P A R T I I

REGIONAL VARIATION IN GRANITIC ROCK

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by

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ABSTRACT

Homogeneous to foliated granitoids dominate the rock suite of the Eastern Goldfields Province. Belts of similar texture and composition tend to be parallel to tectonic belts defined by the trend of metamorphic supracrustal rocks and gneisses.

Cataclastic textures record mild to severe penetrative deformation throughout the area. Recrystallization textures as well as the secondary minerals, epidote, carbonate, prehnite and pumpellyite, record mild but general metamorphic or deuteric recrystallization. This general low-order recrystallization is punctuated locally by more thorough metamorphic recrystallization in gneissic belts.

Fluorite is notably common as an accessory mineral throughout the area. Fluorite, sphene, zircon, and allanite are variously concentrated in several areas.

INTRODUCTION

Granitoid rocks constitute about 70 per cent of the surface area of solid rock in the Eastern Goldfields Province (Fig.1). Despite their importance, these rocks have received little serious attention until recently.

Much of the Eastern Goldfields Province was mapped by the Geological Survey of Western Australia between 1963 and 1974. In the course of this work samples of granitoid rock were collected. Information from thin sections of these samples was used in mapping but no integrated presentation of this material has been available.

The present work is a summary of the petrographic characteristics of granitoid rocks, together with a semi-quantitative study of regional variation in composition over a more limited area. The data has been drawn from thin sections prepared by the Geological Survey in the course of regional mapping, supplemented with material collected specifically for this exercise by I.R. Williams. Almost all the samples were collected since 1960.

The area of study together with a generalized picture of the geological framework of the Yilgarn Block is shown in Figure 1. Places mentioned in the text are located in Figure 11.

PREVIOUS WORK

Archibald and Bettenay (in press) have interpreted the basic architecture of the Eastern Goldfields Province in terms of 'granite tectonics'. Some of this work has been summarized by Binns and Marston (1976). Binns, Gunthorpe and Groves (1976) briefly considered the relation between regional metamorphism of greenstone belts and distribution of granitoids. Lewis and Gower (1978) have described the alkaline rocks of the Fitzgerald Peaks, and Roddick, Compston and Durney (1976) have used granite textures in the interpretation of isotopic data from the Sir Samuel sheet area. Granitic rocks have been dated isotopically in the area of study by Turek (1966), Turek and Compston (1971) and Oversby (1975).

Aspects of granitoid rocks of the Eastern Goldfields Province have been considered by Glikson and Lambert (1973) and Glikson and Sheraton (1972). O'Beirne (1968) discussed the relation of granitoids with porphyritic felsites.

Most regional studies, including explanatory notes for map sheets, have mentioned granitoid rocks; of particular interest are discussions by Gower and Bunting (1976) on the Leonora sheet area.

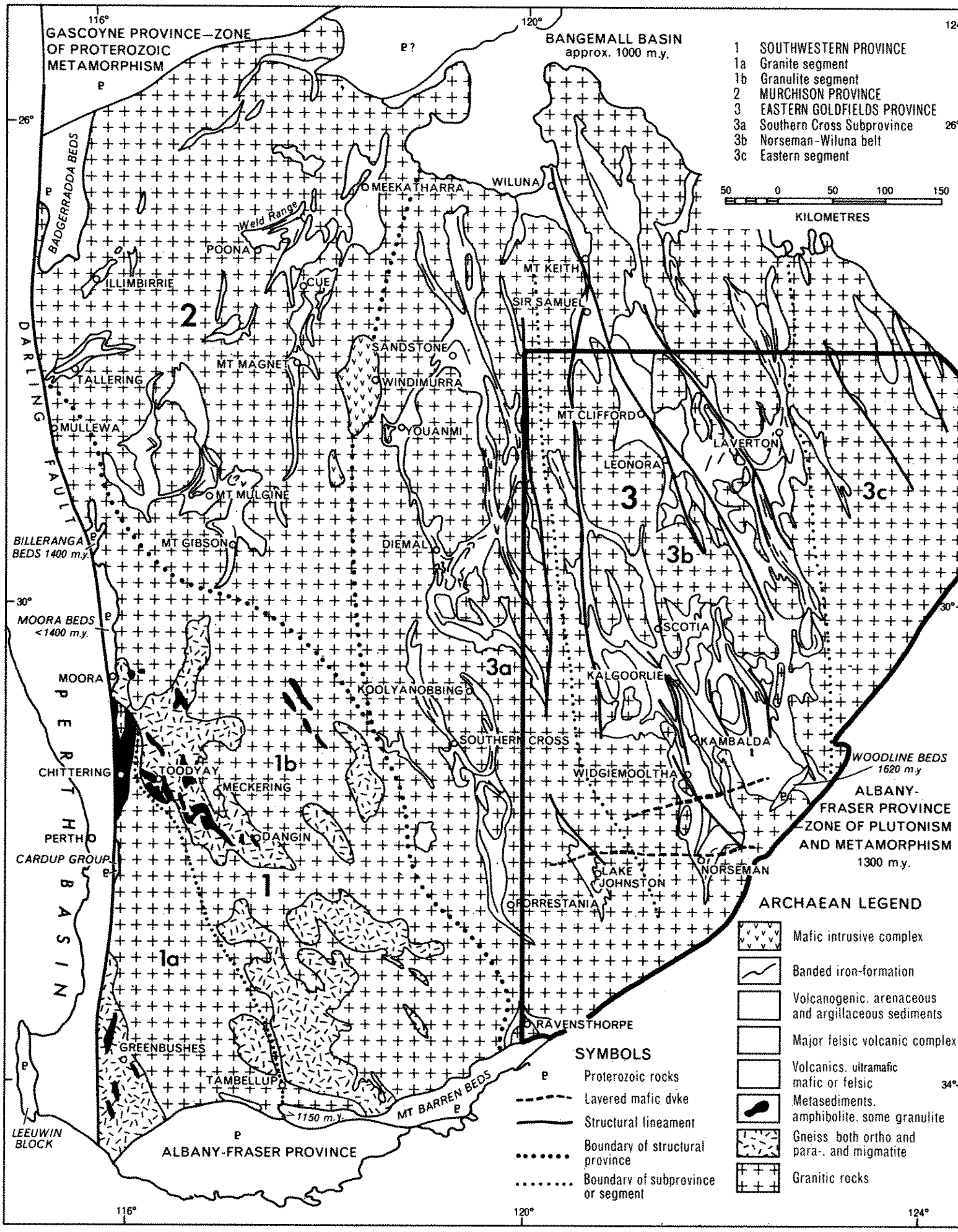

Figure 1. Geologic and tectonic sketch of the Yilgarn Block showing the limits of the area of study (GSWA 17316).

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Other regional mapping projects which contributed data are: Boorabbin (Sofoulis, 1963), Cundeelee (Bunting and van de Graaff, 1977), Edjudina (Williams and others, 1976), Kalgoorlie (Kriewaldt, 1969), Kurnalpi (Williams, 1970), Laverton (Gower, 1974), Menzies (Kriewaldt, 1970), Minigwal (Bunting and Boegli, 1977), Neale (van de Graaff and Bunting, 1975), Norseman (Doepel, 1973), Rason (Gower and Boegli, 1977), Widgiemooltha (Sofoulis, 1966) and Zanthus (Doepel and Lowry, 1970).

The relation of these sheets to the area of the present study is shown in Figure 2.

TERMINOLOGY AND NOMENCLATURE

The term "granitoid" includes all coarse-grained crystalline silicate rocks with a colour index less than 40 and plagioclase less calcic than An_{50}. Metamorphic gneiss and granofels (textural granulite) are included as well as rocks with igneous texture. As adjectives, both "granitoid" and "granitic" are used when the subject is similar to a granite but does not necessarily conform to the restricted definition of the term. Insofar as there is a difference in the terms, "granitic" is used when texture is emphasized, "granitoid" when composition is stressed. Gneiss, unqualified, is a rock of granitoid composition with substantial grain orientation, compositional layering, or both. Because of the difficulty in assigning such foliation to metamorphic deformation or protoclastic flow, use of the word "gneiss" does not mean the rock is metamorphic. However, where gneissic structure is clearly igneous, the term "gneissic granitoid" is applied.

Definitions of the more specific rock names (Fig.3) follow Streckeisen (1973) except that the granite, quartz syenite, and syenite fields of Streckeisen are divided at 35 per cent plagioclase to retain fields for adamellite, quartz monzonite and monzonite.

A small but important subset of rocks of the area are alkaline. Granitoid rocks which do not belong to the alkaline subset are termed subalkaline.

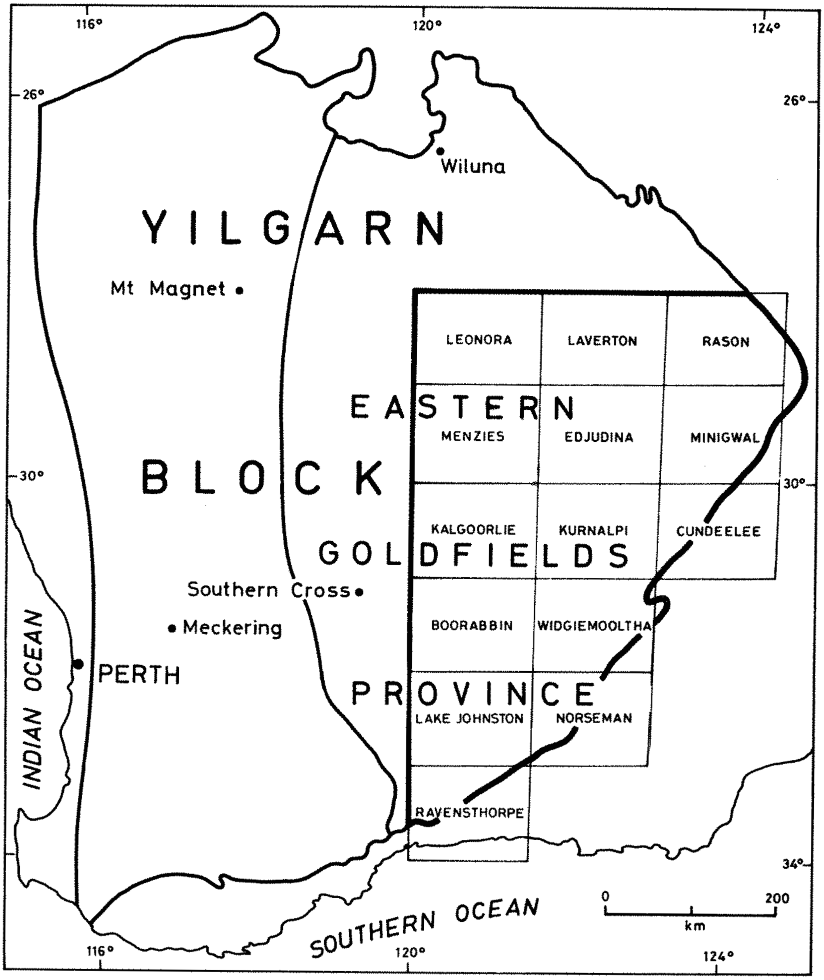

Figure 2. Index to 1:250 000 geological maps in the area of study (GSWA 17317).

Textural terms are largely conventional, self explanatory or defined in the text. A very useful term, applicable to many of these rocks but only in modest current use is "seriate", "A term suggested for variety of granular rocks in which the sizes of crystals vary gradually or in a continuous series" (Johannsen, 1939, p.233).

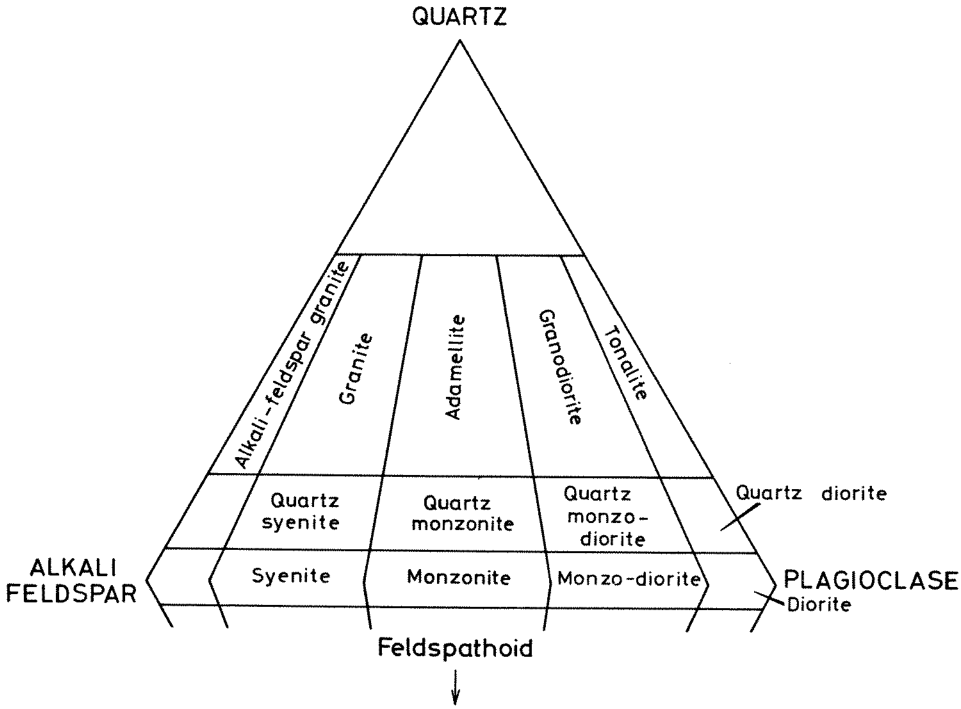

Figure 3. Classification and nomenclature of granitoid rock (GSWA 17318).

REFERENCE TO SAMPLES

Throughout the text reference to specific samples consists of the Geological Survey field sample number followed by the name of the 1:250 000 sheet covering the locality where the sample was collected. The Australian Transverse Mercator yard grid location for each sample mentioned in the text is listed in the Appendix.

PETROGRAPHY

This section includes observations on thin sections and stained slabs of the subalkaline granitoids. Alkaline rocks are discussed in a separate paper (Libby, 1978).

MINERALOGY

GENERAL

The granitoid rocks of the Eastern Goldfields Province range from true granite through tonalite, but are clustered in the adamellite to granodiorite field. Biotite adamellite is the characteristic rock. Thus, major felsic minerals are quartz, plagioclase and potassium feldspar. The manner in which these minerals are combined in individual rocks is shown in Figures 4 , 5 , 6 and 7 which are described later.

Biotite is almost ubiquitous, but other mafic minerals include amphibole and pyroxene, particularly in tonalitic and alkaline phases. Colourless mica is a common secondary mineral. Minor primary minerals include zircon, apatite, tourmaline, sphene, allanite, fluorite and opaques. Secondary minerals include epidote, chlorite, sericite, prehnite, pumpellyite, carbonate, and garnet. Weathering has produced clays and hydrous iron oxide.

MAJOR FELSIC MINERALS

Quartz

Quartz is abundant in most of these rocks, probably averaging about 30 per cent. The average of visual estimates is 26 per cent, but this is probably slightly below the true value, and also includes quartz-poor rocks of the alkaline suite. Quartz ranges from nil to about 50 per cent. Each of the rocks with about 50 per cent quartz is gneissic. Independent evidence suggests these gneisses may be metasedimentary. The granitoids with less than 20 per cent quartz constitute a distinctive group which is considered in a separate paper (Libby, 1978) on alkaline and quartz-poor rocks.

Throughout the Eastern Goldfields Province, quartz in granitoids typically shows some evidence of mild penetrative deformation. Most commonly, it is strained or granulated. Less commonly it seems to have been recrystallized, forming coarse, equant grains, convex against feldspars, or equant blebs within feldspar.

Many samples have large, irregular masses of quartz with uniform extinction; these are typically several times longer than wide, and sinuous in shape (Plate XXII). The dimensions and shape are appropriate for the coalescence of 5 to 10 adjacent quartz grains. A few feldspar grains may be enclosed, but the aspect is not poikilitic. This may be another manifestation of the recrystallization of quartz. Such a grain in sample 17660 (Menzies) is more than 1 cm long and averages 2.5 mm wide in the plane of the thin section.

Feldspars

Plagioclase in the granitoid rocks ranges from albite to andesine. Determinations on 260 samples indicate an average 13 per cent anorthite (standard deviation of 7). Throughout this study, plagioclase has been determined from extinction angles normal to the crystallographic a axis on the flat stage (conversion from angles to composition according to the curves of Tobi (1963) after Kohler).

The significance of the average plagioclase composition is doubtful, as most plagioclase has been altered, either filled with saussuritic epidote or associated with interstitial epidote. In either case the plagioclase probably is less calcic than when originally crystallized.

An unusual alteration effect was noticed in several samples (Plate X). The core of the plagioclase, presumably originally calcic, is crowded with epidote, and has a uniform extinction angle appropriate for a moderate calcium content. Outside the altered core, the extinction angle changes abruptly to a value appropriate for a slightly more calcic composition, before varying gradually to the albitic rim. Assuming that the extinction angles are reflecting only the ratio of Na:Ca, and not structural state, or varying proportions of another ion (?K), the increase in calcium outside the altered core is puzzling. If the outer zone were the product of conventional reverse zoning, it, as well as the inner zone, should be altered. Assuming that the core composition was the equilibrium composition under the conditions of alteration, it may be that a finite amount of Ca above the equilibrium composition was necessary to cause the nucleation of epidote. Once epidote had nucleated, the proportion of Ca in the plagioclase decreased to the equilibrium composition, but where Ca was insufficiently in excess of equilibrium to nucleate epidote the plagioclase remained metastably more calcic than the equilibrium composition.

Plagioclase commonly is subhedral though it ranges from anhedral, particularly in gneisses, to, rarely, euhedral. The overall textures of rocks, to which plagioclase contributed significantly, are considered in a separate section.

Potassium feldspar is almost invariably microcline with well-developed "M" (plaid, or cross-hatch) twinning. Usually it is anhedral; where crystal faces appear they commonly are developed against quartz. Rarely, but most commonly in alkaline rocks, large phenocrysts are quasi-euhedral against all other minerals. Fine film perthite is developed in the great majority of microcline grains, and in the alkaline rocks the alkali feldspar is mesoperthitic. The development of perthite is discussed in greater detail in the section on textures.

QUARTZ AND FELDSPAR RATIOS

In felsic rocks, variations in the proportions of quartz, plagioclase and potassium feldspar, along with differences in the composition of plagioclase, account for most of the variation in chemical composition, and are the basis for most mineralogical classifications. Thus, these relations have been studied in some detail.

Ratios of major minerals in granitic rocks are difficult to assess. Normal thin sections are too small to give a statistically valid sample. To supplement and check estimated data from thin sections, 77 hand specimens were sawn and stained to provide larger samples. Both techniques were used on 19 samples, and provided a means of comparing the techniques. Very significant differences between the two methods emphasize that at least one of the techniques has provided only semi-quantitative data.

The results of counts from stained slabs and estimates of composition from thin sections are shown in Figures 7 and 4 respectively.

Thin-section data

Proportions of quartz, plagioclase and potassium feldspar were visually estimated in 289 thin sections from eight 1:250 000 sheets: Leonora, Laverton, Menzies, Edjudina, Kalgoorlie, Kurnalpi, Boorabbin and Widgiemooltha (Fig.2). The composition of plagioclase was determined in most of these sections.

In principle, the feldspars are classified according to Streckeisen (1973); that is, plagioclase composed of less than 5 per cent anorthite is included with potassium feldspar as alkali feldspar. However, there are several difficulties with this procedure: grains may be zoned through An_5, the albitic composition of a grain may be secondary, and the exact composition is often difficult to determine. Thus, feldspar data was apportioned in two ways. First, all non-potassic feldspar, albite as well as more calcic plagioclase, was combined as plagioclase; potassium feldspar together with perthite constituted alkali feldspar. Second, albite (less than 5 per cent anorthite) was included with potassium feldspar and perthite as alkali feldspar; only the more calcic feldspars were called plagioclase. More precisely, in the second grouping, plagioclase was included with potassium feldspar when the rock failed to produce a significant amount of plagioclase more calcic than An_5. Grains were counted as plagioclase if the composition ranged above An_5 even if the rims of grains fell below that value.

Calculated according to the first method (albite with plagioclase), the average plagioclase content of the granitoids sampled is 41 per cent ($s = 15$) and alkali feldspar (K-feldspar only), 33 per cent ($s = 16$), where s is the standard deviation. Calcualted according to the second method (albite with K-feldspar as alkali feldspar), there is little difference; the average plagioclase ($>An_5$) is 35 per cent ($s = 19$) and alkali feldspar, 39 per cent ($s = 21$). The ratio of mean alkali feldspar to mean plagioclase places the average rock in the adamellite field in either case. The average composition is in the granodiorite side of the adamellite field in the first case, and in the granite side in the second.

Visual estimates of proportions of quartz, plagioclase and alkali feldspar from individual samples have been recalculated to 100 and plotted on the triangular diagrams (Figs 4, 5). In Figure 4 the feldspars have been apportioned according to the first method (albite with plagioclase) and in Figure 5, according to the second method (albite with alkali feldspar). Most estimates were to the nearest 5 per cent, and result in nodes at 5 per cent intervals. Where two or more points have the same value, points are offset slightly for legibility but result in clusters about the nodes.

The plotted points in Figure 4, where albite is included with plagioclase rather than with alkali feldspar, show that adamellite is the dominant rock type. This is consistent with the mean quartz and feldspar ratios considered above. Granodiorite is also abundant, and granite and tonalite are common. Potassium feldspar granites without significant albite are rare. The quartz-poor rocks - syenite, quartz syenite, monzonite, monzodiorite and quartz monzodiorite - are reasonably well represented as a group. These are alkaline rocks with alkali pyroxene and alkali amphibole.

Diorite and quartz diorite are poorly represented. Considering the difficulty in determining the composition of primary plagioclase which has been degraded through saussuritization, some diorites and related rocks may have been identified as gabbro, and not included in the granitoids in this part of the study.

In Figure 5 where albite has been included with potassium feldspar as alkali feldspar, albitic samples which plotted in the body of Figure 4 have migrated to the left margin of the triangle, along the alkali feldspar-quartz join. Because the migrating samples are defined as being free of Ca-bearing plagioclase, all such samples lie strictly on the join despite approximations in plotting to accommodate all of the points. Figure 6 shows the plotted positions of migrating samples before migration. The migrating samples are distributed over the diagram very much in the same way as the plagioclase-bearing samples. The albitic samples do not correlate with samples having a large proportion of potassium feldspar. Failure of granitoids with albitic plagioclase also to have abundant potassium feldspar suggests that the albite-bearing rocks may have been generated randomly from rocks with various plagioclase compositions by secondary albitization consequent on deuteric alteration or metamorphism. Thus

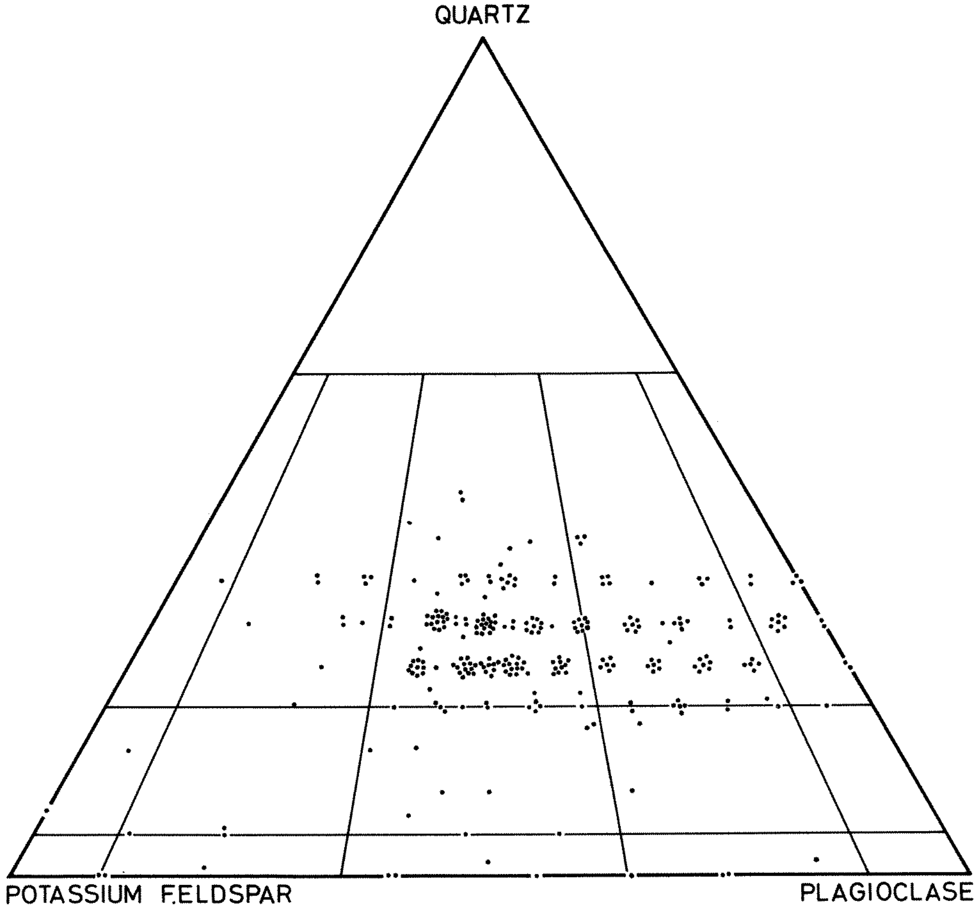

Figure 4. Modal quartz, plagioclase, and potassium feldspar. Albite is plotted as plagioclase. Data are from thin sections. (GSWA 17319)

Figure 4 would seem to be more efficient than Figure 5 as an estimate of mineral proportions in the rock immediately after crystallization.

Data from stained slabs

One hundred and twenty four samples for staining were collected in 1973 by I.R. Williams, mainly from the Kalgoorlie, Boorabbin, and Widgiemooltha sheets, and the western third of the Menzies sheet. Scattered samples are from the Leonora, Cundeelee and Balladonia sheets. The rocks were sawn, etched with hydrofluoric acid, and stained with sodium

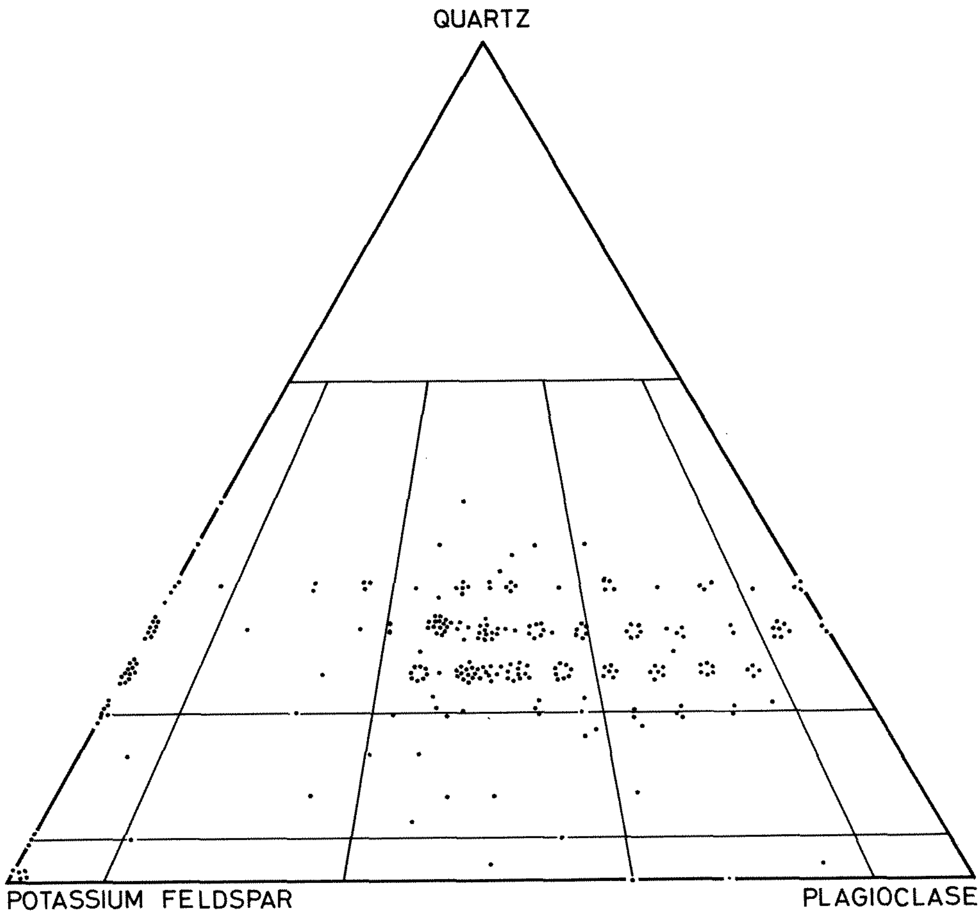

Figure 5. Modal quartz, plagioclase, and potassium feldspar. Albite is plotted as alkali feldspar. Data are from thin sections. (GSWA 17320)

cobaltinitrite, leaving quartz clear, plagioclase chalky-white, and potassium feldspar bright yellow. About 1 000 points were counted on each rock by noting the mineral at the intersection of grid lines ruled at a spacing of 4 mm on a plastic overlay.

Some of the samples were collected outside the study area, and others were either too fine grained for point counting or failed to stain adequately. Seventy-seven samples were chosen for further study. Although potassium feldspar was well stained in most samples, the distinction between plagioclase and quartz was obscured in many cases by a tendency of plagioclase in some samples to remain glassy, lessening its contrast with the glassy quartz. Repetition of point counting on several samples by a

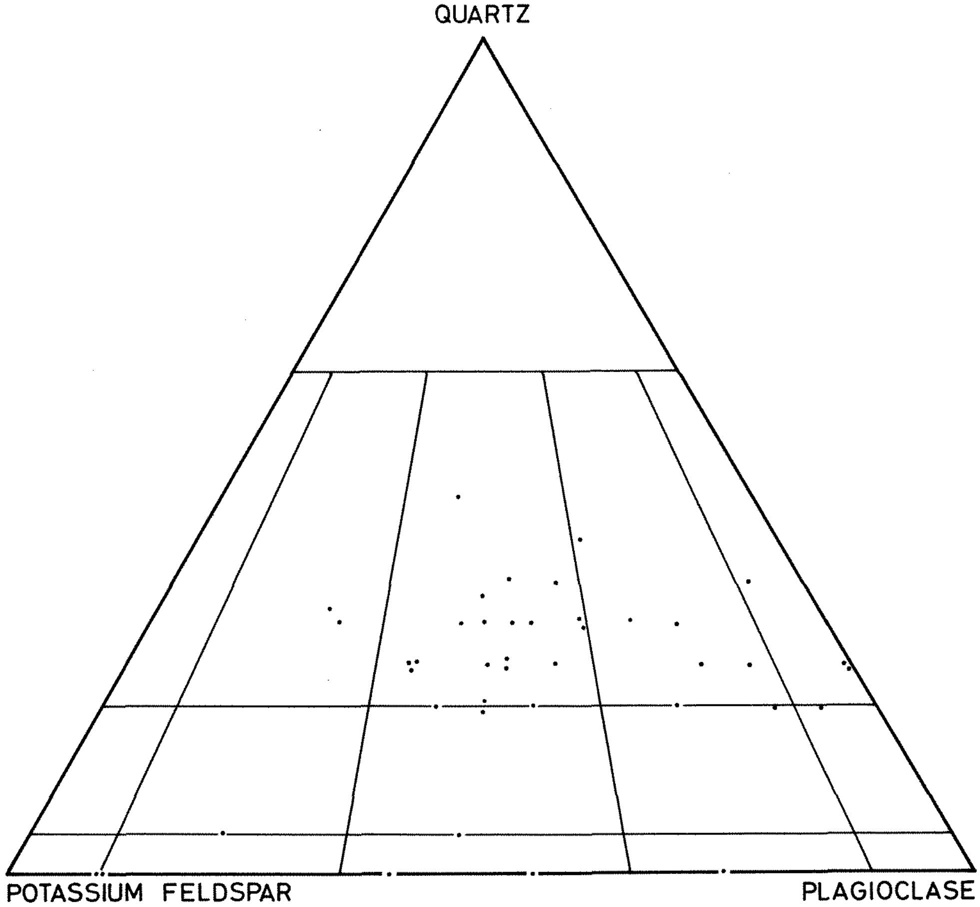

Figure 6. Modal quartz, plagioclase and potassium feldspar. Only samples in which plagioclase is albitic. Albite is plotted as plagioclase. Data are from thin sections. (GSWA 17321)

second operator confirmed that quartz:plagioclase ratios were less reliable than total potassium feldspar values. Average differences between values obtained by the second operator and those by the first operator were: potassium feldspar, -3 per cent; quartz, -3.5 per cent; and plagioclase, +6.5 per cent. The reported values probably are no more accurate than 5 per cent, but the errors were quite systematic, suggesting that relative values are more useful.

Quartz and feldspar data from stained slabs have been plotted on a triangular diagram in Figure 7. The general pattern is similar to that of Figure 4, which is a plot of data from the thin sections, described above.

In both diagrams, the average composition is in the granodiorite side of the adamellite field. The data from slabs differ from thin-section data mainly in the more restricted compositional range and the greater apparent proportion of quartz. Probably quartz was both overestimated in stained slabs and underestimated in thin sections. The more restricted compositional range among stained slabs may be partly due to rejection of syenite and monzonite, as they commonly are porphyritic with a medium-grained matrix which would be unsuitable for counting under low-power magnification. Samples for staining were collected predominantly from the more potassic western zone and the thin section samples were collected mainly from the less potassic eastern zone. This may explain the lower proportion of granodiorite and tonalite among the stained rocks.

Although some of the difference between data from thin sections and data from slabs is real, some is an artifact of the techniques. To study the effect of the techniques on the results, 19 of the samples with thin-section data were also slabbed. The average difference in percentage between the thin section and slab values for each mineral was calculated. Stated as mean ($\bar{x}$) and standard deviation (s), these differences are: potassium feldspar, $\bar{x} = -1.4$, $s = 9.6$; plagioclase, $\bar{x} = -8.6$, $s = 13.2$; quartz, $\bar{x} = +11.1$, $s = 6.0$. Differences are positive when the mineral seems more abundant in stained slabs than in thin sections. The small difference between thin section and slab results for potassium feldspar suggests that the data for this mineral are reliable. The plagioclase and quartz data seem less reliable.

MAJOR MAFIC MINERALS

The mafic suite in the granitoid rocks of the Eastern Goldfields Province is dominated by brown biotite, but a few samples, especially tonalite and alkaline rocks, contain amphibole. Pyroxene is a primary mineral in alkaline rocks and is a metamorphic phase in some gneissic granitoids.

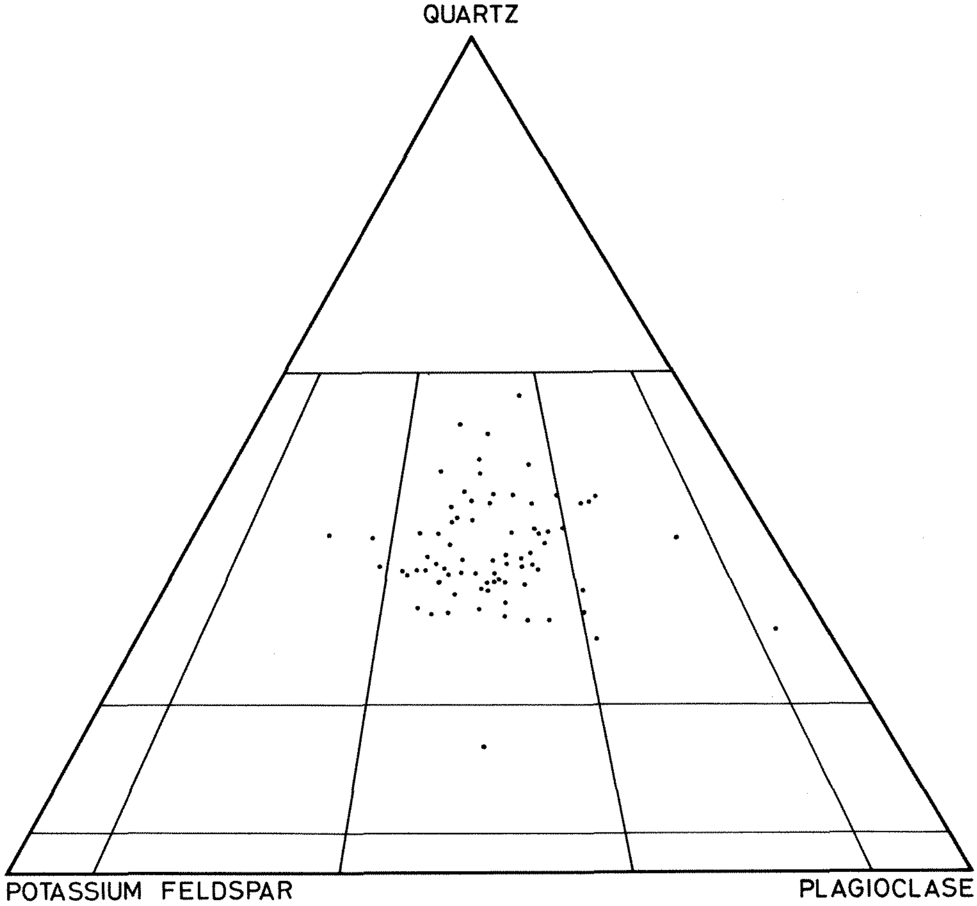

Figure 7. Modal quartz, plagioclase and potassium feldspar. Data are from stained slabs. (GSWA 17322)

Biotite

The biotite in almost all samples is deep brown; rarely, it is green (sample 24801, Edjudina), or olive green (sample 24802, Edjudina). Most of the biotite is subhedral-blocky to irregular, but occasionally is euhedral, hexagonal in outline (sample 24832, Edjudina). In rocks with independent evidence of significant cataclasis, biotite forms aggregates of equant or platy grains, and where planar cataclasis is more intense elongate aggregates of finely comminuted biotitic material are common. The colour of the biotite in these cataclastic habits is not consistently different to biotite which seems to have primary igneous form. The blocky habit of biotite seems to correlate with other indications of primary igneous crystallization, such as zoned or euhedral to subhedral plagioclase.

Much biotite is fresh and unaltered, but more than half has been partly altered to green chlorite, and some has been entirely chloritized. The biotite of some weathered samples has been altered to a complex of iron hydroxides. Biotite, especially when partly chloritized, has acted as host to secondary epidote, sphene, fluorite, prehnite and pumpellyite.

Amphibole and pyroxene

An appreciable number of samples contain amphibole. Much of this, however, is in material which shows independent evidence of metamorphism. Of the remainder, most is in the alkaline or quartz-poor rocks. However, even after eliminating these associations, some samples with hornblende remain. Of these, a few, as sample 39003 (Laverton), are granodiorite or tonalite with moderately calcic plagioclase. Ferrohastingsitic amphibole, dark green with a small optic axial angle and strong dispersion, is common in the suite of granitic rocks which have been recrystallized, are cataclastic, or show other evidence of metamorphism.

Igneous clinopyroxene is clearly present only in samples of the alkaline and quartz-poor suite described by Libby (1978). Green clinopyroxene, apparently diopsidic, is present in several gneisses (sample 41475, Boorabbin), and in granitic rocks which show independent evidence of metamorphic recrystallization. Optical properties suggest that clinopyroxenes in the non-alkaline granitic or metamorphosed granitic rocks are restricted to diopside-hedenbergite, whereas the pyroxenes of the alkaline suite seem to range from diopside-hedenbergite through aegirine-augite to aegirine.

COLOURLESS MICA

Plagioclase has been sericitized in almost all of the granitoid rocks of the Eastern Goldfields Province, and in many grains the mica has grown to appreciable size as individual flakes. Coarse interstitial muscovite is also common but in no case does it seem likely that appreciable colourless mica is a primary igneous mineral. Most of the rocks with coarse, interstitial, colourless mica have independent evidence of recrystallization The abundance of muscovite in a few gneissic rocks may have genetic significance, suggesting a peraluminous composition and sedimentary parentage. Examples of possible peraluminous gneisses are samples 17655 and 17681 (Menzies) and 2364 (Kurnalpi).

MINOR MINERALS

The minor minerals described in this section include the accessories which are present in small amounts in most or many granitoids, minerals which may be major constituents of some rocks, but which are not abundant in the granitoids of the Eastern Goldfields Province, and finally secondary minerals regardless of abundance which are not products of thoroughgoing metamorphic recrystallization of the enclosing rock.

Accessory minerals

Zircon, apatite and opaque minerals are common, though they vary in abundance and habit.

Zircon averages several medium grains per thin section, but ranges from coarse and abundant to fine and rare, and was not found in some rocks. Large, metamict grains with the shape and habit of zircon are common in some areas as seen in sample 40807A (Edjudina) and 31131 (Laverton). Pleochroic haloes surround zircon where it is in contact with biotite.

Apatite is similarly variable. Most granitoids in which apatite was noted to be either coarse or particularly abundant, either had metamorphic elements or belonged to the alkaline suite. One of several exceptions is sample 39003 (Laverton) which is a calcic oligoclase granodiorite with abundant coarse apatite.

Most opaque minerals in the granitoids of the Eastern Goldfields Province are black under oblique reflected light, suggesting magnetite, but hematite and titanium-bearing opaques are present. Sulphides seem scarce, possibly they have been oxidized to hematite.

Minor primary minerals

The remaining minor primary minerals are tourmaline, sphene, allanite and fluorite. They are less common than zircon, apatite or opaque minerals but where present they may be much more abundant than the common accessories.

Tourmaline was identified only in sample 11099 (Kurnalpi), an alkaline rock, and sample 41480 (Leonora), a blastomylonite gneiss. The thinly scattered, generally fine tourmaline in Yilgarn Block rocks poses a problem for the source of the nearly-ubiquitous coarse clastic tourmaline in sandstones of the Bangemall Basin.

Sphene is common, both as spindle-shaped grains (Plate I) which are probably of igneous origin, and as irregular masses associated with chlorite (Plate II), probably a consequence of the alteration of biotite. Primary sphene is most common in rocks which contain andesine, but is also common in rocks with plagioclase which is less calcic, even where there is no epidote to suggest that the sodic composition of the plagioclase may be due to albitization. Much of the sphene of the Eastern Goldfields Province has patchy pleochroism and is a warm, orange colour. The patchy colour does not seem to be parallel to growth zones. Especially strong colour is associated with lowered birefringence. Deer and others (1962, p.74) attribute orange colour to rare-earth elements. The same source suggests that lowered birefringence is due to substitution of any of various elements for titanium. The geographic distribution of sphene is discussed in a later section.

Allanite is commonly metamict in Archaean rocks and is thus difficult to identify in thin section. In some instances grain shape, cracking of surrounding minerals, or association with non-radioactive epidote provides reasonable evidence that the metamict material is allanite. In the Eastern Goldfields Province allanite is restricted to certain plutons, in which it may be abundant. The regional distribution of allanite is discussed in a later section. Metamict allanite from the Laverton sheet is pictured in Plate IX.

Fluorite is a common accessory in the granitoid rocks of the Eastern Goldfields Province; it was found in 79 of the 278 thin sections of granitic rock studied. Fluorite is especially abundant in the western part of the Menzies and Leonora sheets but is also common in the Boreas Adamellite in the northern part of the Laverton sheet. Details of the regional distribution of fluorite are discussed in a later section.

The associations of fluorite were studied in 67 samples. It is enclosed in plagioclase in 58 (Plates V and VI), interstitial in 41 (Plates VII and VIII), enclosed in potassium feldspar in 10, and enclosed in chlorite in 9 samples. Fluorite was also found in muscovite, biotite, sphene, allanite and hornblende. Where fluorite is enclosed in plagioclase it is usually in the calcic, or formerly calcic, core of the grain, suggesting that fluorite grew during alteration of feldspar by the combination of F with Ca released by albitization of the plagioclase.

The purple colour of the fluorite is patchy, even in very small grains. Usually, fluorite enclosed in the core of plagioclase grains is colourless, but fluorite associated with chlorite is more commonly coloured, as is interstitial fluorite, especially where it is in contact with opaque grains or zircon. In a few cases, a grain which is largely colourless is coloured where it is in contact with an opaque grain.

Secondary minerals

Secondary minerals include kyanite, garnet, epidote, pumpellyite, prehnite, chlorite, sericite, carbonate, and hydrous iron-oxide. Some of these are normally considered to be metamorphic minerals, others are normally considered to be products of low grade hydrothermal alteration or weathering. The lower grade materials, iron-oxide and sericite are abundant; garnet, pumpellyite and prehnite are less common in granitoids; and kyanite was found only in an associated schist.

Hydrous iron-oxide is a common, incomplete pseudomorph of mafic and opaque minerals in samples which have been severely weathered, and is a minor stain in most samples. It may be secondary after sulphides.

Sericite has been described in the section on colourless mica. It is almost ubiquitous as an alteration product of plagioclase, grades into coarser, discrete grains of colourless mica in plagioclase, and is interstitial in some samples.

Carbonate is a sparse component of about ten per cent of the rocks studied; it is found in metamorphic, alkaline, and altered igneous granitoid rocks alike. Rarely is it abundant, as in the heavily carbonated and sericitized sample 15507 (Edjudina). It seems to be a product of low-grade alteration in most cases, but could be metamorphic in a few of the gneisses.

Chlorite is an abundant product of complete or partial alteration of biotite. It acts as a host to secondary epidote, sphene, fluorite, prehnite, pumpellyite, opaques and other minerals. Some of these inclusions seem related to the release of elements on the breakdown of biotite to chlorite, others do not. All the coarse chlorite seems related to the breakdown of mafic minerals; there is little or no independently crystallized coarse metamorphic chlorite.

Pumpellyite and prehnite typically are found in rocks which have been mildly recrystallized and severely sericitized, or in which feldspars have been heavily dusted with cryptocrystalline secondary material. Thus, they seem to be products of low-grade alteration or of metamorphism which has failed to bring either the textures or mineral assemblages into equilibrium with the metamorphic conditions. Grains of pumpellyite are small and scarce. They are commonly between 20 μm and 60 μm in diameter, and there are seldom more than two or three grains in any thin section. Birefringence is moderate and dispersion of optic axes strong, resulting in anomalous interference colours, probably in the upper part of the first order. Colour is variable between grains and within grains. Most commonly the pumpellyite is pleochroic in shades of pale to bright yellow, but some grains are green and a few range from yellow to green. Nearly colourless material in sample 41472 (Norseman) was confirmed as pumpellyite by X-ray diffraction (written communication, M. Pryce, West. Australia Government Chemical Laboratories, 26 August 1975). Typical pumpellyite is pictured in Plates III and IV.

Pumpellyite was found in 35 of the 289 thin sections studied in detail. The distribution of pumpellyite does not seem to conform to patterns of metamorphism which have been suggested, or to any accepted tectonic framework. Furthermore, it does not seem to be concentrated in areas defined in this report on other mineralogical criteria. Further study of pumpellyite in these rocks should prove productive.

The identification of prehnite ranges from tentative to confident. It was found only in seven, widely scattered samples. The only evident regional association is that three of the seven prehnite-bearing samples are in the belt west of the Coolgardie-Mount Ida greenstone arm of the Kalgoorlie greenstone belt. Correlation with other calc-silicate minerals is more convincing than correlation with tectonic belts. In four of the seven prehnite-bearing samples pumpellyite is also present as an accessory and in three of those, epidote is also present. Presumably, the three calcium-aluminium-silicate minerals did not develop simultaneously. In one of the other three samples epidote is an accessory, and in the other two the prehnite is associated with a carbonate mineral.

Prehnite and pumpellyite, along with sericitization of feldspars and development of blebby quartz, show that at least some of the granitoid rocks of the Eastern Goldfields Province have been partially recrystallized, even where penetrative deformation is not evident. It is not clear whether the alteration producing this recrystallization is the result of deuteric alteration, local hydrothermal alteration or regional metamorphism.

Epidote is a characteristic alteration product of calcium-bearing plagioclase. It is abundant in the Eastern Goldfields Province, both as finely granular saussuritic alteration of plagioclase and as coarser interstitial grains. Commonly, saussuritic epidote has low birefringence and is probably clinozoisite; whereas interstitial epidote has higher birefringence and is pistacite.

Garnet was found in five samples. Four of these are the gneissic rocks associated with the Coolgardie-Mount Ida greenstone arm of the Kalgoorlie greenstone belt in the northern part of the Kalgoorlie sheet (sample 9155C), the Menzies sheet (samples 17617A and 17625) and the south-central part of the Leonora sheet (sample 40575D). These rocks are gneisses, but, except for sample 40575D, have compositions similar to other granitoids of the area. Sample 40575D is rich in quartz, and may be a paragneiss. These four localities are from the general trend of "metamorphic domains" mapped by Bettenay (Binns and Marston, 1976). The fifth garnet-bearing sample (38143) is from the northeastern part of the Laverton sheet. The rock has been crushed and partly recrystallized under stress. It is isolated; no other samples from this area are similarly metamorphosed.

The five garnet-bearing samples are all gneissic, and the garnet is most easily explained as a product of medium or high-grade metamorphism.

Kyanite was found in a schistose phase of the gneissic rock of Maroon Range in the central part of the Leonora sheet (sample 39805). Although not from a granitoid rock it is included as a mineral from an associated rock unit.

TEXTURE AND MICROSTRUCTURE

GENERAL

Typical granitoid rocks in the Eastern Goldfields Province are hypidiomorphic granular, although well-formed feldspars may be less common than in many granitic terrains, possibly because penetrative cataclasis and mild to severe recrystallization have affected the rocks of much of the area. Nonetheless, euhedral feldspar does exist, especially in the alkaline and more calcic rocks.

CATACLASIS AND RECRYSTALLIZATION

Cataclastic and healed cataclastic textures

Almost all rocks are at least mildly cataclastic, or have a texture which suggests healed cataclasis. Quartz in most rocks is strained, and is often polygonized into mosaic pseudomorphs of primary grains, or completely recrystallized and redistributed about the rock in fine grains. In some samples quartz is drawn out into a mortar sheath around feldspar grains, or forms blastomylonitic trains. Much of the feldspar has been bent or fractured. A more subtle recrystallization texture is the development of quartz blebs (Plate XXI), often within feldspar grains, and often forming rounded bipyramids of quartz in the margins of feldspar grains. The origin of the blebby quartz is uncertain, but associations suggest that, despite the occasional quasi-euhedral habit, blebby quartz may be due to recrystallization following comminution of quartz into mortar. The large, roughly oriented amoeboid seas of quartz (Plate XXII) described earlier may also be a recrystallization product. They may result from the amalgamation after comminution of several adjacent grains which originally were independently oriented.

Most samples are even textured but porphyritic and seriate textures are also abundant. Seriate texture (Plates XXIII and XXIV) is common even in normal adamellites; grains range evenly from coarse or very coarse to medium, or even in some cases, fine. Again, it is possible that the seriate rocks have been deformed penetratively and recrystallized, the ultimate size of a grain depending both on the size to which it was reduced and on the size, proximity and number of neighbouring quartz grains. A possible secondary origin of seriate texture is shown in Plate XXIII; in Plate XXIV the texture probably is dominantly igneous.

Metamorphic textures

Although some gneissoid rocks are deformed and mildly recrystallized igneous granitoids, others, true gneisses, have fully crystalloblastic texture with strongly oriented micas.

The relation between gneiss and the less recrystallized isotropic granitoids is not clear. There is some suggestion in the southwest corner of the Menzies sheet that isotropic granitic rock may grade into gneissic rock, suggesting that the gneiss may be in part metamorphosed granite, but the evidence is not compelling. Kriewaldt (1970) has said that the granitic mass north of Lake Ballard is intrusive on the east and strongly foliated on the west, suggesting gradation from an isotropic, igneous aspect into a gneissic, metamorphic habit. Archibald and Bettenay (in press) have been particularly concerned with these relationships (Binns and Marston, 1976).

TEXTURAL AND MICROSTRUCTURAL CLASSIFICATION

Textures and microstructures in thin sections were graded roughly in progression from those suggesting a metamorphic origin to those suggesting an unrecrystallized igneous origin. These grades are: gneissic, foliated granitic, statically recrystallized, cataclastic granitic, hypidiomorphic granular (granitic), and igneous.

Gneissic rocks (Plate XI) are equigranular with strongly oriented mafic grains. The mafic grains are at least partly enclosed in individual quartz or feldspar grains. Quartz grains define at least a weak foliation, either by elongation and orientation of individual grains, or by variation in abundance in succeeding layers.

Foliated granitic rocks (Plate XII) have obviously been deformed, but recrystallization is less complete than in gneissic rocks. Mafic minerals are less than perfectly oriented, and compositional layering is weak or absent. Still, planar deformation is obvious and is more prominent than recrystallization in rocks of this class. Mylonites are included in this group.

Statically metamorphosed rocks (Plates XIII, and XIV) have the granoblastic, even-grained texture of the gneisses, without grain orientation or compositional layering to define a planar element. Crystallographic faces on quartz and feldspar, typical of hypidiomorphic granular texture, are absent or rare. Grain junctures at 120^{o} are characteristic.

Cataclastic granitic rock (Plate XV) has igneous features such as subhedral feldspars or multiple oscillatory zoning in plagioclase, but grain margins have been crushed by cataclasis, with or without the development of a significant directional fabric.

Hypidiomorphic granular granitoids (Plates XVII, XVIII and XVI) have typical granitic texture. Quartz is interstitial and feldspars are in part subhedral, though crystal faces are seldom as abundant as in illustrated examples of this texture (Joplin, 1964, Fig.55A, B and C). Plagioclase may have weak oscillatory zoning.

Igneous rocks (Plates XIX and XX) have textures which can be considered prima facie evidence of igneous crystallization. Such textures are euhedral plagioclase with multiple, euhedral, oscillatory compositional zoning; quartz or biotite grains which are euhedral but not enclosed in other grains; and plagioclase twins in synneusis relationship (Johannsen, 1939, p.234) to form combination twins (Ross, 1957). Synneusis texture or combination twinning suggests that grains have drifted together in a melt. Ross (1957) and Vance (1957) discuss combination twinning and coalescent growth which indicate synneusis.

The variation in textures across the area reflects varying tectonic and petrogenetic conditions. Resolution of these trends is poor at the sample spacing used in this report but some trends are recognizable and are reported in a later section.

INTERGROWTHS OF FELSIC MINERALS

Perthite and myrmekite are common throughout the area. Granophyre (sample 38327, Leonora) is very rare and the samples which are granophyric may be genetically closer to the felsites than to the coarse-grained granitoids.

Perthite

The feldspars of more than 60 per cent of the granitoids studied are perthitic or antiperthitic. Most of these have film perthite but patch perthite is also common. Antiperthite is rare. Mesoperthite is characteristic of alkali feldspar of the alkaline suite.

Myrmekite

More than 60 per cent of the samples examined have at least a trace of myrmekite.

Myrmekite seems to be abundant in rocks which contain oligoclase, and rare in albitic rocks. In order that the relation between the development of myrmekite and the composition of plagioclase could be studied systematically, the samples were arranged in three lists according to the amount of myrmekite in the rock. The mean composition of plagioclase was then determined for each list. In the first list were rocks with abundant myrmekite, in the second, rocks in which myrmekite is rare, and in the third, rocks in which no myrmekite was found. The mean anorthite content of plagioclase from samples with abundant myrmekite is 15.4 (s = 4.5); in samples with minor myrmekite it is 12.3 (s = 5.6); and in samples without myrmekite it is 10.4 (s = 8.1). The amount of myrmekite decreases as the anorthite content of plagioclase decreases. At the same time the spread in values (standard deviation, s) increases. These relations are shown in the histograms, Figure 8A, B and C. Histogram A shows that the most common plagioclase in the rocks with abundant myrmekite is sodic oligoclase; histogram C is bimodal, showing that both albite and andesine are characteristic of myrmekite-free rocks. In other words, myrmekite is associated with intermediate plagioclase, and rare in rocks with plagioclase which is either more calcic or less calcic.

The meaning of the relationship between plagioclase composition and myrmekite is not clear. Probably the rocks which contain andesine have a different crystallization history than the more sodic rocks. A few possibilities for oligoclase and albite-bearing rocks are that: 1) a threshold value for calcium in plagioclase is necessary for the development of myrmekite, 2) the more albitic rocks were originally the same composition as those with sodic oligoclase but calcium was lost, and myrmekite annealed during metamorphic recrystallization, or 3) the oligoclase-bearing and albite-bearing suites are unrelated, the albitic rocks not having experienced the physical conditions necessary for the development of myrmekite. The third explanation seems unlikely as all properties seem gradational between albite-bearing and oligoclase-bearing suites (histogram B); there is no reason to prefer either of the two remaining alternatives.

The time of development of myrmekite is not clear. It may be late magmatic, deuteric, or metamorphic; but, whatever the origin, the development and preservation of myrmekite has favoured rocks which have a narrower range of plagioclase compositions than is characteristic of the granitoid rocks of the Eastern Goldfields Province as a whole.

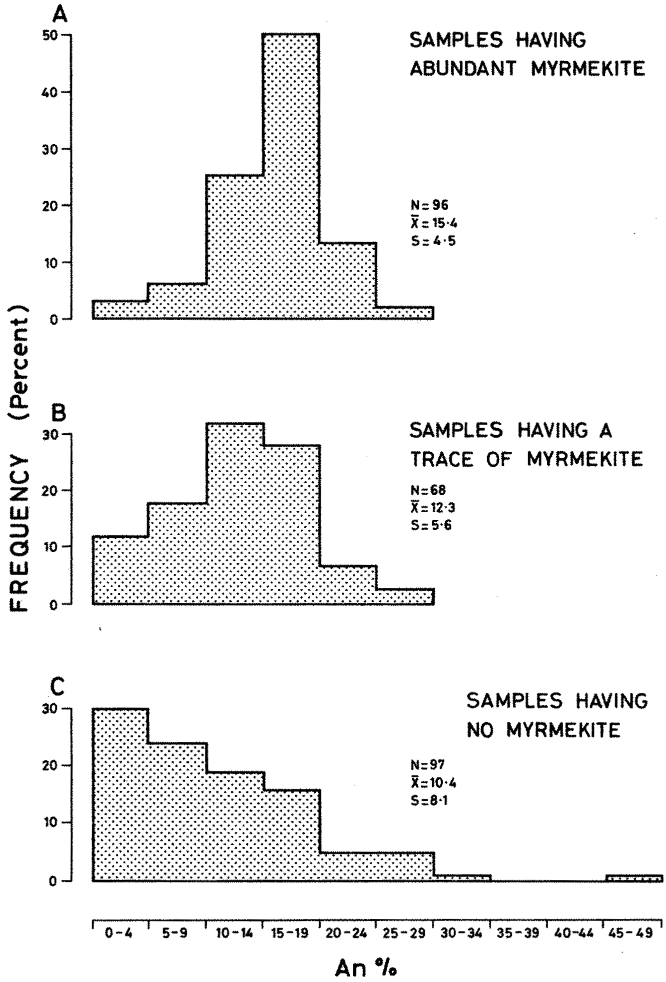

Figure 8. Relation between Ca-content of plagioclase and development of myrmekite. (GSWA 17323)

REGIONAL PETROGRAPHY

In the preceding sections, average properties of granitoid rocks from the study area have been considered. However, the character of an area is defined as much by the distribution of materials within it as by its average properties. In this section the distribution of selected properties over the area is discussed.

DISTRIBUTION OF POTASSIUM FELDSPAR

The technique of staining, and determining mineral ratios from stained slabs was described in the section on major felsic minerals. Although the study covered a limited part of the Eastern Goldfields Province (Fig.9), it suggests the type of variation that can be expected over the entire area. Various comparisons of results suggested that, of the various properties measured, the data on potassium feldspar are the most reliable, so these were used for regional mapping.

The study area can be divided into four zones on the basis of distribution of potassium feldspar (Fig.9). The western zone occupies the western half of the Boorabbin and Kalgoorlie sheets; the central zone lies along the eastern side of the Boorabbin and Kalgoorlie sheets; and the eastern zone trends north-northwestward across the eastern part of the Widgiemooltha sheet and central part of the Kurnalpi sheet. A fourth, northeastern, zone is suggested in the northeast corner of the Kurnalpi sheet.

The eastern and western zones are characterized by an abundance of potassium feldspar; the central zone has less potassium feldspar. The fourth zone, in the northeastern corner of the Kurnalpi sheet, also seems to have less potassium feldspar, but control is poor. The differences between zones are subtle in raw data, but striking on the trend-surface map (Fig.9).

Trend-surface analysis is a mathematical technique for extracting general patterns from data cluttered with random or interfering values. Trend-surface maps are plots of patterns generated by the trend-surface analysis of geographically distributed data. Care is needed in the interpretation of trend-surface maps, as even mathematically random data result in a map which may seem to have an interpretable pattern. The order of a trend-surface map is a statement of the complexity of the mathematical function used to generate the map, and determines the complexity of the pattern generated. The contours of a first-order, or linear, map are all straight, parallel lines, the contours of a plane showing the average direction and rate of increase of values. A second-order, or quadratic, map has a simple paraboloidal pattern. Very high order maps tend to duplicate the raw data in their complexity and are less useful than lower orders for drawing regional trends from geological data. Fourth-order maps

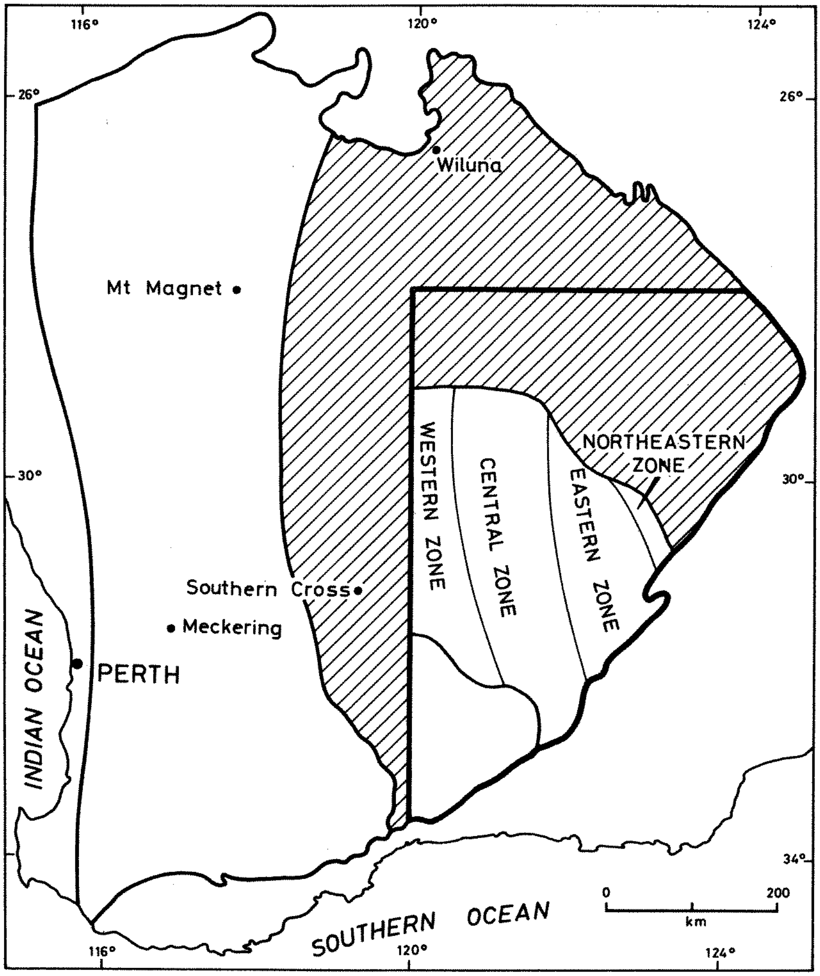

Figure 9. Area of study of potassium feldspar in stained slabs showing zones defined on abundance of potassium feldspar. (GSWA 17324)

normally have enough detail to pick out major trends but are simple enough so that the trends are not masked by detail.

A fourth-order trend-surface map (Fig.10) of potassium feldspar values in the area from which stained slabs were drawn shows well-defined north-northwesterly trends. The three zones suggested above are clearly shown, with abundant feldspar in the eastern zone, less in the central zone and more, again, in the western zone. A fourth zone, with less potassium feldspar, is suggested in the northeast corner of the map.

The line marking the maximum rate of change in abundance of potassium feldspar from high values in the western zone to lower values in the central

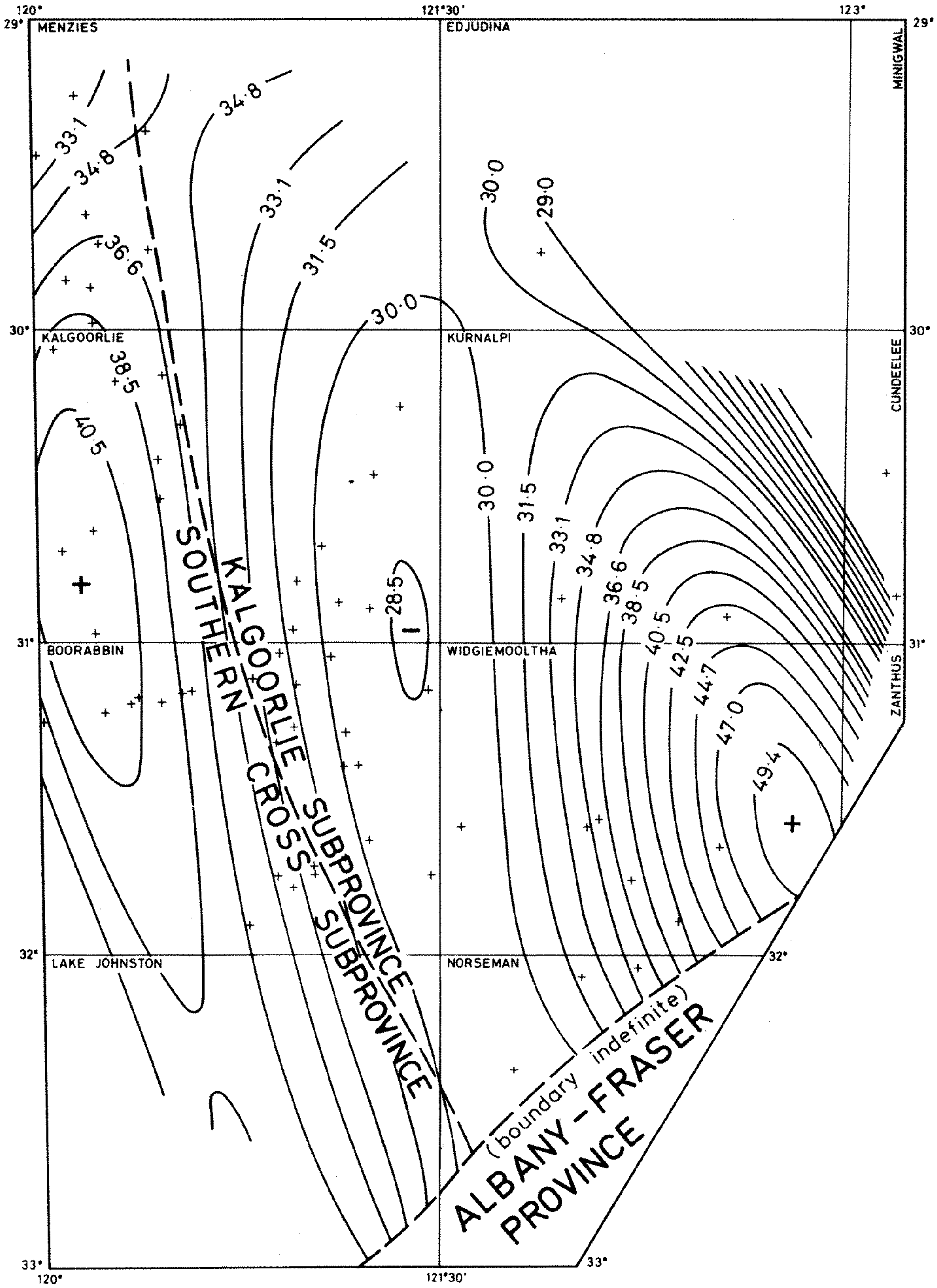

Figure 10. Trend-surface map on potassium feldspar. (GSWA 17325)

zone lies very close to the line drawn by Williams (1974) separating the Southern Cross and Kalgoorlie Subprovinces of the Eastern Goldfields Province.

Because the patterns of percentage potassium feldspar were obscure in the raw data, statistical tests were applied to the data to examine the significance of the differences from zone to zone. According to a test of the significance of the difference in means (t-test), the mean potassium feldspar content of rocks from the western zone differed from that of the central zone at the 99.75 per cent level of significance. This is a strong indication that the difference is real and justifies the distinction between the zones.

Early in the study it seemed that the western and central areas differed in scatter of values as well as in amount of potassium feldspar; the central zone seemed more heterogeneous. The statistical 'F' test measures the significance of differences in scatter (variance) between two sets of data. The 'F' test did not support the hypothesis that the variances of the western and central zones differed significantly, although the difference in variances of the western zone and the pooled central and eastern zones is significant at the 95 per cent level. This is to be expected if the central and eastern zones do indeed form separate populations. Means and standard deviations for each area are listed in Table 1.

TABLE 1. A comparison of potassium feldspar concentration in four areas in the Eastern Goldfields Province.

	Western area	Central area	Pooled central, eastern and southern areas
Number of samples, N	27	38	50
Mean K-feldspar, $\bar{x}$	30.56	25.34	26.45
Standard deviation, s	5.44	6.42	7.70
Variance, s^2	29.63	41.28	59.23

The western zone, rich in potassium feldspar, corresponds to the eastern part of the Southern Cross Subprovince of the Eastern Goldfields Province. The eastern zone corresponds to an axis of alkaline and quartz-poor rocks, the Leonora-Cowarna trend, described in an accompanying report (Libby, 1978) on alkaline granitoid rocks. Possibly the central zone, together with the small area of low values for potassium feldspar in the northeastern corner of the trend-surface map, is typical of the Kalgoorlie Subprovince. In this model the eastern zone, rich in potassium feldspar, is anomalous. This suggestion is supported by the anomalous alkaline petrographic character of the rocks of the eastern zone.

The western zone seems to correlate with the region of postkinematic intrusions of Bettenay (Binns and Marston, 1976); the gradient between the two zones corresponds roughly to the region of dynamic metamorphic domains, synkinematic granitoid diapirs and undifferentiated gneisses. The central zone corresponds roughly to Bettenay's static metamorphic domains.

REGIONAL GEOCHEMISTRY OF K_2O AND MgO

Chemical data on granitoid rocks from the Eastern Goldfields Province have been listed by Joplin, 1963; O'Beirne, 1968; Gower and Bunting, 1976; Thom and others, 1977; and Joplin, 1975. These analyses are scattered and most are accompanied by little discussion. However, Davy (1976, 1977) has considered at length the implications of 252 analyses generated from granitoid rock of the Leonora and Laverton sheets and the Archaean portion of the Rason sheet. The granitoids were analysed for trace elements, and Fe_2O_3, MgO, CaO, K_2O, Na_2O, TiO_2, and, except on the Rason sheet, SiO_2.

The area of the two and one-half sheets was divided by Davy into 6 zones separated by major tectonic lineaments. Average K_2O and MgO values progress sequentially from zone to zone. Lack of convincing evidence of similar trends within zones suggests that each inter-lineament zone is characterized by a particular 'granite' composition.

The detailed modal study of the present work is consistent with Davy's data. Both studies suggest that north-northwestward trending compositional zones are parallel to the north-northwest trending major tectonic discontinuities and belts of grossly similar lithology. Both studies are consistent with the proposal that abrupt changes in composition coincide with major tectonic lineaments.

Some care should be exercised in the comparison of the two studies as the general lithological character of the central and eastern belts changes from greenstone terrain in the area of the present study to granitic in the area studied by Davy.

DISTRIBUTION OF MINOR MINERALS

Whereas the distribution of major minerals establishes the general tectonic framework of the area, subtleties of petrogenesis or areas favourable for exploration for economic minerals may be shown by the distribution of minor minerals either within individual plutons or as characteristics of plutons of certain areas.

FLUORITE

Fluorite is widely distributed through the granitoid rocks and felsites of the Eastern Goldfields Province, but is particularly, generally, and abundantly developed in a few areas.

The largest area of high fluorite concentration is on the southwestern corner of the Menzies sheet, mainly west of the track from Mulwarrie to Mulline and south of a line from Mulline to Galah Rocks. All of the samples rich in fluorite are biotite adamellite. Quartz is abundant, and feldspar ratios are variable; either plagioclase or microcline may be dominant.

The plagioclase of the fluorite-bearing adamellite is dominantly sodic oligoclase ranging from An_8 to An_{17}, though epidote is common and the calcium content may originally have been slightly higher. Most samples are myrmekitic, and potassium feldspar is microcline with film perthite. Colourless mica is universally developed as sericitic alteration of plagioclase but is also common as discrete plates inside plagioclase and is less common as interstitial grains. Epidote is a common minor mineral. Persistent accessories include zircon, apatite and opaque minerals. Metamict allanite is present in 4 of the 17 samples studied. Pumpellyite and carbonate minerals are present in several samples as minor secondary minerals.

The texture of the fluorite-bearing rock dominantly is igneous or granitic; however, near the Ida Lineament metamorphic recrystallization has been imposed on the primary textures. Here the fluorite bearing granitoids are close to the 'dynamic metamorphic domains' and gneisses of Bettenay (Binns and Marston, 1976, Fig.7). The fluorite seems to have either survived significant recrystallization or postdated it.

The Boreas Adamellite at the north edge of the Laverton sheet is host to the other major concentration of fluorite. The Boreas Adamellite has been traced north from Mount Boreas in a belt up to 20 km wide for at least 50 km onto the Duketon sheet, and has been reported by Bunting (pers. comm.) from the middle of the Kingston sheet almost 200 km north of Mount Boreas. The five fluorite-bearing samples of the Mount Boreas unit on the Laverton sheet have a remarkably uniform composition, even though their texture varies from medium to very coarse grained. All are quartz-rich biotite adamellites, and microcline is dominant in all but one. The plagioclase composition ranges from An_{12} to An_{15}. All samples are perthitic and myrmekitic. Intergranular colourless mica and discrete, coarse mica grains within plagioclase as well as sericitic alteration of plagioclase are common. All samples have questionable metamict allanite, and all contain zircon, apatite and opaque minerals. Most samples are porphyritic. Microcline phenocrysts in some samples have inclusions of various minerals which are elongated parallel to the adjacent grain boundaries, suggesting incorporation of microlites during growth in an igneous environment. Further work on the geochronology, petrology and structure of the Boreas Adamellite is in progress.

SPHENE

Sphene is widely distributed in granitoids throughout the Eastern Goldfields Province, particularly as primary grains in rocks with plagioclase of intermediate composition, and as secondary grains associated with chlorite where chlorite has resulted from the alteration of biotite.

Primary sphene (Plate I) is particularly abundant in the northeastern part of the Laverton sheet, the southwestern part of the Edjudina sheet, and the northeastern part of the Widgiemooltha sheet. The latter two areas are in the Leonora-Cowarna trend of abundant syenite and support the suggestion that this is a distinctive petrogenetic province.

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Coloured sphene is particularly characteristic of the northwestern corner of the Laverton sheet and is scattered through the alkaline rocks of the Leonora-Cowarna trend.

ALLANITE

Small, irregular grains of metamict allanite (Plate IX) are difficult to distinguish from other metamict radioactive silicates. However, it seems clear that allanite is less widely distributed than sphene, but in rocks where it is identified it tends to be prominent.

Probable allanite is abundant in four areas. In the northeastern corner of the Laverton sheet allanite accompanies coarse-grained, orange-coloured sphene in a plutonic association consisting mainly of granite, but with less adamellite. The association is presumably rich in radioactive and rare-earth elements. Again on the Laverton sheet, most thin sections of the Boreas Adamellite at the north edge of the sheet contain questionable allanite, which is associated in this unit with abundant fluorite.

A third area with a small amount of allanite is the Leonora-Cowarna trend of alkaline felsites and granitoid rocks. This axis corresponds not only to the belt of syenitic rock but also to a similarly weak concentration of orange sphene and microcline-rich granitoids.

The fourth area is larger but more diffuse; it includes a large belt along the western edge of the study area; that is, the western third of the Leonora and Menzies sheets, the western half of the Kalgoorlie sheet and much of the Boorabbin sheet. This area includes the granitoids lying west of the Coolgardie-Mount Ida arm of the Kalgoorlie greenstone belt and is largely restricted to the granitoids of the Southern Cross Subprovince of the Yilgarn Block as defined by Williams (1974). The northern part of this area, at least, is characterized by fluorite as well as allanite.

Allanite seems to favour granite (strictly defined) and seems to be associated with fluorite, and with sphene which has unusual colour.

DISTRIBUTION OF TEXTURES

Textural categories were described in the section on textures. When samples with these textures are plotted on a map only vague, ill-defined trends appear, presumably because of both the great spacing of samples and the subjective nature of the data.

Several of these weak patterns may have petrogenetic significance. In Figure 11 the region has been subdivided into several areas. Each area is characterized by a dominant texture. Some of these areas correspond to mapped geological units, others do not.

The most obvious textural trend is the belt of gneissic rock from near Norseman northward along the west side of the Kalgoorlie greenstone belt and along the Ida Lineament to the Lawlers Anticline near Agnew at the north edge of the Leonora sheet (Fig.11, area I). Both deformational textures and varied lithology, including gneiss and greenstone, follow this trend. This belt corresponds to the zones of dynamic metamorphic domains and undifferentiated gneiss, migmatite and synkinematic diapirs of Bettenay (Binns and Marston, 1976, Fig.7).

In the south part of the belt, the gneiss seems to be exposed in a discontinuous series of gneiss domes at the southwestern edge of the broad greenstone belt centred approximately on Kalgoorlie. These correspond to the 'synkinematic granitoid diapirs' of Bettenay (Binns and Marston, 1976).

Northward, the gneiss seems more continuous east of an arm of the greenstone belt from Coolgardie to Mount Ida and east of the Ida Lineament (Kriewaldt, 1970, p.5; Thom and Barnes, 1977, Fig.2; and Binns and Marston, 1976, Fig.7). However, even in this area there may be domal elements; an example of this is the pattern on the Menzies sheet (Kriewaldt, 1970) about 20 km east of the physiographic Mount Ida. Gneissic samples 17623 and 17626 (Menzies) are from this ovoid area of "granite" and "gneissic granite".

Looking again at the gneiss domes in the south, sample 41478 (Widgiemooltha) is from Fifty Mile Rock on Pioneer Dome and sample 41475 (Boorabbin) is from Depot Rocks on Spargoville Dome. Northward along the Coolgardie-Mount Ida arm of the greenstone belt, samples 17650, 17651 and 17652 (Menzies) are west of the Coolgardie-Mount Ida arm, sample 17625 (Menzies) seems to be from within the greenstone and samples 17623 and 17626 (Menzies) were mentioned above from a possible dome on the east side of the greenstone.

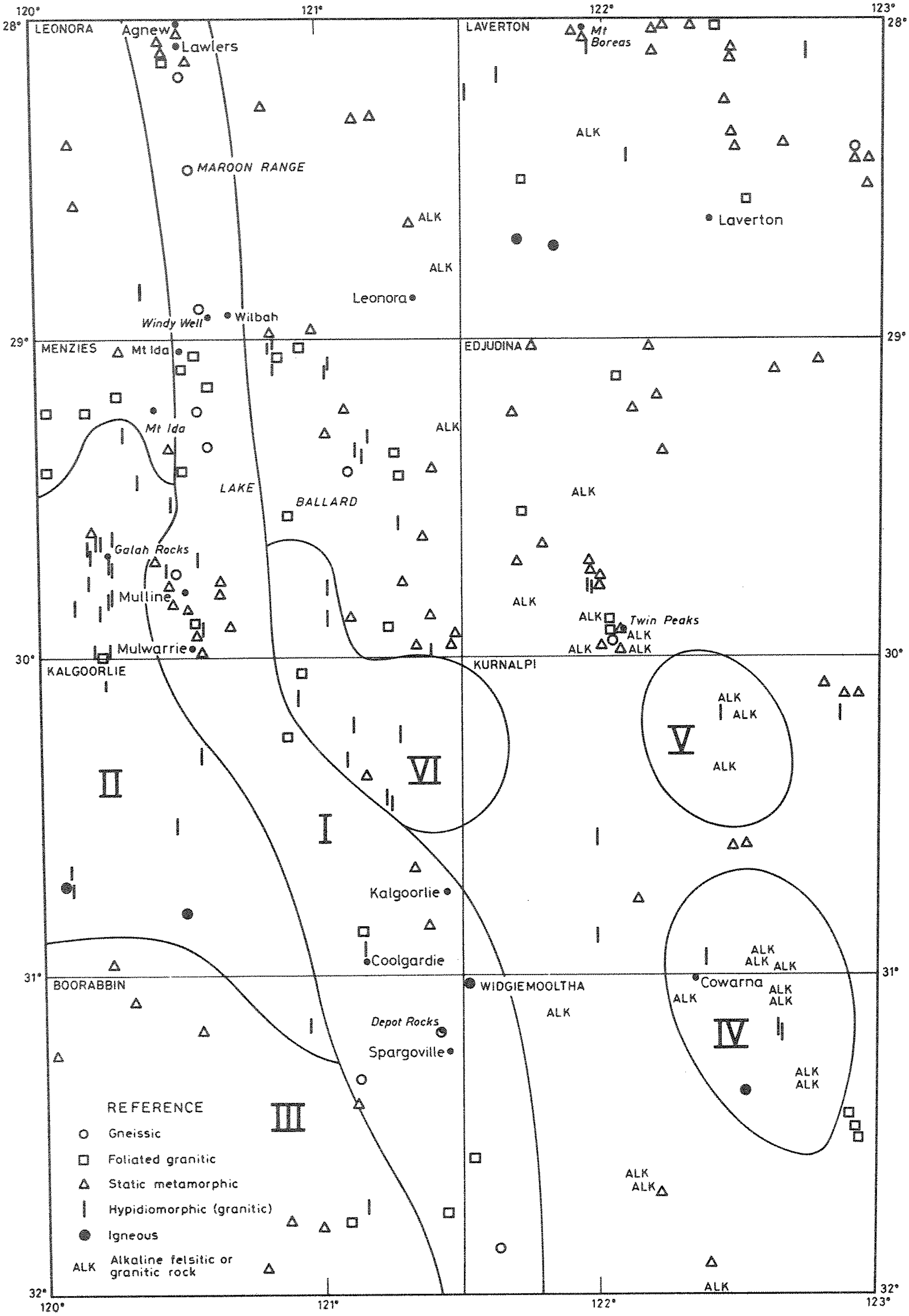

Figure 11. Textural trends.

I. Gneissic trend

II. Igneous and hypidiomorphic textures west of the gneissic trend

III. Statically metamorphosed granitic rocks of the Boorabbin map sheet.

IV, V, & VI. Ill-defined areas of hypidiomorphic granular and igneous textures. (GSWA 17326)

Northward on the Leonora sheet, garnet-bearing sample 40575 is from the broad gneissic area in the vicinity of Windy Well. Samples 39805 and 39806 (Leonora) from the Maroon Range are a kyanite-bearing schistose phase of the gneissic sequence east of the Ida Lineament. The northernmost gneiss found in this area is sample 32708 (Leonora) in the core of the Lawlers Anticline (see Davy, 1978 for chemical analysis).

The quartz-rich, garnet-bearing gneiss of Windy Well and the kyanite-bearing rocks at the Maroon Range suggest that some of the gneiss may be metasedimentary.

Gneisses outside the Norseman-Agnew gneiss belt seem isolated because of the great spacing of samples.

West of the Coolgardie-Mount Ida greenstone arm in the south part of the Menzies and north part of the Kalgoorlie sheets, granitic textures predominate, suggesting igneous granitoids with little metamorphic recrystallization (Fig.11, area II). This is the region rich in fluorite and may be a single batholithic mass or a suite of small related granitic plutons.

South of area II, still west of the gneiss and greenstone belt, static metamorphic textures predominate (Fig.11, area III) through much of the western two-thirds of the Boorabbin sheet. Isotropic crystalloblastic textures interspersed with granitic and weakly gneissic textures continue southward into the Lake Johnston sheet which was not studied in detail.

Areas IV, V and VI in Figure 11 are characterized by granitic to igneous textures but are ill defined. Areas IV and V lie on the southern part of the Leonora-Cowarna trend and may reflect the little-recrystallized igneous origin of that zone. But this igneous trend is interrupted by granofelsic to gneissic metamorphic rocks in the complex near Twin Peaks on the Edjudina sheet.

Thus, textural mapping has outlined one metamorphic trend of regional significance, and has suggested regional tendencies in a few other areas, but sample spacing seems too great at this scale to show trends in the rest of the area.

CONCLUSIONS

The granitic rocks of the Eastern Goldfields Province are clearly not a single homogeneous mass, but are variable both in composition and texture. Compositional trends tend to follow tectonic trends represented by the greenstone belts and tectonic lineaments. Tectonic subprovinces seem to be characterized by recognizably different bulk mineralogical composition.

The degree of deformation and recrystallization is as variable as the composition. Mild to severe penetrative deformation and recrystallization has affected most rocks of the area. Wide distribution of prehnite, pumpellyite, carbonate, and epidote suggests widespread metamorphism of granitoid rocks at low grades; local garnet gneisses indicate more restricted belts of intense metamorphism. The possibility of regional metamorphic mapping on the basis of secondary mineral assemblages deserves further study.

Considering the amount of compositional and structural information contained in the granitic rocks, an understanding of the history of the granitic units would seem to be critical to an understanding of the tectonics of the Eastern Goldfields Province.

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APPENDIX

LOCATION OF SAMPLES

Samples are located according to 1:250 000 sheets and the Australian Transverse Mercator Grid, in yards. The first digit of each coordinate indicates hundreds of thousands of yards. Four-digit coordinates have a precision of 100 yards, three-digit coordinates, 1000 yards. Accuracy is somewhat less. Letter suffixes have been omitted.

BOORABBIN	
41409	298-/132-
41475	445-/144-
EDJUDINA	
15507	4727/3773
24808	5029/3159
24831	4764/3049
24832	5021/3190
40807	423-/079-
KALGOORLIE	
9121	413-/261-
9155	392-/257-
KURNALPI	
2364	519-/191-
6852	556-/213-
11099	571-/167-
LAVERTON	
29964	4552/4993
31131	587-/475-
31142	610-/464-
38143	522-/524-
39003	4766/4434
LEONORA	
32708	3474/5054
38327	4172/4808
39805	3500/4700
39806	3500/4700
39812	4480/4150
40575	357-/415-
41480	341-/515-
MENZIES	
17606	2970/3559
17609	3325/3505
17614	3214/3075
17616	3065/3048
17617	3468/3938
17620	3825/4030
17623	3530/3780
17625	3570/3644
17626	3573/3873
17641	Not available
17650	3452/3175
17651	3452/3175
17652	3454/3170
17655	3365/3217
17656	3318/3262
MENZIES (cont.)	
17660	Not available
17662	3200/3206
17681	4170/3681
17686	4005/3095
17693	4248/2963
20979	4088/3246
WIDGIEMOOLTHA	
41478	466-/058-

P L A T E S

PART II

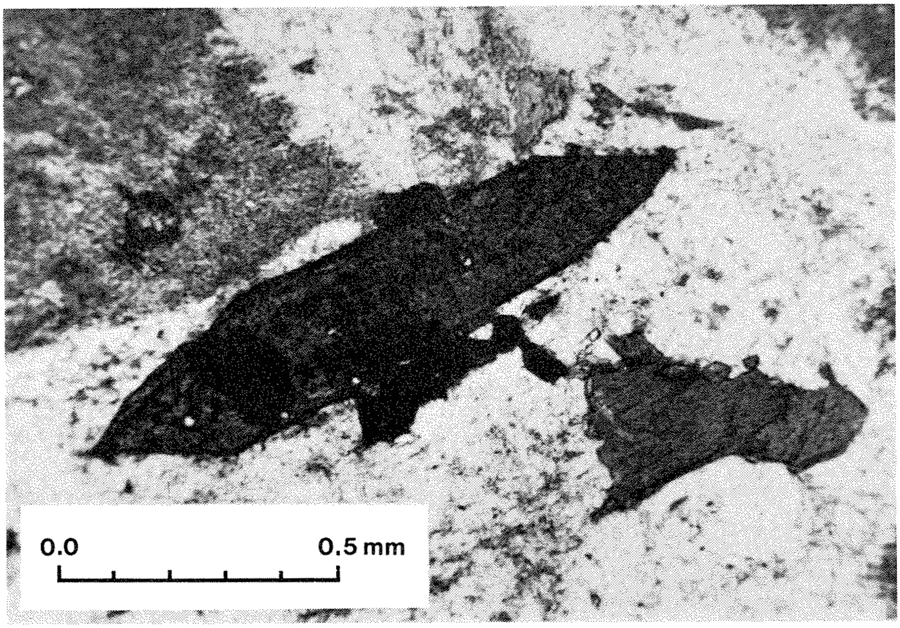

Plate I. Sphene, euhedral.

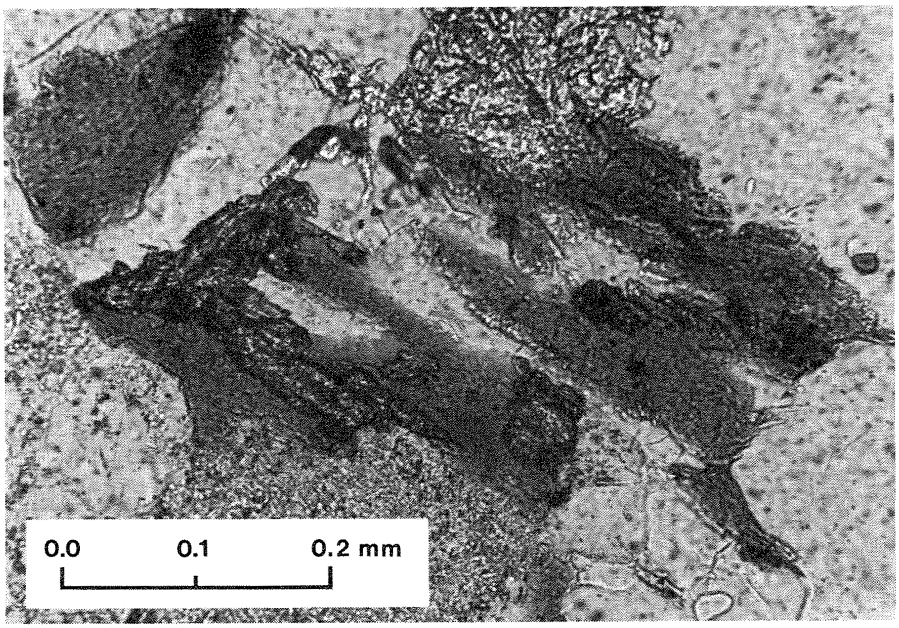

Plate II. Secondary sphene in chlorite.

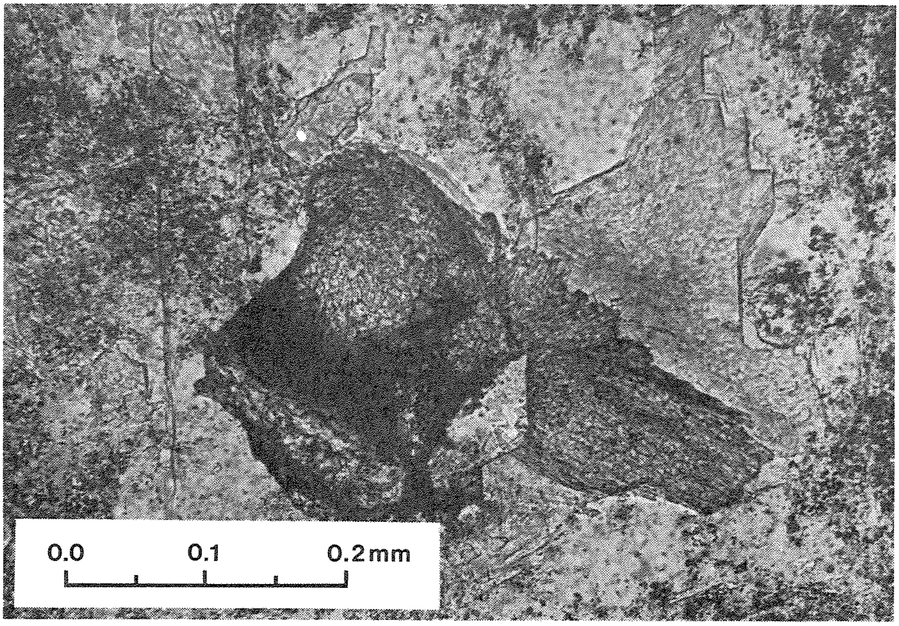

Plate III. Pumpellyite.

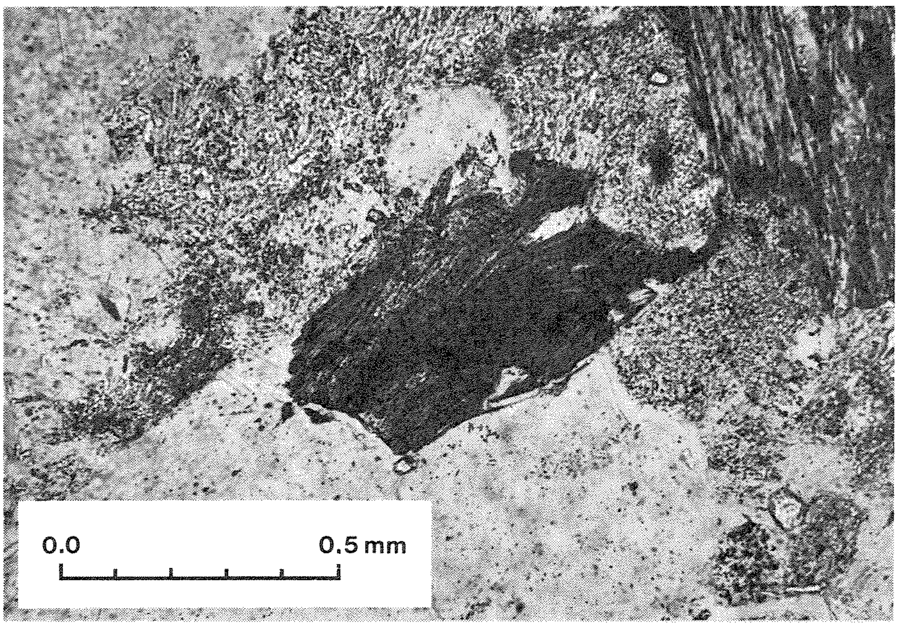

Plate IV. Pumpellyite.

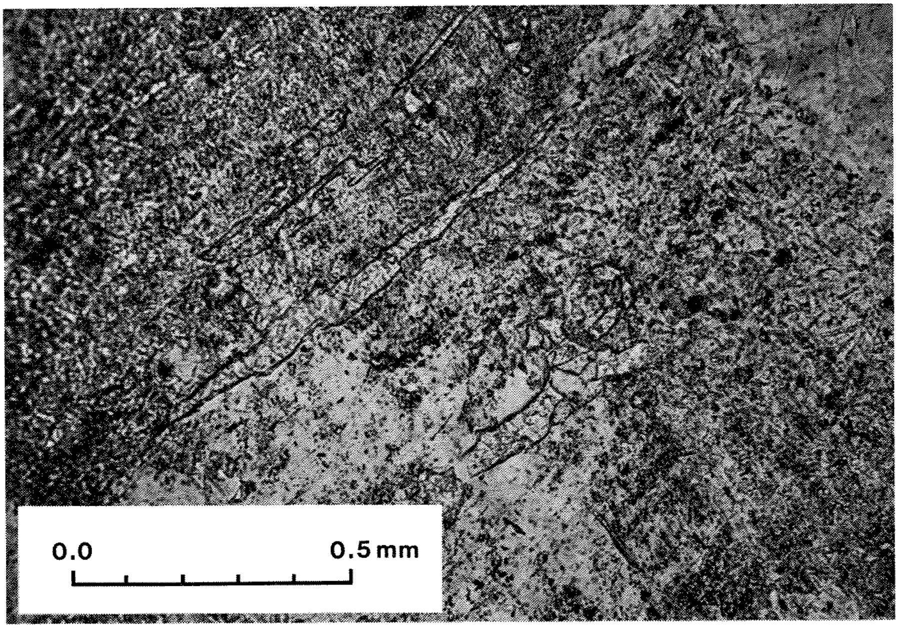

Plate V. Fluorite, veins along plagioclase cleavage.

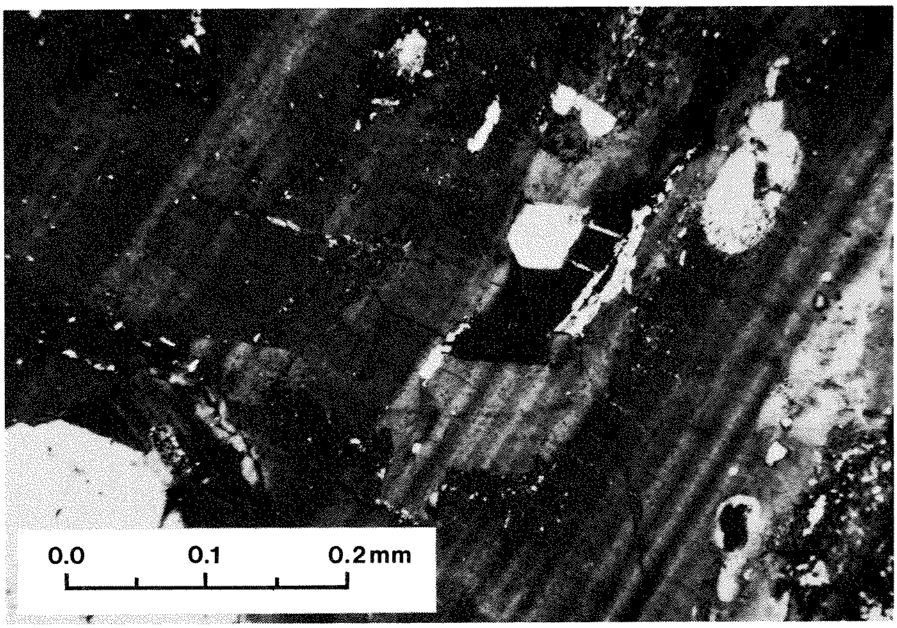

Plate VI. Fluorite in plagioclase.

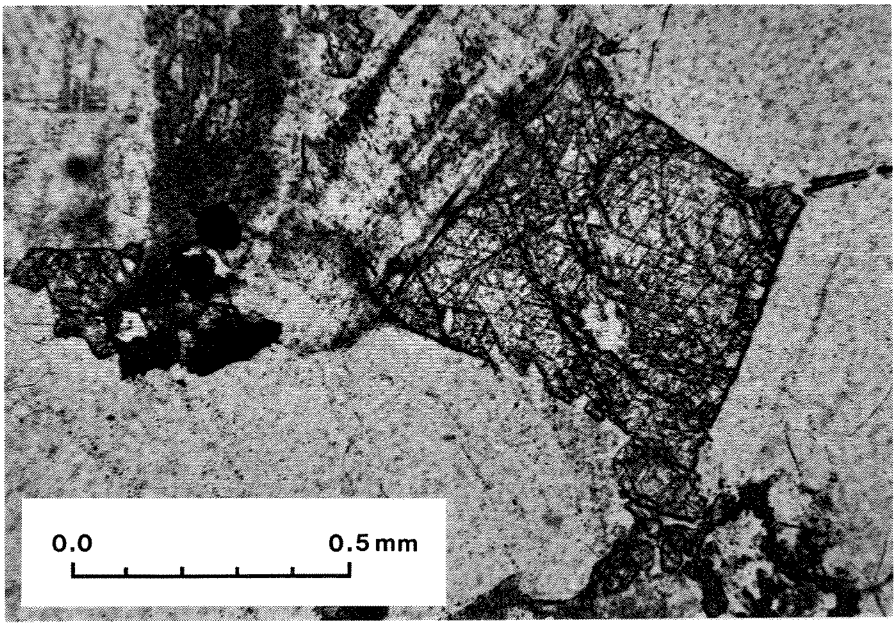

Plate VII. Fluorite, interstitial.

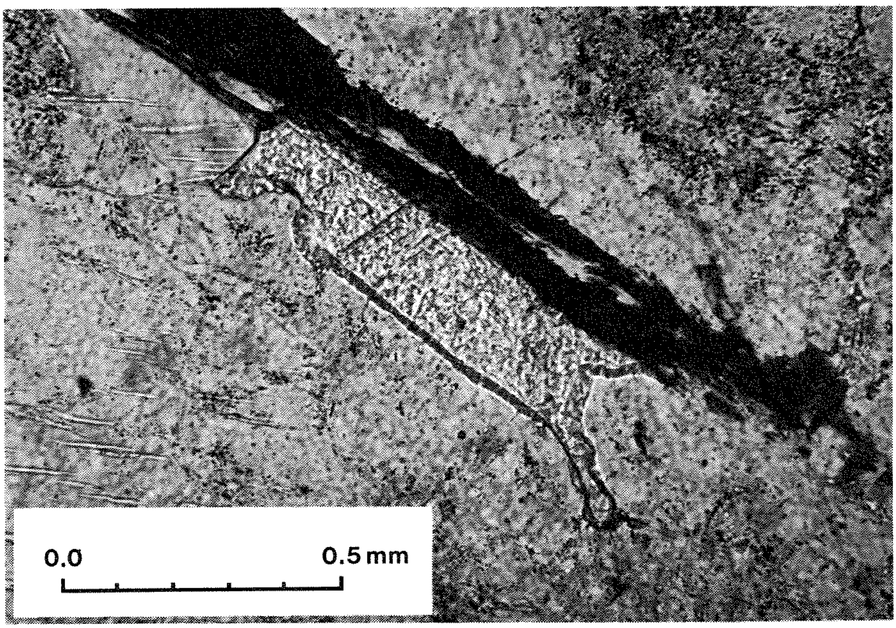

Plate VIII. Fluorite with biotite.

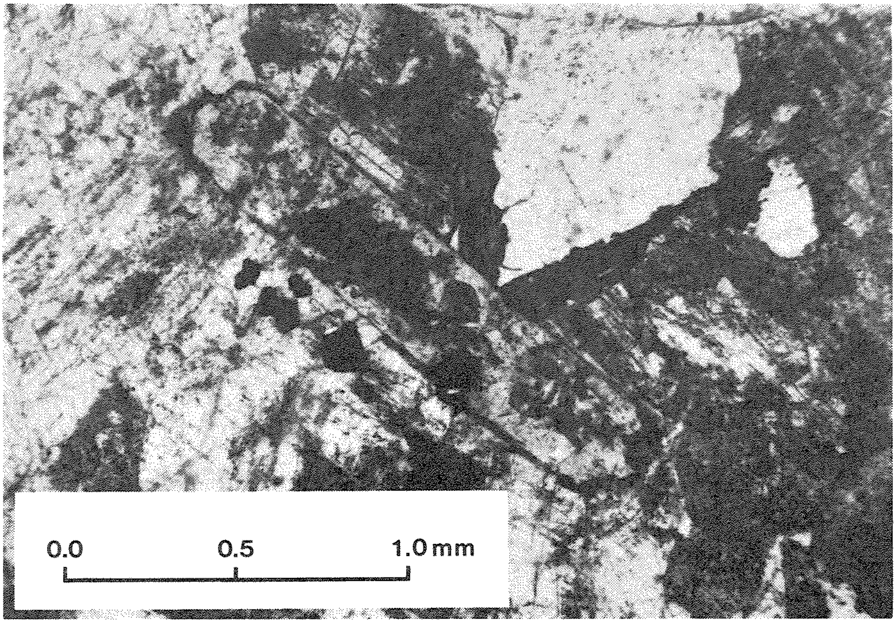

Plate IX. Allanite, metamict.

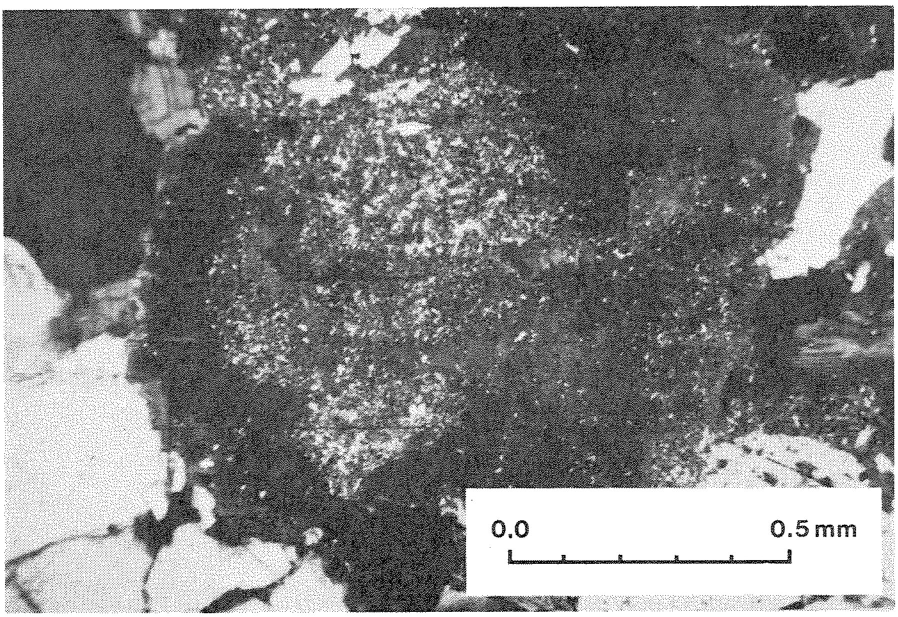

Plate X. Alteration of plagioclase core with reversal of relative core-rim composition.

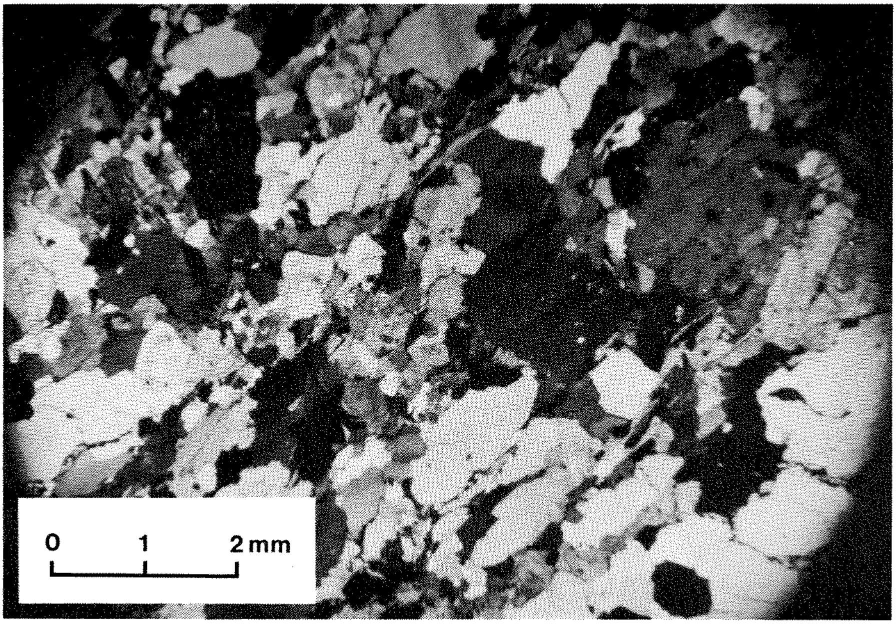

Plate XI. Gneissic texture.

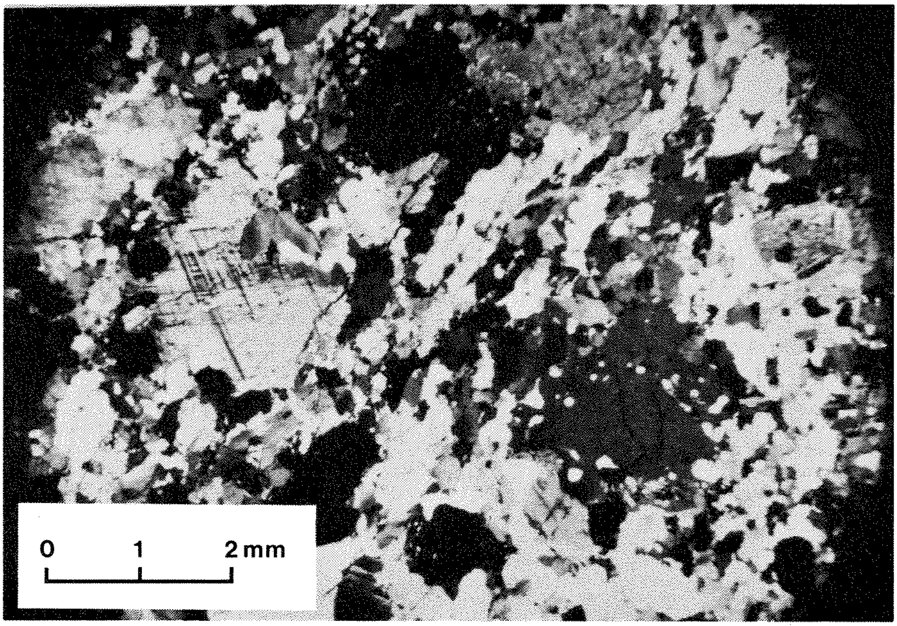

Plate XII. Foliated granitic texture.

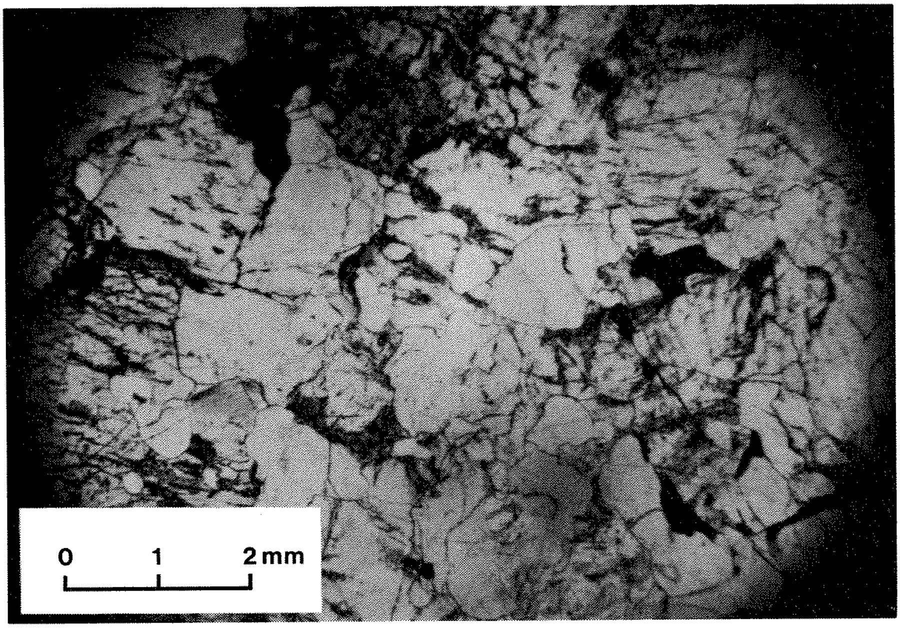

Plate XIII. Static metamorphic texture, plain light.

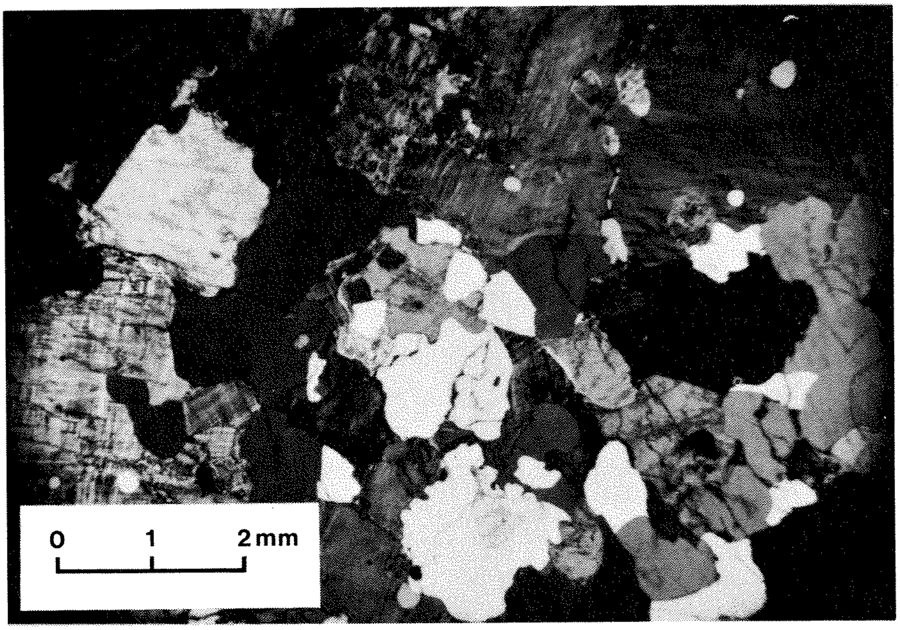

Plate XIV. Static metamorphic texture, crossed polarizers.

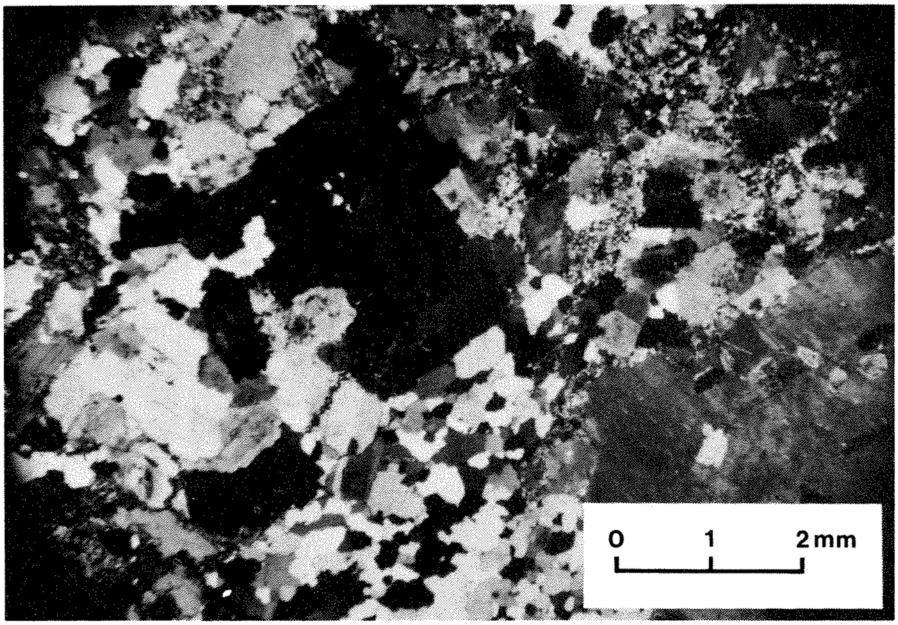

Plate XV. Cataclastic granitic texture.

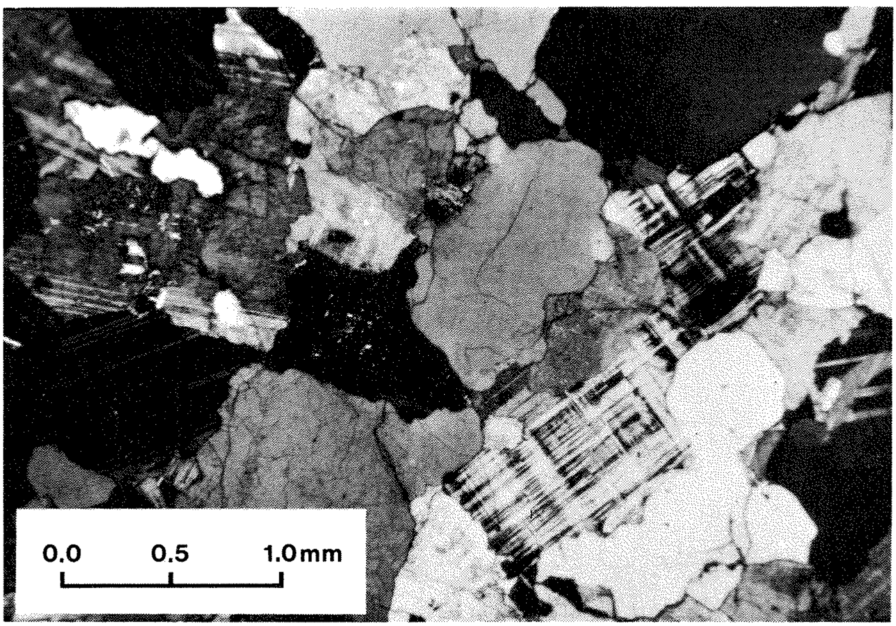

Plate XVI. Transition texture between static metamorphic and hypidiomorphic-granular texture.

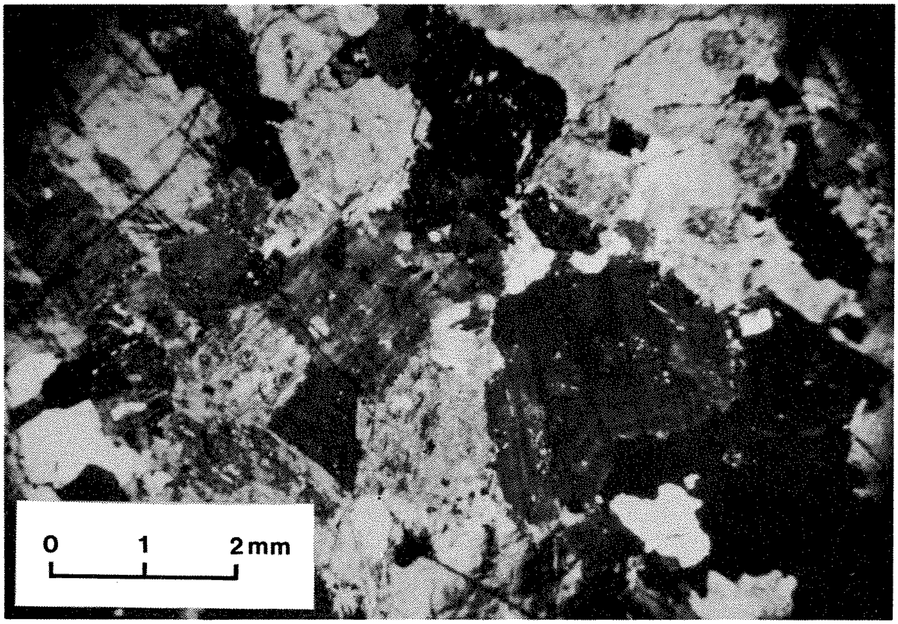

Plate XVII. Hypidiomorphic-granular texture.

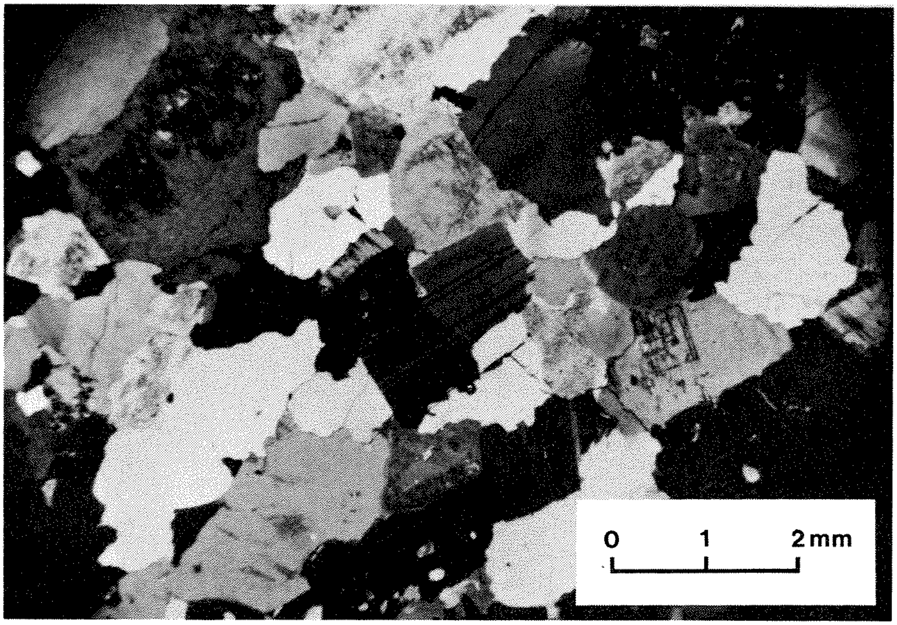

Plate XVIII. Hypidiomorphic-granular texture, exceptional development.

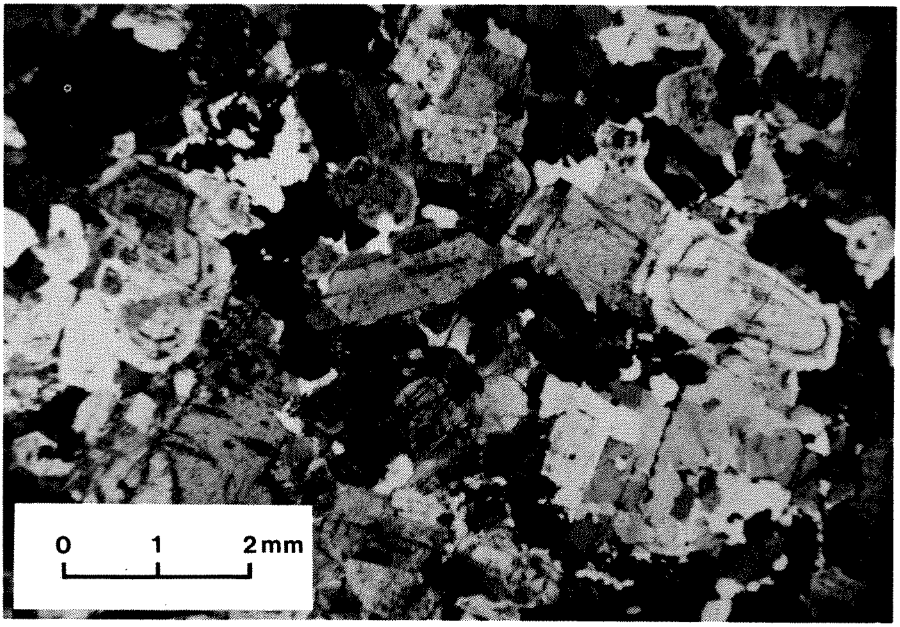

Plate XIX. Igneous texture.

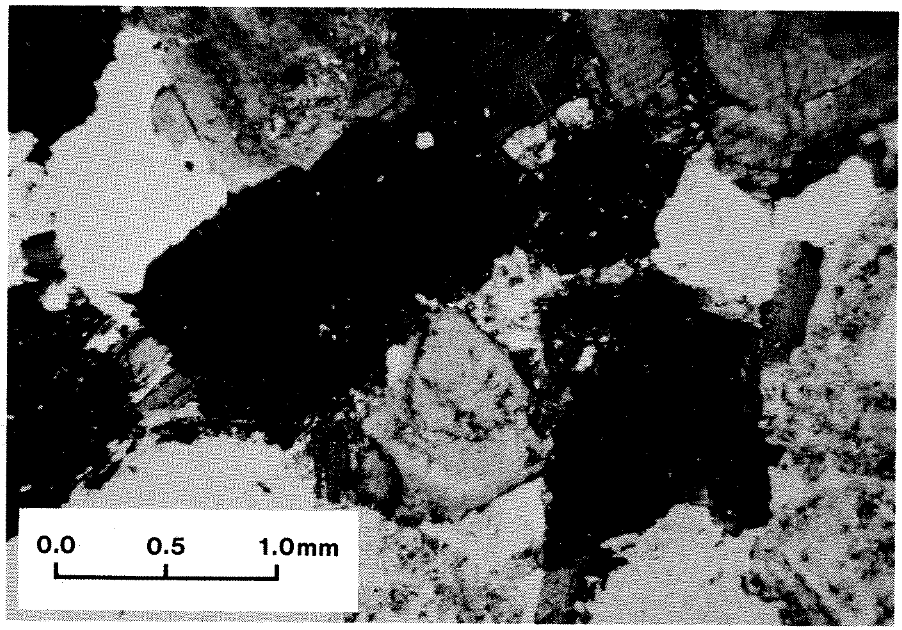

Plate XX, Igneous texture.

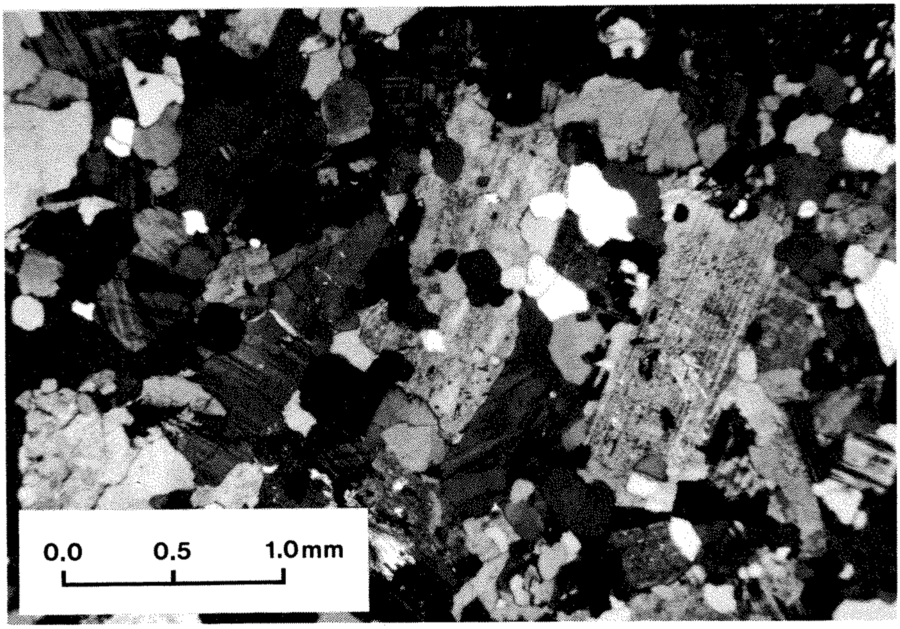

Plate XXI. Blebby quartz, suggesting recrystallization.

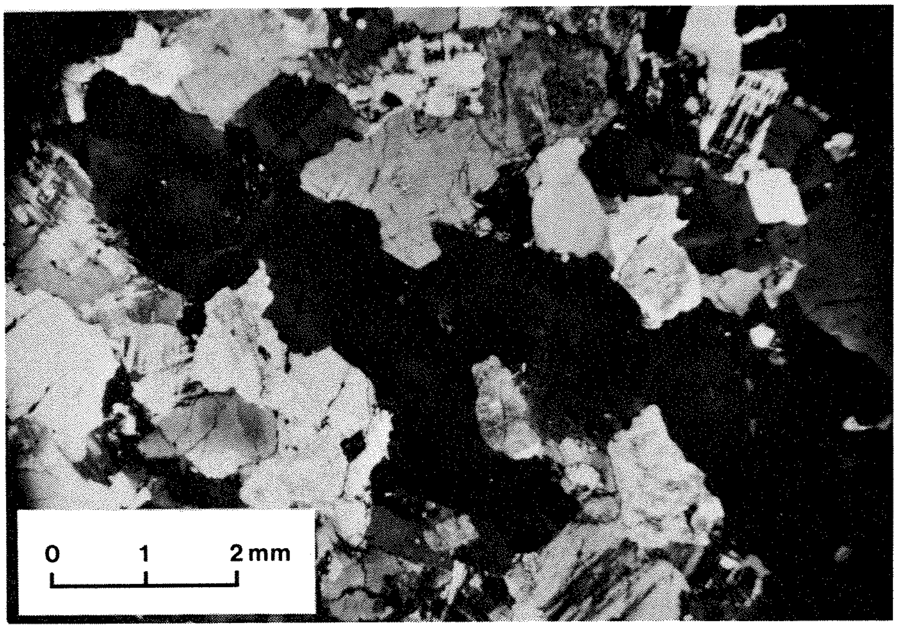

Plate XXII. "Sea" of coarse, sinuous quartz.

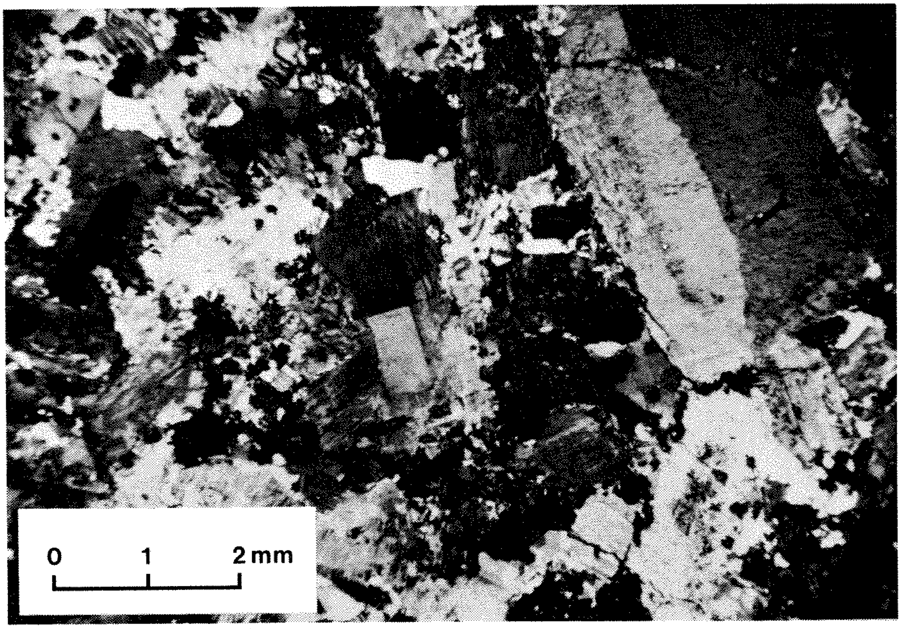

Plate XXIII. Seriate texture, possibly secondary.

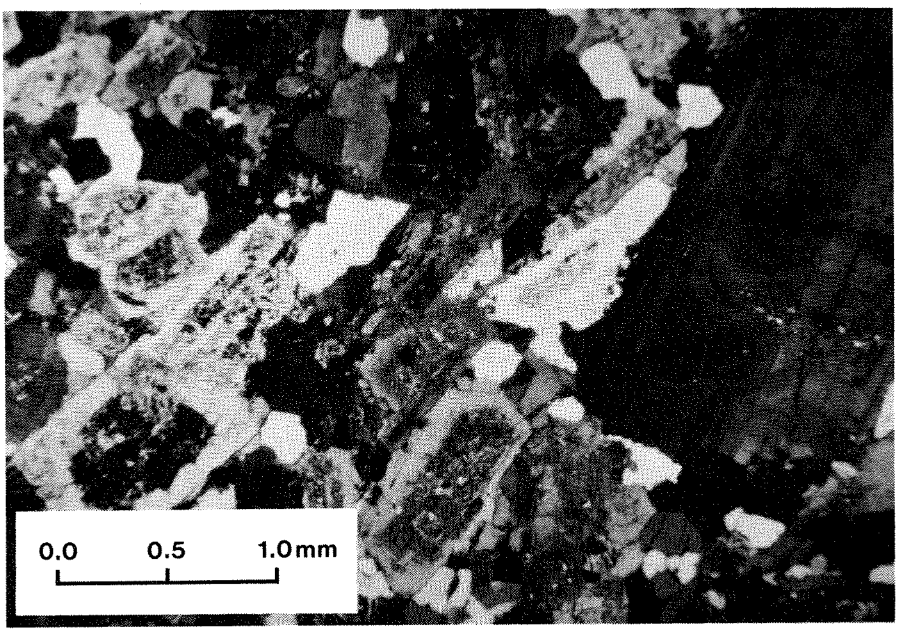

Plate XXIV. Seriate texture, probably primary.