constituents, viz. biotite and hornblende. If, for instance, the granite contains accessory biotite (<4 percent), it is a bxxx type. If it contains essential hornblende and accessory biotite, it is a Hbxxx type. Tin mineralization occurs in granitic rocks with D.I. > 85 and P.I. < 4 and a low color index.

Using major element data (D.I. and ternary diagrams) and petrographical data (C.I., petrographical score and P.I.) it appears that the Klipkloof Granite and the differentiated parts of the Nebo Granite may be specialized with respect to tin.

Sattran and Klominsky (1970), Hesp and Rigby (1974), Smith and Turek (1976) and Biste (1979) used the Köhler-Raaz indices (Köhler and Raaz, 1951) to investigate the tin specialization of a granite. According to these authors a tin-granite has Köhler-Raaz indices of $+qz = 60$ to 70 , $F = 20$ to 30 and $fm = 5$ to 15 , where $+qz$ is free Si occurring as quartz, F is Na, K and Ca content in feldspars and fm is femic cations

and Ca in micas, pyroxenes and amphiboles. For the calculation of the indices, see Köhler and Raaz (1951) and Hesp and Rigby (1974).

If the Nebo and Klipkloof Granite are plotted on the diagram of Köhler and Raaz (1951) (Fig.6.8), it is evident that the Klipkloof Granite and the differentiated Nebo Granite qualify as tin granites.

Juniper and Kleeman (1979) found that Sn-mineralizing granites form compact groups, distinct from granites not associated with mineralization, when plotted on the ternary diagrams of $\text{SiO}_2 - \text{CaO} + \text{MgO} + \text{FeO} - \text{Na}_2\text{O} + \text{K}_2\text{O} + \text{Al}_2\text{O}_3$, $\text{Na} + \text{K} - \text{Fe} - \text{Mg}$, and $\text{Ca} - \text{Na} - \text{K}$. The field of U-mineralizing granites was introduced by Wilson and Akerblom (1982). It is evident from Figure 6.9, 6.10 and 6.11 that the granites of the Groblersdal area overlap with the fields of U- and Sn-mineralizing granites, with the exception of the least differentiated Nebo Granite.

According to several authors (Stemprok, 1970; Tauson and Kozlov, 1973; Smith and Turek, 1976; Haapala, 1977; Tischendorf, 1977; Taylor, 1979; Biste, 1979; Olade, 1980 and Yeates et al. 1982), tin-granites usually contain anomalous amounts of the trace elements Sn, F, Cl, Li, B, Rb, Nb, Th, U, REE and Cs, and are depleted in Ba, Sr and Zr. The U and Th concentrations in Klipkloof Granite are about three to four times higher than the granite average of Yeates et al. (1982), who found values of 4, 8 and 17 ppm U and Th respectively to be typical. According to Yeates et al. (1982) high U (greater than 8 ppm) and Th values are normally accompanied by high Sn concentrations and mineralization may be present.

Fig. 6.8.: The Ba/Rb ratio has been recommended as the best indicator of mineralization (Tauson and Kozlov, 1973). The ratio is up to 80 times lower in ore bearing granites compared to the barren granites. Because of the low Ba content of albitized

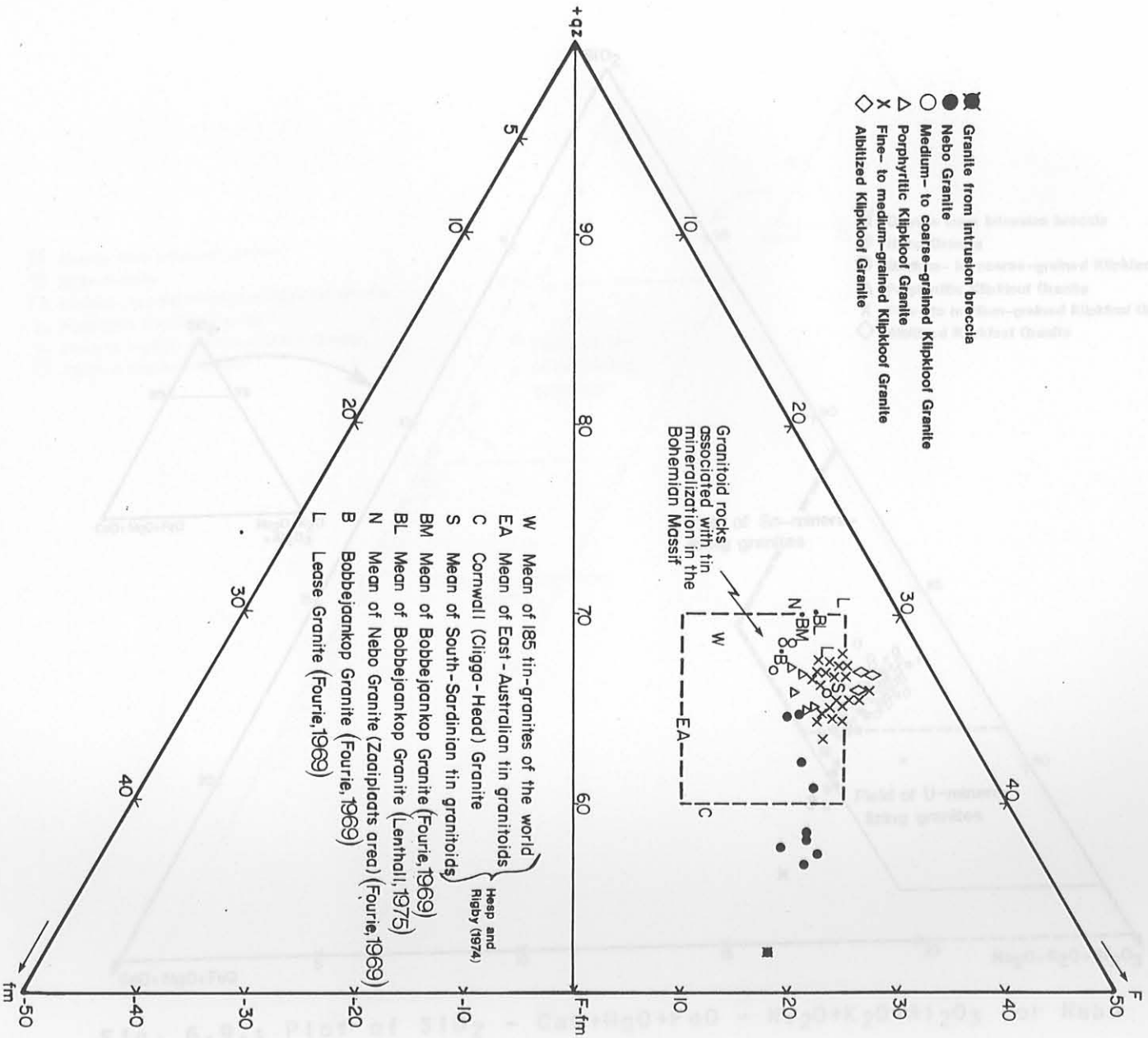


Fig. 6.8.: The Köhler-Raaz diagram indicating the tin specialization of the Bushveld granites.

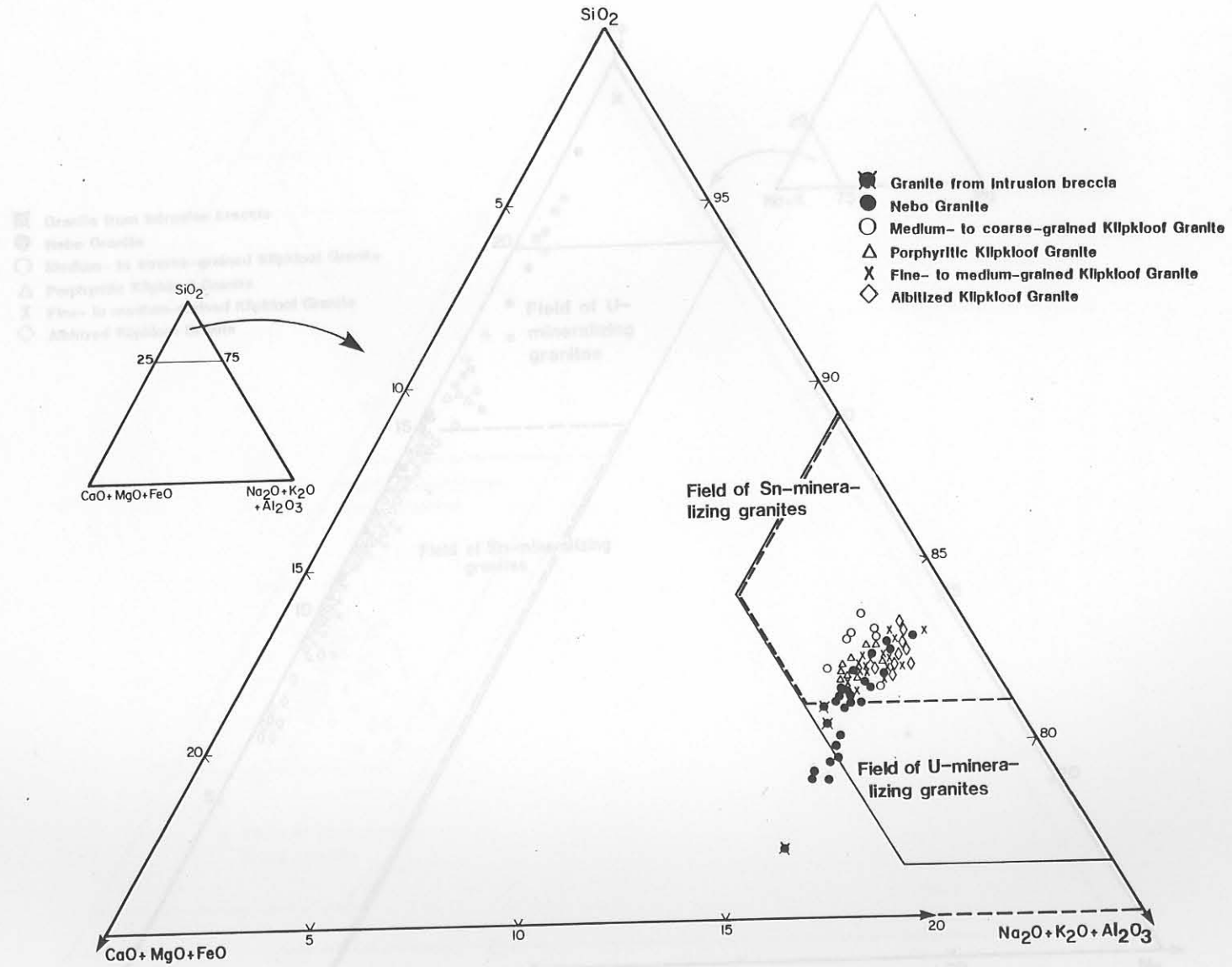


Fig. 6.9.: Plot of $SiO_2 - CaO + MgO + FeO - Na_2O + K_2O + Al_2O_3$ for Nebo and Klipkloof Granite.

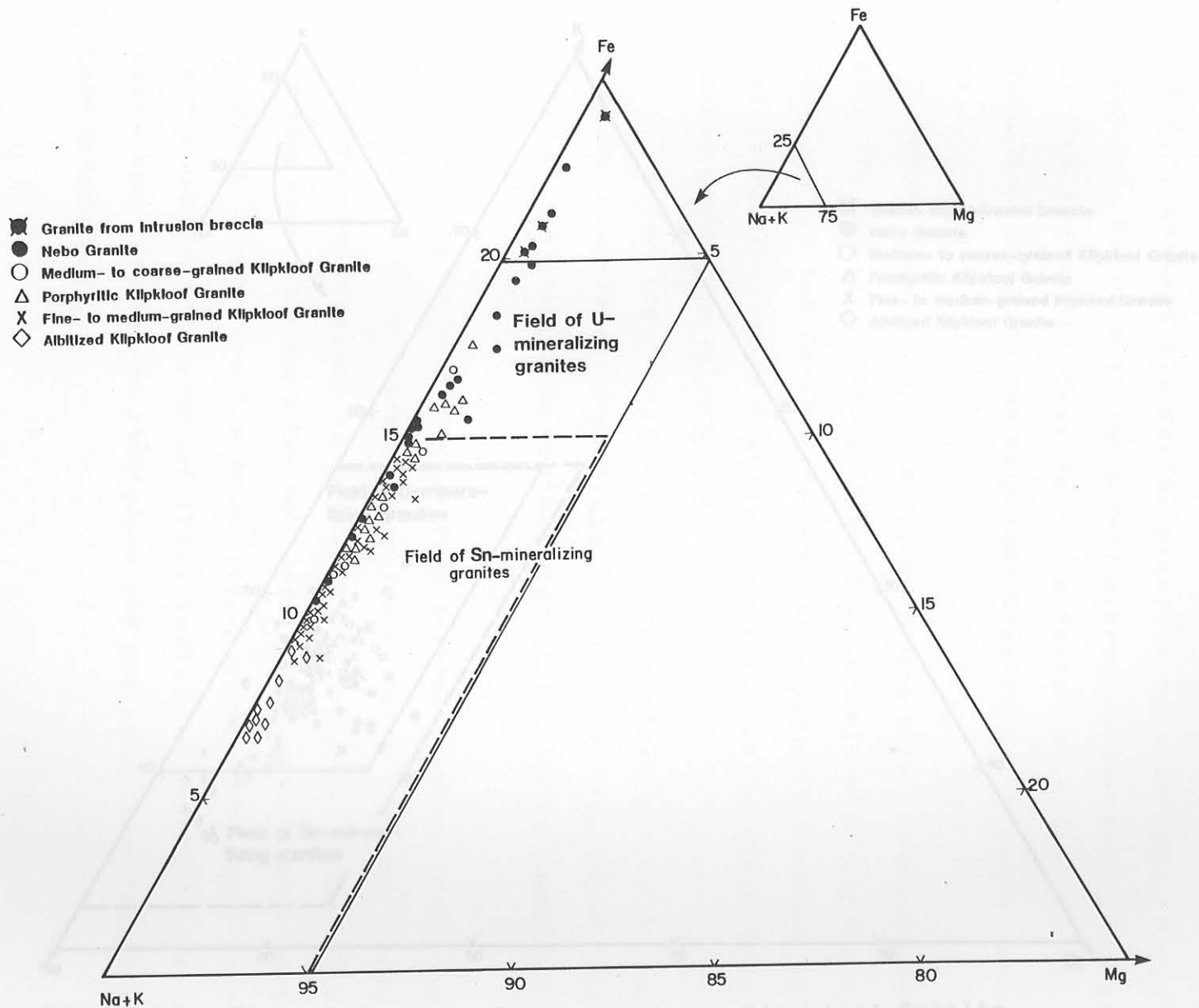


Fig. 6.10.: Plot of Fe - Na+K - Mg for Nebo and Klipkloof Granite.

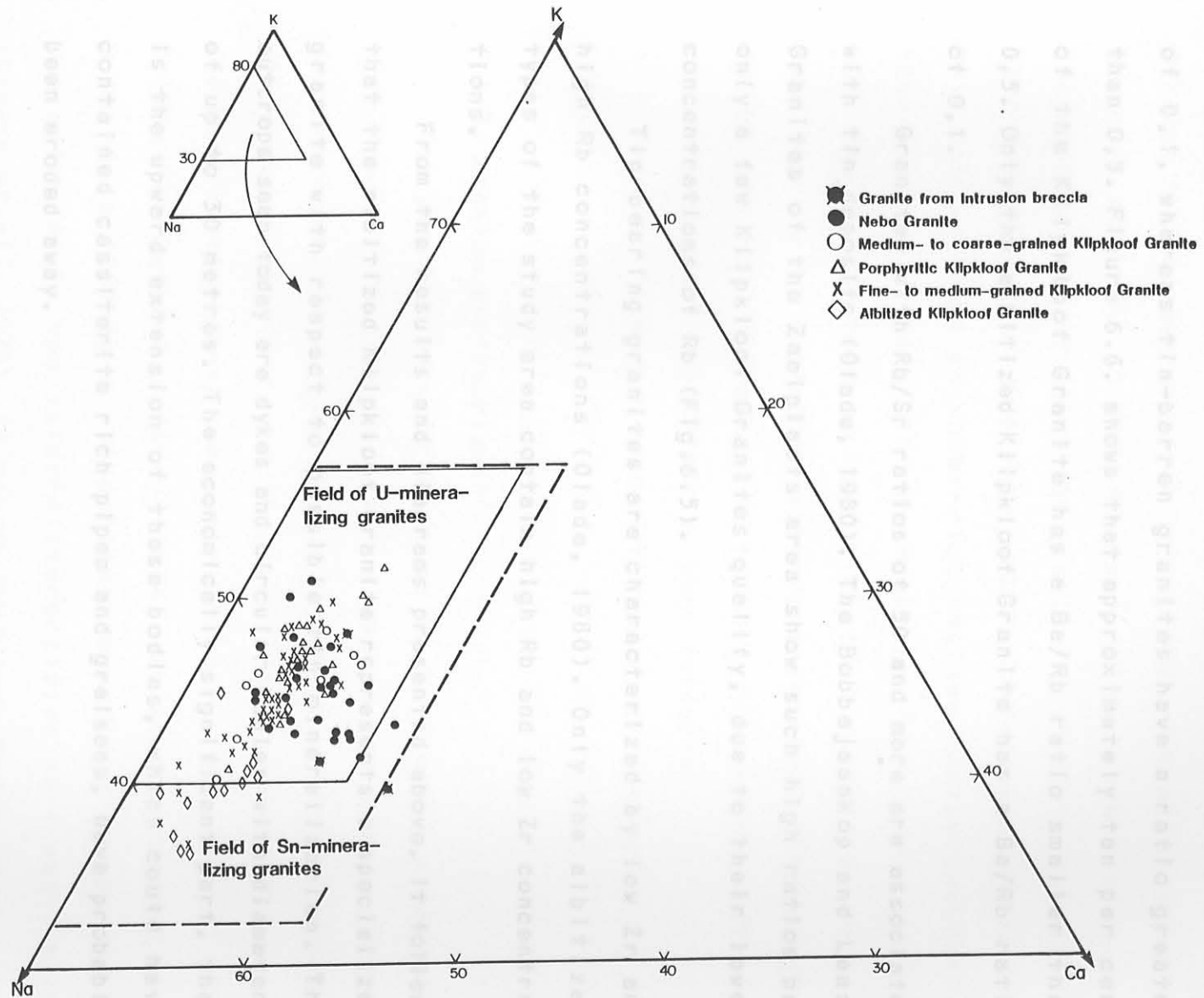


Fig. 6.11.: Plot of K - Na - Ca for Nebo and Klipkloof Granite.

and fine- to medium-grained Klipkloof Granite, the ratio is about 100 times lower than those of undifferentiated Nebo Granite. According to Olade (1980), tin-bearing granites of Nigeria (Jos Bukuru and Rob complexes) have a Ba/Rb ratio of 0,1, whereas tin-barren granites have a ratio greater than 0,5. Figure 6.6. shows that approximately ten per cent of the Klipkloof Granite has a Ba/Rb ratio smaller than 0,5. Only the albitized Klipkloof Granite has a Ba/Rb ratio of 0,1. Granites with Rb/Sr ratios of 50 and more are associated with tin deposits (Olade, 1980). The Bobbejaankop and Lease Granites of the Zaaipplaats area show such high ratios but only a few Klipkloof Granites qualify, due to their lower concentrations of Rb (Fig.6.5).

Tin-bearing granites are characterized by low Zr and high Rb concentrations (Olade, 1980). Only the albitized types of the study area contain high Rb and low Zr concentrations.

From the results and diagrams presented above, it follows that the albitized Klipkloof Granite represents a specialized granite with respect to possible tin mineralization. The outcrops seen today are dykes and circular bodies with diameters of up to 30 metres. The economically significant part, that is the upward extension of these bodies, which could have contained cassiterite rich pipes and greisens, have probably been eroded away.

6.3.2.2. Molybdenum and Tungsten.

The chemistry of Mo and W is similar. There is, however, a difference in geochemical behaviour of the two elements, as Mo, like Cu, is strongly chalcophile (Kuroda and Sandell, 1954). This behaviour accounts for flakes of molybdenite present in many samples of Klipkloof and differentiated

Nebo Granite.

Tungsten is only found in pegmatites or high-temperature quartz veins and seldom occurs in the granite itself (Wedepohl, 1969, 74-F-2). Ivanova (1969) noted in his work in eastern Siberia that normal granites in regions of W mineralization are not enriched in this element. High concentrations of tungsten only occur where the granite is directly associated with a W deposit. Wedepohl (1969, 74-F-1) postulates that W is concentrated in water-rich residual solutions rather than in crystallizing silicate minerals.

The Mo content of the Klipkloof and differentiated Nebo Granite is sporadic, with some samples containing up to 30 ppm Mo. The molybdenite occurrences are indicated on the geological map (Plate 1, back folder).

No significant W concentrations were recorded in the area.

6.3.3. Uranium and Thorium.

The geochemistry of uranium is intimately associated with that of thorium and both elements are stable in the 4+ valences. There is also a close relationship between the crystal chemistry of thorium, uranium and zirconium and many isostructural compounds are known, e.g.

$ZrSiO_4$ - $ThSiO_4$ - $USiO_4$ (Bayer, 1974). In the tetravalent form U is classified as a lithophile element and tends to be concentrated in the later differentiates of igneous melts (Rogers et al., 1978). It may be oxidized to the hexavalent state as the complex uranyl ion UO_2^{2+} which generally permits more extensive separation into fluid and volatile phases. This is not true in the case of Th, which cannot exist in the hexavalent state (Whitfield et al., 1959). The hexavalent U is more soluble than tetravalent Th, which explains the more rapid loss of U than Th in weathered surface samples.

The general increase of U and Th with differentiation is explained by their large size and high ionic charge, which prevents their entry into lattices of common rock-forming minerals. The Th/U ratio can either increase (Whitfield et al., 1959; Rogers and Ragland, 1961) or decrease (Larsen and Gottfried, 1961) depending on redox conditions and volatile content (Pagel, 1982). Investigations by Heier et al. (1966) have shown high Th/U ratios of greater than four to be typical of granitic rocks and ratios below three to be rare. According to them the oxidation of U^{4+} to U^{6+} is prevented if magmatic crystallization occurs in a system that is closed with respect to oxygen, in which case the Th/U ratio would stay constant throughout the crystallization history of a magma and could even decrease in strongly differentiated rocks. Most granite crystallization, however, takes place under oxidizing conditions with loss of the vapour phase (Heier and Brooks, 1966). If, however, the volatile phase of the granitic rest magma is retained during crystallization, a constant Th/U ratio would result, which would decrease in the last differentiates (Heier and Brooks, 1966).

Uranium and thorium may occur in several mineralogical settings:

1) Primary and important U- and Th-bearing minerals, such as uraninite and thorite.

2) U and Th replacing other elements in common accessory minerals, such as monazite, allanite, zircon, sphene and apatite.

3) U- and Th-bearing minerals occurring as sub-microscopic inclusions in silicates and fluorite. U may occur as molecular or ionic disseminations, where it is not tightly held, because it can be extracted by weak acids in a short time (Larsen and Gottfried, 1961).

The uranium and thorium content of the Nebo Granite increases as the rocks become more differentiated in the upper part of the sheet (Fig.6.12). The Klipkloof Granite is characterized by high U and Th concentrations, compared to the granite average of 3,5 ppm U and 12 ppm Th.

The Th/U ratio of the Klipkloof Granite is generally lower than the ratio of the Nebo Granite (Fig.6.13). This is anomalous, because in most case studies of Th and U distribution in granites it has been found that the ratio increases in more differentiated rocks (Whitfield et al., 1959; Rogers and Ragland, 1961; Heier and Rogers, 1963; Rogers et al., 1978; Rye and Roy, 1978). This is considered to be due to a loss of U as a result of increasingly oxidising conditions during crystallization of the magma. In the form UO_2^{2+} , uranium is highly soluble and is normally lost with a volatile phase. Therefore the Th/U ratio increases as the melt evolves. The lower Th/U ratio of the Klipkloof Granite may be due to crystallization in a closed system and retention of the volatile phase. If this is the case, deposits of tin and copper together with the high U values should be present. Such deposits have not yet been found, except for the small molybdenite deposit on Varschwater 23JS and a pipe-like copper deposit in felsites, which may originate from the granites below, on Kwaggavoetpad 163JS.

According to Heier and Brooks (1966), abundance of tourmaline in highly differentiated granites is an indication that the magma retained its volatile phase. Tourmaline spheroids in the albitized granite may indicate the possibility of such a process.

Heier and Brooks (1966) concluded from their study of the Heemskirk Granite, West Tasmania, that the low Th/U ratio in highly differentiated rocks of a granite batholith is due to "immersion" of the highly differentiated granite

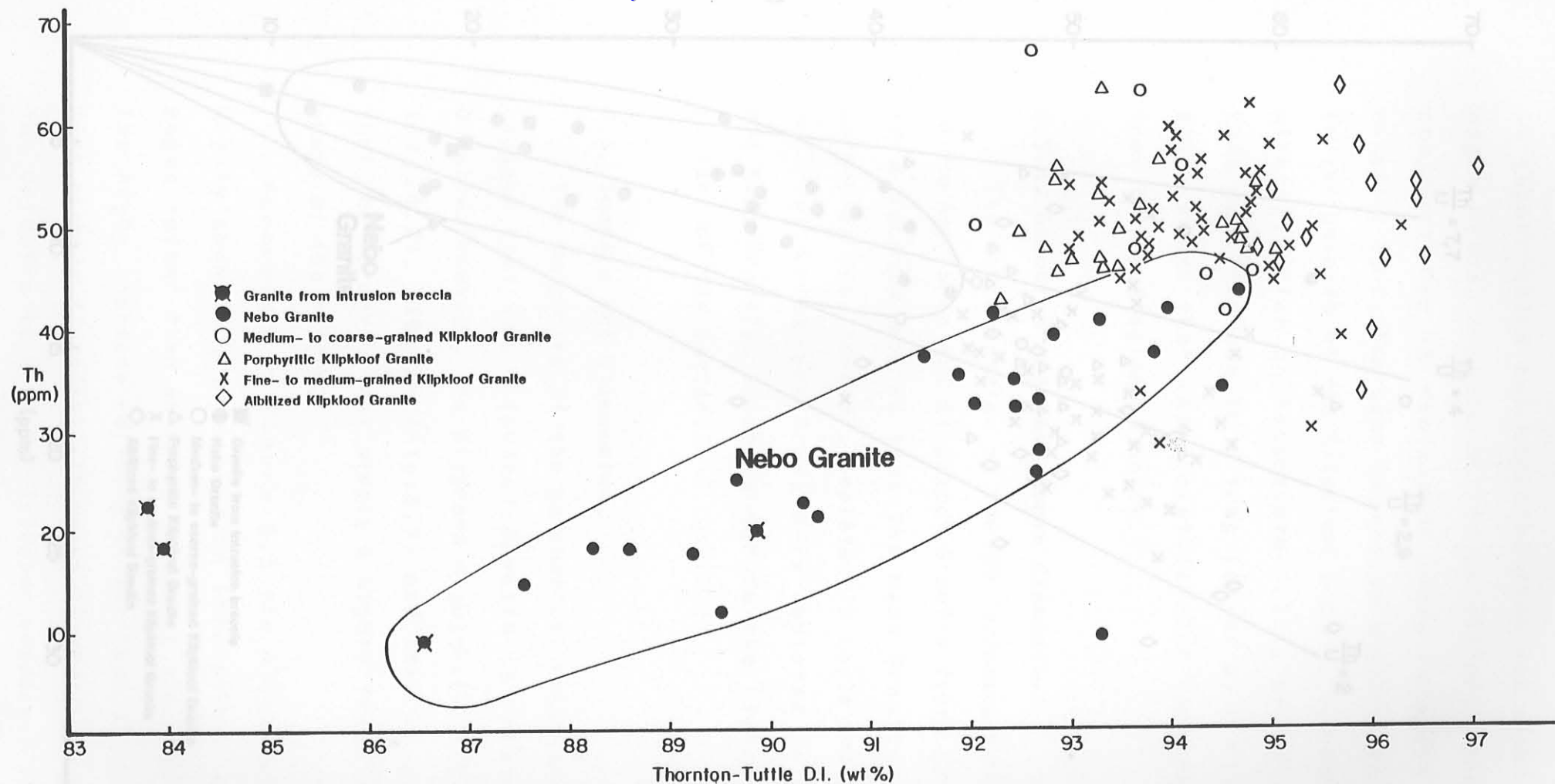


Fig. 6.12.: Plot of Th against the Thornton-Tuttle D.I. for Nebo and Klipkloof Granite.

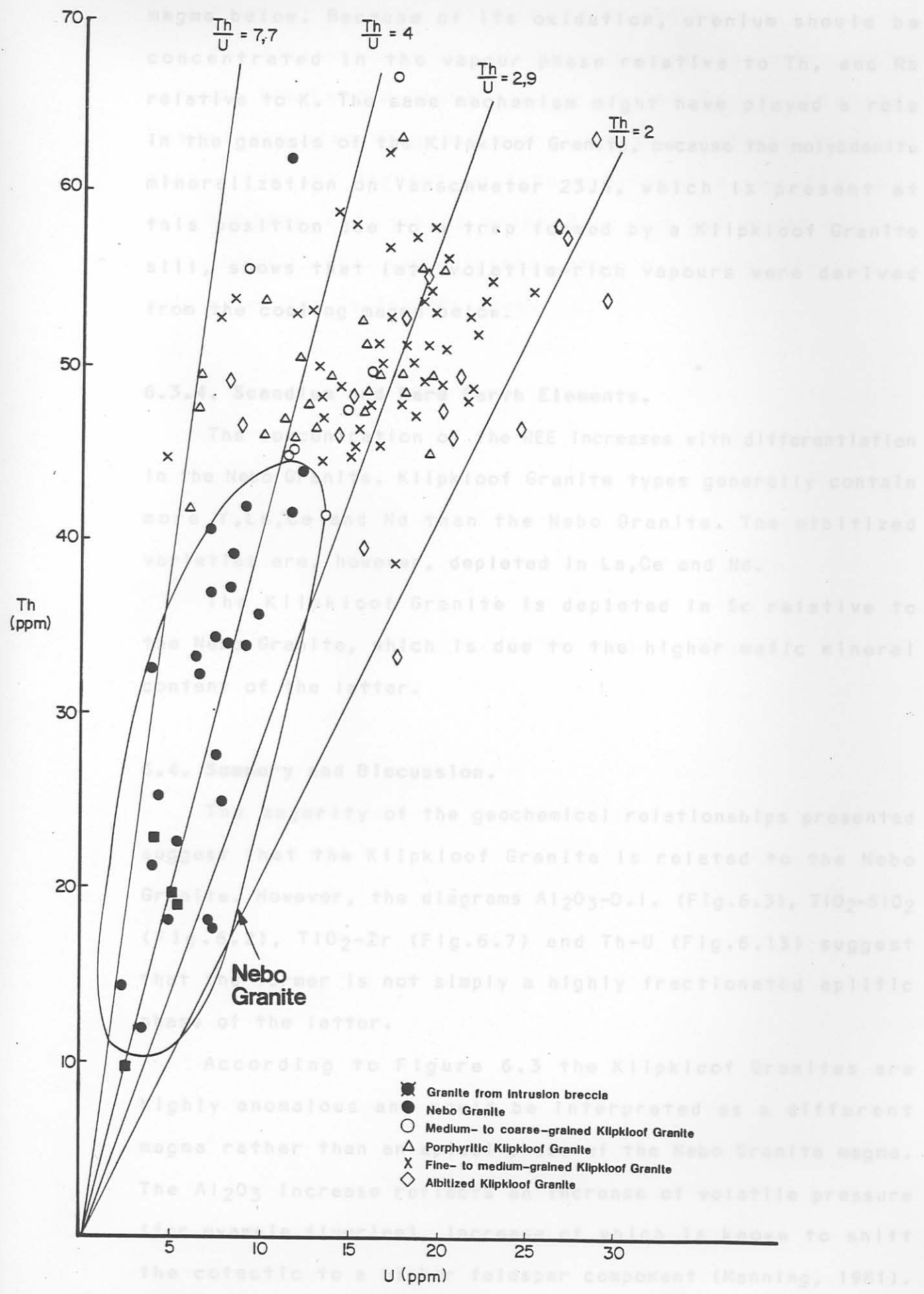


Fig. 6.13 Plot of Th vs. U for various types of granite. Taking Fig. 6.2 and Fig. 6.7 into account, the relationship

in vapour which has migrated from the slowly crystallizing magma below. Because of its oxidation, uranium should be concentrated in the vapour phase relative to Th, and Rb relative to K. The same mechanism might have played a role in the genesis of the Klipkloof Granite, because the molybdenite mineralization on Varschwater 23JS, which is present at this position due to a trap formed by a Klipkloof Granite sill, shows that late volatile-rich vapours were derived from the cooling magma below.

6.3.4. Scandium and Rare Earth Elements.

The concentration of the REE increases with differentiation in the Nebo Granite. Klipkloof Granite types generally contain more Y, La, Ce and Nd than the Nebo Granite. The albitized varieties are, however, depleted in La, Ce and Nd.

The Klipkloof Granite is depleted in Sc relative to the Nebo Granite, which is due to the higher mafic mineral content of the latter.

6.4. Summary and Discussion.

The majority of the geochemical relationships presented suggest that the Klipkloof Granite is related to the Nebo Granite. However, the diagrams Al_2O_3 -D.I. (Fig.6.3), TiO_2 - SiO_2 (Fig.6.2), TiO_2 -Zr (Fig.6.7) and Th-U (Fig.6.13) suggest that the former is not simply a highly fractionated aplitic phase of the latter.

According to Figure 6.3 the Klipkloof Granites are highly anomalous and could be interpreted as a different magma rather than an apical phase of the Nebo Granite magma. The Al_2O_3 increase reflects an increase of volatile pressure (for example fluorine), increase of which is known to shift the cotectic to a higher feldspar component (Manning, 1981).

Taking Fig.6.2 and Fig.6.7 into account, the relationship

between Nebo and Klipkloof Granite is obscure, because it is not one of a simple differentiation sequence.

7.1. The difference in Ba, Sr and especially Rb concentration between the Lebowa Granite Suite of the Groblersdal and Zaaiplaats area (Fig.6.5 and Fig.6.6) points to the fact that different degrees of late metasomatic reaction and sub-solidus alteration existed in the two areas (Twist, pers. comm.). This could perhaps explain the high tin favourability of the Zaaiplaats area.

able differences in their TiO_2 and Al_2O_3 contents. The difference in TiO_2 values is probably due to the chloritization of biotite, whereas the higher Al_2O_3 values may have resulted from an increase in volatile pressure.

Post-magmatic changes have played a major role in the geochemical signature of the Klipkloof Granite. These include late hydrothermal alteration and albitization of the feldspars. Albitization had a major effect on the trace element geochemistry of the rock, wherein trace elements normally present in perthite (Ba) were lost in solution.

The granites of the Groblersdal area are not as altered as the granites of the Zaaiplaats area, which is evident from figures 6.5 and 6.6. The first differentiates of Nebo Granite in the two areas have the same composition. Only the later differentiates are different in the respect that the rubidium content is higher in the granites of the Zaaiplaats area. The albitized Klipkloof Granites have similar rubidium contents compared with the Leese Granite of the Zaaiplaats area. It is well known that a high degree of alteration took place at Zaaiplaats (Strydom, 1983 and Coetzee, 1984), which is also reflected in the tin mineralization in the area. The plots of Sr against Rb and Ba against Rb are therefore a good exploration tool, because an increase in rubidium due to late-stage alteration, could be associated with minerali-