174

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Order-Disorder in Coexisting Plagioclase and Alkali Feldspar from the Mineral Range of Southwest Utah

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by

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ABSTRACT

Estimates of degree of order were made on 30 chemically-analyzed pairs of coexisting alkali and plagioclase feldspars sampled transverse to the granitic Mineral Range pluton of Southwest Utah. The degree of order is estimated from measurements of certain X-ray (powder diffraction) reflection separations or the optic angle (2Vx) or both. Chemical analyses were obtained mainly by X-ray Emission Spectroscopy; sodium was determined by Flame Emission Spectrophotometry.

The orthoclase phase of the alkali feldspar is significantly less ordered than coexisting plagioclase. This difference is discussed in terms of the Arrhenius relationship, $K = A e^{-E/RT}$, assuming that the temperature of inversion for orthoclase is lower than that of plagioclase and/or that E for the orthoclase inversion is higher than E for the inversion of plagioclase. In either case the rate of inversion for orthoclase would probably be significantly less than that of plagioclase and may explain the difference in degree of order between the two feldspars.

Crystallization or post-crystallization confining pressures may favor ordering in Na-plagioclase rather than the coexisting orthoclase. Recent experimental work indicates a significant difference in unit-cell volumes between the disordered and ordered (smaller cell volume) polymorphs of the Ab-rich alkali feldspars but no significant difference between the orthoclase rich polymorphs.

The variations in degree of order among the potassium feldspars and among the plagioclase feldspars are not observedly related to the present borders of the pluton. Higher order in the plagioclase is associated with increasing fractionation but variations in order among the potassium feldspars cannot be correlated with any data gathered in this report. Thus plagioclase may fingerprint crystallization conditions much better than coexisting potassium feldspar and the effective inversion temperature of potassium feldspar may be significantly lower than its crystallization temperature.

Plagioclase rims are consistently more ordered than the corresponding cores. This is expected because ordering in the plagioclase studied increases with increasing fractionation, and recent experimental work shows that Na-rich plagioclases order more rapidly than Ca-rich plagioclase.

Estimated relative amounts of exsolved Ab in the alkali feldspars increase regularly with the Na content calculated from the chemical analyses but is not related systematically to order-disorder variations in the orthoclase phase.

Some results and conclusions derived from the analytical procedures used in this study may be of general interest.

1. Separation of quartz from oligoclase by metallurgical flotation is practical in geologic problems.
2. Estimation of quartz percentages in quartz-plagioclase mixtures with X-ray diffraction is a reliable technique.
3. An values for plagioclase determined by the 2θ (111)-2θ (1$\bar{1}$1) are consistently higher than those calculated from the chemical analyses.
4. X-ray spectrographic determinations of minor or trace amounts of Fe, Rb, Sr, and Ba varies significantly with sample weights.
5. The time and effort necessary for making synthetic standards is more profitably spent in obtaining natural standards.

TABLE OF CONTENTS

ILLUSTRATIONS

Figure Page

Illustrations-Continued

Figures in Appendix A

LIST OF TABLES

Tables in Appendix A

INTRODUCTION

The original purpose of the writer was to study order-disorder variations in coexisting feldspars (alkali and plagioclase) from granitic plutons of varying sizes, shapes, and depths of intrusion. It became evident soon after a summer of field sampling, corresponding with petrologists, and becoming aware of necessary laboratory techniques that the study was too broad, and so it was narrowed down.

The purpose of the study outlined in this paper is to relate observed variations in degree of order in coexisting feldspars from a granitic pluton to their crystallization or post-crystallization history inferred from compositional, petrographic, and field data. The Mineral Range of southwestern Utah was chosen for study because it promised to give results which could be reasonably interpreted. It is for the most part structurally and compositionally homogeneous yet may vary from epizonal on the east to katazonal on the west.

Two most interesting (related) results which appear to emphasize the hazards of detailed petrologic or geologic interpretation based solely on study of one mineral group emerge from this study. These are: the apparent large difference in degree of order between coexisting feldspars which probably formed at about the same time and under similar conditions; and the role played by crystallographic and chemical features peculiar to each mineral in the development of the degree of order recorded.

The concept of order-disorder in the feldspars goes back to Barth's (1934) suggestion that polymorphism among the potassium feldspars is apparently related to interchange of silicon and aluminum atoms among the tetrahedral sites. The exact physical meaning of order in the feldspars is unknown; furthermore, it appears to be different between feldspars with different Si:Al ratios. The feldspars studied in this paper, alkali feldspars and Na-rich oligoclase, are structurally similar and have a Si:Al ratio of 3:1, or close to it. Therefore, we can generalize briefly about the physical meaning of order. If maximum order prevails, almost all the Al atoms are concentrated on the average at one tetrahedral site, but are distributed at random among the tetrahedral sites for those feldspars with minimum order. Thus we can visualize two limiting structures; one with a maximum degree of order (100% order) and one with a minimum degree of order (0% order) with perhaps an infinite number of structural variants (polymorphs) in between.

Terms or phrases like structural state, thermal state, obliquity, triclinicity, volcanic and plutonic, are all used to describe what appear to be structurally different feldspars and are generally correlative with the concept of order. The phrase "degree of order" is used herein because it has no genetic connotations and expresses descriptively what is perhaps the dominant mechanism of feldspar polymorphism.

The mechanism of ordering or disordering (polymorphism) in the feldspars may be diffusive, displacive, substitution related to the large cations, or a combination of all three. The consensus is that diffusion (migration of Si and Al atoms among tetrahedral sites) is dominant because of generally continuous changes associated with feldspar polymorphism.

In this paper, estimations of the degree of order in percent are based on certain X-ray reflections and the optic angle, $2V_X$. It is generally assumed that these parameters probably reflect degree of order although I am aware of only a single instance of direct correlation; that between optic angle and degree of order for the potassium feldspars (Finney and Bailey, 1964).

This report is divided into four main parts. The first three parts; procedures and techniques, the geology of the Mineral Range, and the interpretation of results are treated in that order and form the main body of the report. The discussion on the chemical analyses and the petrography of the samples are included as Appendix A and B respectively. All illustrations except for a few extra large ones and those relating to the chemical analyses are given at the end of the main body.

I am grateful for financial, personal and professional help which contributed to this study. Two Grants-in-Aid of Research from the Society of the Sigma Xi provided travel funds for collecting samples and funds for two silicate analyses. Funds from five Research Grants-in-Aid from the Mackay School of Mines defrayed the costs of necessary laboratory supplies and some partial chemical analyses.

Professor Alex Volborth, of the Nevada Mining Analytical Laboratory, allowed me to use his sample preparation, X-ray fluorescence, and wet chemical laboratories. Harold Vincent, chemist for the NMAL, performed two silicate analyses in addition to many single analyses. Paul Weyler, chemist for the NMAL, operated the Flame Photometer and Atomic Absorption units for determination of Na and Mg respectively. Both men helped me with wet chemical procedure and in interpreting discrepancies among some of the chemical analyses.

Brent Fabbi, research assistant at the NMAL, helped in the operation of the X-ray Fluorescence unit and in the interpretation of some of the calibration curves.

Dr. Frank Bowdish, Professor of Metallurgy at the Mackay School of Mines, showed me how to successfully float quartz from oligoclase.

The faculty and staff of Pomona College at Claremont, California kindly allowed me to use their geology library.

Lucy, my wife, checked many of my calculations, arranged the material for the tables, and typed the first draft.

Professor David B. Slemmons made me aware of the attractive problems of feldspar mineralogy. This research resulted from my association with him.

PROCEDURES AND TECHNIQUES

This section is concerned primarily with the sequence of work involved in producing clean feldspar fractions, X-ray diffraction and optical techniques, and the determination of Anorthite content.

Obtaining Clean Feldspar Fractions

After making one thin section from each sample to be studied, 75 to 150 grams of material was broken from each sample with a steel G-pick. The resulting fragments were reduced to pea-size in a diamond (iron) mortar, screened, and portions of the plus 115 mesh fraction ground on a mull board until about 40 grams were obtained on a 250 mesh screen. The 40 gram samples were deslimed by decanting with ordinary tap water until the decantate was clear. The wet samples were dried overnight or for several hours in an oven. The magnetic fraction was then removed from each sample with a Frantz Isodynamic Magnetic separator (Model L1, 125 v, 1.84 amps max.); ordinarily little or no magnetic material was recovered after three runs. The samples then consisted largely of feldspars and quartz. Next a flotation cell was prepared consisting of a small milkshake-like mixer equipped with an automatic stirrer. Air for the cell was supplied through a plastic tube. Samples were conditioned for flotation with HF at pH 3 for five minutes. A few drops of a 1% solution of Alamine (4-Laural Primary

Amine) were added to the conditioned sample as a floating agent and each sample run was floated five times. The results (Table 1) show that quartz in excess of three percent is present in only two of the seventeen samples floated. Samples 3706 and 3716 contain 12 and 24 percent quartz after flotation. The only recorded change in procedure for these two samples is in the pH. The pH at the beginning of flotation for samples 3706 and 3716 was 2.7 and 3.0 respectively, and at the end of flotation 3.8 and 4.2. The pH range at the beginning of flotation for the remaining fifteen samples was 2.2 to 2.6 and at the end of flotation 2.4 to 3.6. The poor results on the above two samples may thus be due to inadequate pH control.

Quartz was separated from the feldspars in only seventeen of the thirty-two samples studied; however, the effectiveness of the separation was unknown and it seemed inadvisable to risk losing substantial amounts of the already small samples.

The next step involved separation of alkali feldspar from the plagioclase or plagioclase plus quartz fractions (for those samples containing quartz) with heavy liquids. No attempt was made to separate quartz from the plagioclase with heavy liquids, because many of the plagioclase fractions studied are in the quartz density range. The heavy liquid was prepared by mixing technical grade diethylene glycol or butyl "Carbitol" ((2-beta-butoxyethoxy) ethanol) and acetylene tetrabromide (tetrabromoethane) with densities of 0.95 and 2.96 respectively at 20 degrees centigrade.

The density desired was first approximated by the density curve of Dr. Lon S. McGirk of the Mackay School of Mines. Then by adding small volumes of diethylene glycol the desired density was obtained exactly by trial and error with a 25 ml pycnometer which had been previously calibrated with de-aerated (boiled) distilled water. The temperature of the laboratory varied by several degrees while the work was in progress so that all densities measured were corrected to 25 degrees centigrade using the temperature coefficient of pure acetylene tetrabromide (0.0017 per degree Centigrade). All density changes recorded for runs of days and weeks duration were less than .006 gr/ml. The sensitivity of the method used is about .001 gr/ml.

The samples were placed first in separatory funnels containing about 100 milliliters of liquid with density 2.588 (or 2.593 for 9 samples) to separate alkali feldspar from the plagioclase and quartz fraction. The samples varied from 8 to 30 grams and passed a 115 mesh but not the 250 mesh screen. Then the plagioclase and quartz fraction was placed in heavy liquid 2.775 and the alkali feldspar fraction in heavy liquid 2.530 for further separation from other minerals. The "lights" obtained from the alkali feldspar fraction in liquid 2.530 are insignificant but the "heavies" from the plagioclase and quartz fraction in liquid 2.775 ranged up to 2 grams with two important exceptions; samples 3707 and 3710. The heavies from these samples constitute about 20 and 4 grams respectively. The chemical analyses show abnormally high percentages of Fe, Ba, and Rb for both feldspar fractions from sample 3710 and for the plagioclase fractions from sample 3707. Perhaps this accounts for the large yield of "heavies" from these two samples. In addition the high percentage of heavy elements in the plagioclase fraction of 3707, the high K content, and the abnormally low Ca content suggest that the alkali feldspar fraction sank with the plagioclase in initial separation with liquid 2.588. This may be the reason for the low yield of alkali feldspar in the initial separation (less than .1 g) and hence no pellet 3707Ks. The percent alkali feldspar impurity in the plagioclase fraction of 3707 as estimated by grain count (Fig. 1) is normal and does not support the suggestion given above. However, chemical analyses of samples 3707 and 3710 were not used in geologic interpretation, although they were used to define some of the calibration curves in Appendix A.

During the sink-float procedure, the heavy and light fractions in each funnel were manually stirred with a glass stirring rod to obtain the best possible separation. Each fraction was stirred in a manner such that the other fraction was least disturbed. After six to twelve stirrings per sample, I observed no net sinking or rising of grains in the liquid and recovered the heavies from the bottom of the funnel. In a few of the samples small amounts of material remained in suspension in the liquid even after settling for several days. The suspended material was drained off with the heavies. The fractions recovered from the separatory funnels were washed free of heavy liquid with acetone, dried in an oven at about 90 degrees centigrade, run through the magnetic separator at the rate of about 30 grams per hour, weighed and placed in small capped plastic containers.

Prior to pelletizing the major impurities were estimated by grain counts using the petrographic microscope and an automatic point counter (Fig. 1). I used a sodium light source for most samples because the relative movement of the Becke line is more easily identified than with filtered white light. Counting time per sample was about 1½ hours and 1000 grains were counted per sample. The average traverse across the slide was about 125 square millimeters. Counting was performed on a regular flat stage in index oil 1.530 without temperature control. The index oil was checked periodically with an Abbé refractometer.

The chief dark impurities observed in feldspar fractions are biotite, chlorite, and hornblende in that order of abundance. They seldom occur as separate grains but are nearly always locked or included with a feldspar grain. Sericite-like inclusions exceed 1½ percent in plagioclase fractions 3704, 3705, and 3707 but are included with the dark inclusions. Acicular rutile or silliminite-like inclusions are common in the plagioclase fractions of samples 3701, 3702, 3704, 3709, and 3710. Except for eleven samples (two alkali feldspar and 9 plagioclase) total dark impurities comprise less than one percent. There is a weak correlation between the feldspar fractions and percent dark minerals in the hand specimen as estimated from thin section.

The only minerals identified as light colored impurities with the exceptions noted above are plagioclase or quartz in the alkali feldspar fraction and alkali feldspar in the plagioclase fraction. No effort was made to distinguish quartz from the plagioclase in the grain mounts. It is of interest to note here that the alkali feldspar impurities in the plagioclase occur as discrete grains and exceed 2 percent in only one sample while up to 50 percent of the plagioclase impurity may be locked with the alkali feldspar and may comprise from 2 to 4 percent of the sample. It is possible that much of the plagioclase impurity results from the microperthitic texture of the alkali feldspar but there is little correlation between degree of microperthite development observed in thin section and percent plagioclase impurity. In fact, some samples show very weak development of perthite but a high percent of plagioclase impurities. The plagioclase fractions are generally cleaner than the alkali feldspar. The dusty appearance of grains in transmitted light suggests other major impurities which I could not evaluate (See Fig. 2). These impurities may be significant for accurate interpretation of minor and trace element analyses but were neglected in this study.

One error occurred during the sink-float operation and resulted in mutual contamination of plagioclase fractions from samples 3701, 3705, 3710, 3711, and 3725. After recovering these samples from the separatory funnels and washing them in the usual way with acetone, they were placed in a pre-heated oven to dry. Apparently too much acetone remained and spattering resulted, with small clumps of material transferred from one beaker to another because I had neglected to cover the beakers. Because of slight differences in color among the samples I could identify the foreign clumps and discarded them with a spatula. As an added precaution I scraped about 1/16 inch off these and other samples present even though no spattering results could be observed.

Calculating Feldspar Compositions From the Chemical Analyses

Please refer to Appendix A for a detailed discussion of the chemical analyses. In short, weight percents of Al, Si, K, Ca, Fe, Rb, Sr, and Ba were determined by X-ray Emission Spectrography while

Na and Mg were determined by Flame Emission and Flame Absorption Spectrophotometry respectively. Mg values were discarded because of correlation between percent MgO and percent femic impurities. Fe is assumed to be trivalent, substituting for Al, and mol proportions of Fe_2O_3 were added to those of Al_2O_3. SiO_2 in excess of that necessary to accommodate mol proportions of the oxides of the alkalis, alkaline earths, and Al_2O_3 plus Fe_2O_3 was considered as quartz and calculated out of the plagioclase analyses. The spread of the raw oxide totals for the alkali feldspars is less than that of the plagioclase and peaks out closer to 100 percent (Fig. 14).

Feldspar compositions used in this study are listed in Table 5. Other lists of feldspar compositions are given (Tables 1-4) mainly in support of Table 5. They also show that significant differences can result between different methods commonly used in determining feldspar compositions.

Initially I determined mol percent feldspar using the sample formula:

$$\text{mol \% An} = \frac{CaO \times 100}{2Na_2O + 2K_2O + BaO + SrO + 2Rb_2O}$$

The values substituted in the equation are mol proportions obtained by dividing oxide percent by molecular weight of the oxide. Then in order to accommodate specific graphs using weight percent feldspar molecule, I determined weight percent anorthite for the plagioclase feldspar using only Na_2O and CaO (Table 1). I determined weight percent Orthoclase in the alkali feldspars using only K_2O (Table 2). Weight percent feldapar is determined by multiplying weight percent oxide times the ratio of the weight of a particular oxide to the weight of the ideal feldspar formula. Weight percents of all the feldspar molecules determined are tabulated and totaled in Tables 3 and 4. Some of the feldspar totals are unacceptably high or low suggesting an error in the chemical analyses. Moreover in the alkali feldspar there is consistent deficiency in silica and alumina in those samples with high feldspar totals but a consistent excess of silica and alumina in those samples with low feldspar totals. This suggests that the error may lie in the analyses of sodium, calcium, or potassium. The error appears to be in the sodium analyses as shown in the table below. Columns 2 and 4 show albite content and resulting feldspar totals as determined from sodium analyses by Paul Weyler and Larry Herber. Columns 1 and 3 show albite content from sodium analyses by Harold Vincent or Hiroshi Asari and their resultant feldspar totals. With one exception, 3729Ks, the totals of column 3 are closer to 100 percent than those in column 4. I assume then that incorrect sodium analyses account for alkali feldspar totals in excess of 100 ± 3 percent and corrected the percent albite in samples 3700Ks, 3701Ks, 3706Ks, 3708Ks, 3712Ks, 3715Ks, 3715Ks, 3719Ks, 3720Ks according to the formula:

Sample	Weight percent albite			Totals - Weight % feldspar	
	1		2	3	4
	HAV	HA	PPW & LJH	HAV or HA	PPW & LJH
3715P1		79.04	77.77	99.88	98.61
3723P1	86.74		82.93	100.02	96.21
3706Ks	18.85		23.69	100.55	105.79
3710Ks	28.60		19.97	102.47	93.84
3711Ks		20.73	30.04	97.65	106.96
3714Ks	23.78		25.64	99.56	101.42
3715Ks		18.02	23.69	98.09	103.76
3729Ks	19.72		22.34	98.02	100.64

Wt. % albite = 100 - wt. % (An + Or + Ba + Sr + Rb feldspar)

One plagioclase sample, 3731Pl was corrected also by this method. Samples 3704Pl, 3717Pl, 3721Pl, 3704Ks, 3717Ks, and 3721Ks had been corrected by adjusting the sodium content so that the mol proportions of the alkali and alkaline earth oxides correspond to the alumina as determined by X-ray analyses. The assumption underlying these corrections is that albite can be determined more accurately by difference (presuming good X-ray analyses) than by direct calculation from analyses obtained by Flame Emission Spectrophotometry.

The An, Ab, and Or values used in geologic interpretation are given in Table 5. All the plagioclases are calculated to 100 percent because the majority contained quartz in the analyses. But only those alkali feldspars corrected for sodium are calculated to 100 percent. The remainder total to 100 ± 2 percent.

The feldspar totals in weight percent cannot be used as an estimate of reliability of analyses because of the correction for sodium and the accompanying quartz (Tables 1 and 2). However, the anorthite content estimated from optical determinations is in good agreement with, though generally lower than, that calculated from the chemical analyses. The difference is 5 percent or less for 28 of the 32 samples (Fig. 3-C). The lower anorthite content calculated from the chemical analyses may be due to unlocking of the albite phase from the perthite during grinding and subsequent settling with the plagioclase fraction during heavy liquid separation. The only independent check on the Orthoclase phase of the alkali feldspar is from the $(20\bar{1})$ method of Tuttle (1958) on five of the samples studied; see table below.

Sample	Weight percent Orthoclase		Homogenization Time	
	Calculated	(20$\bar{1}$) method	Hours	Temp - C°
3720Ks	67.0	70	94	850
3722Ks	70.7	71	94	850
3723Ks	70.1	73	94	850
3727Ks	76.4	79	94	850
3728Ks	79.9	80	160	950

The Orthoclase determinations were performed in aluminum holders on heated alkali feldspar powders mixed with spectrally pure quartz obtained from Professor Volborth's laboratory. The value of 2θ for the (10$\bar{1}$0) reflection of the quartz used is 20.889 but this value was adjusted to 20.860 prior to any measurements to correspond to the "d" value of 4.2549 Angstroms used by Tuttle (personal communication, 1966) in constructing the original diagram. The X-ray diffraction data was gathered at room temperature.

Estimating Degree of Order In The Feldspars

I arrived at degree of order of the plagioclase by weighting X-ray order 80 percent over optical order. X-ray order is strongly favored because it represents measurements from an aliquot of about 75 grams while optical order represents measurements from about five grains on the average. X-ray order is determined for the plagioclase by plotting weight percent anorthite calculated from the chemical analyses against certain X-ray reflection separations. Optical order is determined by plotting the optic angle, $2V_x$, against weight percent anorthite obtained according to the a-normal method with the universal stage.

The degree of order of the orthoclase phase of the alkali feldspar is the average order obtained from plotting $2V_x$ on two different diagrams (Figs. 9 and 10). X-ray order could not be established for the orthoclase phase because, with only one exception, the reflection pair $(1\bar{3}1)$-(131) necessary for determining degree of order was not resolved. However, a crude X-ray method of estimating relative changes in degree of order based on profile widths (see Table 7) was used. Even though the sensitivity and precision of the method is poor, the relative change in order among the samples is similar to that indicated by the optic angle. The degree of order obtained by plotting $2V_x$ against bulk Or content, the optic angle, and the average relative degree of order estimated from X-ray composite peaks show similar trends (Fig. 11). Thus the optical order was considered to be useful for petrologic interpretation.

The degree of order of the albite phase of the alkali feldspar is estimated from the reflection pair $(\bar{1}32)$-(131). For plotting purposes it is assumed that all the calcium from the bulk alkali feldspar analyses is in the albite phase. The optical order for the albite phase was not determined because cleavage and/or twinning necessary for orientation are not developed distinctly.

X-ray powder diffraction methods

All X-ray data presented are obtained from strip chart recordings of powder diffraction profiles; no camera or single crystal techniques were used. A North American Philips (Norelco) X-ray unit equipped with a LiF monochromator was used. Conditions and settings for the unit are: 35 Kv and 20 mA power, Cu K-alpha radiation, ½ degree 2θ per minute scanning speed, 2 inches per degree chart speed. The 2θ range for plagioclase is from 20 to 35 degrees and that for the alkali feldspars from 19 to 35 degrees.

The samples used for diffraction work are the pellets which had been previously used for fluorescence. The only diffraction data not obtained from previously fluoresced pellets is that listed for 3707Ks and that used to determine orthoclase content of alkali feldspar by the $(20\bar{1})$ method.

For diffraction work the pellets were friction fitted in the center of a small, square aluminum plate which is attached to the lower flat surface of the goniometer shaft with a small spring. Prior to positioning that part of the pellet surface which would contact the goniometer shaft was covered with household Saran wrap to protect it from abrasion and contamination from the shaft.

All diffraction values presented are the average of a forward and reverse run. The pellets were run in the forward diraction, rotated 90 degrees in the horizontal and run in the reverse direction.

<u>Plagioclase</u> Smith (1956) and Smith and Gay (1958) recommend 2θ separations for the reflection pairs $(\bar{1}32)$-(131) and (131)-$(1\bar{3}1)$ for determination of structural state (degree of order as used in this study) in the range An_0 to An_{20} and An_{20} to An_{40} respectively. Their recommendations were followed: the data are listed in Table 6. They also recommend the function Gamma which includes the reflection (220) for the range An_{20} to An_{40} but this reflection is not resolved in my

samples. Recently Baumbauer, et al., (1967) suggest use of the reflection pair $(\bar{2}41)$-$(\bar{2}\bar{4}1)$ at approximately 36 degrees 2θ. The 2θ separations for the reflection were measured and recorded in the pair $(1\bar{1}1)$-$(\bar{2}01)$ but were not used in interpreting degree of order because it is recommended only for values above An_{70}.

The degree of order in percent is obtained from modified diagrams of structural state by assigning zero percent order and 100 percent order to the volcanic (high temperature) and plutonic (low temperature, metamorphic) boundaries of the diagrams (See Figs. 4, 5, and 6). The degree of order is assumed to vary linearly between the limiting curves. The idea of calibrating structural state diagrams in percent degree of order for plagioclase is from Slemmons (1962b) and is extended to similar diagrams for the alkali feldspars of this study.

The degree of order indicated by each reflection pair for the plagioclase is shown in Fig. 7-A and the agreement between the two reflection pairs is good. Twenty-one samples agree within five percent, eight within ten percent and only three disagree by more than ten percent. The agreement is so close that it is difficult to refrain from using an average value of the two methods. Optical values for degree of order agree about as well with average X-ray values (Fig. 3-A) as with the X-ray values used (Fig. 7-B). Thus most of the samples correspond to the precision expected from any pellet as estimated from the quadruplicate average values. The maximum deviation of the average value of a forward and reverse run from the average of all eight values for the quadruplicate determinations is given below. The resulting range in degree of order is also given.

Reflection pair	Maximum deviation of delta 2θ in three quadruplicates	Resulting range in degree of order
$(\bar{1}32)-(1\bar{3}1)$	± .011	±2½%
$(131)-(1\bar{3}1)$	± .018	±4½%
$(1\bar{1}1)-(20\bar{1})$	± .010	±9%

The optical order is compared with the X-ray order in the plagioclase in Figure 7-B and the agreement is good. Twenty-one of the samples agree to within five percent, nine to within ten percent, and two within twelve percent. The degree of order used for petrologic interpretation is derived from Figure 7-B by weighting X-ray order 80 percent over optical order and is shown in Figure 16.

Alkali feldspars The orthoclase and albite phases of the alkali feldspars are recognized on the X-ray charts from all samples. The reflection pairs $(1\bar{3}1)-(131)$ and $(1\bar{3}0)-(130)$, which are normally used to determine obliquity (degree of order as used in this study) of the orthoclase phase, are not resolved. Both reflection pairs for all but one sample show up as single profiles with varying broadness. The relative differences in degree of order among the samples were approximated by the ratio: peak height to profile width at one-half peak height. The ratios obtained are listed in Table 7 and plotted in Figure 8-A. Both reflection composite profiles show similar trends of optical order of the orthoclase phase. The trend of relative order obtained from the average of both composite profiles is roughly parallel to the trend of optical order when anchored to the curve for optical order (Fig. 8-B)

The precision of the X-ray method for estimating relative order of the orthoclase phase is judged from the maximum ratio range found in the quadruplicates. The maximum deviation of the average of a forward and reverse run from the average of eight measurements on three different quadruplicates as well as the resulting range in degree of order to be expected is given below.

Reflection composite	Maximum deviation of ratio: $\frac{\text{peak height}}{\text{profile width}}$	Resulting range in degree of order
$(1\bar{3}1)$-(131)	±1.0	± 5 %
$(1\bar{3}0)$-(130)	±1.0	± 3½%

The maximum deviation given corresponds to ratios from about one to six. The variations between the forward and reverse runs on some samples with ratios higher than six where no quadruplicate checks are available suggest deviations even higher than those given in the table above (See Table 7, samples 3724Ks through 3726Ks).

The 2θ separations for the reflection pairs $(1\bar{1}1)$-$(\bar{2}01)$, and $(\bar{1}32)$-(131) were obtained for the albite phase of most alkali feldspar samples. The data is listed in Table 8 and the degree of order is obtained from the plagioclase diagrams (Fig. 4 and 6). Data for the $(1\bar{1}1)$-$(\bar{2}01)$ reflection pair is plotted mostly as a matter of interest, but is not used in petrologic interpretation. The precision expected from the pair $(\bar{1}32)$-(131) cannot be estimated because of lack of replicate analyses.

Optical methods

Routine petrographic data was collected from at least two thin sections per sample with a Leitz trinocular polarizing microscope using the binocular eyepiece and regular accessories. The same microscope assembly equipped with a Leitz 4-axis universal stage was used to obtain the anorthite content of the plagioclase and the optic axial angle (2Vx) necessary for determining the optical degree of order.

The microscope and universal stage were prepared according to the procedure of Naidu (1958) and the glass components checked for strain with the Berek compensator. Hemispheres and a glass plate with indices of refraction 1.516 were used exclusively. The suggestions of Munro (1963) were followed for the universal stage work; condensor out, use of low power objective (UM2), and substage and objective diaphragms partly closed. Each optic angle recorded is the average of two determinations 90 degrees apart according to the method of Fairbairn and Podolsky (1951). All inclined extinctions measurements were corrected with the Universal Stage Protractor (Emmons, 1943) and a Nomograph for Refractive Index correction (Hallimond, 1950).

Plagioclase In this study optical degree of order and optical determination of An content are mutually dependent and so both are discussed below. The An content of plagioclase was determined with the universal stage according to the a-normal method of Tobi (1963) and estimated degree of order from the optical angle (2Vx). Extinction methods discussed by Slemmons (1962a) require measurements on both subindividuals of a twin and were not generally applicable in this study because of the fine twinning. It is much more difficult to find Albite twins with two adjacent broad subindividuals than one broad and one fine in the albite-oligoclase range studied. Since the a-normal method by itself does not distinguish between volcanic (high temperature) and plutonic (low temperature, metamorphic) feldspars, there was a range of about seven percent An in the albite-oligoclase range studied. It was assumed that the An content can be resolved with the optic angle and thus the degree of order determined. The following typical set of measurements is given for illustration. An extinction angle of zero degrees and optic angle (2Vx) of 85 degrees indicates a range of An_{16} (high temperature) to An_{20} (low temperature) according to the data of Tobi (1963) and accordingly a range in degree of order from 82 to 85 percent from Slemmons' chart (1962b). The average value for the degree of order, 83.5 percent, multiplied by the range in An content, 4.0, equals 3.3 and this product is added to An_{16} to give $An_{19.5}$ (rounded to nearest one-half). The plagioclase content, $An_{19.5}$, is then plotted against 2Vx, 85 degrees, to arrive at the final recorded degree of order, 84.5 percent. The An content and 2Vx on the core and rims of about five crystals per sample were measured (Tab. 9). The degree of order for all measurements is plotted in Fig. 3-B. The average degree of order for cores and rims for a given sample plotted in Fig. 3-A is taken only from those crystals on which core and rim measurements were made.

In order to compare optical order with X-ray order, a representative value for optical order must be obtained despite the systematic difference between core and rim values (Fig. 3-A). Core and rim measurements were normally obtained from that part of the crystal showing highest and lowest An contents respectively. Since the rim normally consists of a definite zone wholly or partly surrounding the crystal, its volume is probably more than the volume of the core which is generally a small zone at the center of the crystal. Thus average optical order should probably be biased in favor of the rim. The optical order is determined from that value two-thirds the distance from core to rim (Fig. 3-A). The value so obtained agrees fairly well with the average of two X-ray values (Fig. 3-A) and with the X-ray values used in petrologic interpretation (Fig. 7-B).

Alkali feldspars The degree of order of the orthoclase phase of the alkali feldspar is taken from an average of two methods based on the optic axial angle 2Vx. The optic axial angle and associated petrographic data is shown in Table 10. In the first method (Fig. 9) degree of order is read directly from a curve established by Finney and Baily (1964). In the second method, degree of order is taken from a structural state diagram calibrated in degree of order by assigning zero, 30, and 90 percent order to sanidine, orthoclase, and microcline respectively (Fig. 10). The agreement between the two methods is fairly good (Fig. 8-A). Nineteen samples agree to within five percent, ten are within ten percent and two greater than ten percent. I must point out that the Or content used in Fig. 10 is that calculated from chemical analyses of the alkali feldspars. However, the 2Vx was always measured on the Or phase if the specimen is observedly microperthitic. Since most specimens are microperthitic, the degree of order shown in Figure 10 may be about 10 percent low because the orthoclase phase is probably about 10 percent richer in orthoclase content than the bulk analysis of the alkali feldspar show.

The X-ray order plotted on Figures 8A and 8B may be misleading without further explanation. The X-ray values are plotted only to show the general agreement between variations in the trend of optical order with that of the estimated relative X-ray order. The absolute placement of the two different X-ray parameters in percent degree of order is fictitious. The X-ray values are plotted only to lend support to the apparent variations in optical order.

GEOLOGY OF THE MINERAL RANGE

The description of the general geology of the Mineral Range and the geology and petrography of the Mineral Range pluton is taken largely from the works of Crawford and Buranek (1945), Earll (1957), and Condie (1960). Condie (1960) studied the genesis of the Mineral Range pluton more thoroughly than the others so his observations are expected to be more significant. The observations along the traverse agree generally with Condie's, but Condie suggests a non-magmatic origin of the Mineral Range pluton whereas my interpretation is magmatic.

General Features

The Mineral Range of southwestern Utah, arcuate in plan view, about thirty miles long and five miles wide, includes the largest granitic pluton in Utah (Fig. 12). The average relief of the range is about 3000 feet with the highest point, Granite Peak, in the central part of the range at 9619 feet. The small granitic batholith comprising the bulk of the core of the range constitutes the geologic frame of reference for this study.

Paleozoic sedimentary rocks predominate at the northern tip of the range and together with Mesozoic sedimentary rocks and Cenozoic volcanics comprise most of the rocks in the southern part of the range. The sedimentary rocks are pertinent to this study insofar as they bear on the origin of the Mineral Range pluton.

The emplacement of the Mineral Range pluton probably occurred during late Cretaceous or early Tertiary time. This estimate is based on gentle doming evident in the Indianola conglomerate in the northern part of the pluton, and in the southern part by the Cave Canyon fault contact of the pluton with an easterly dipping series of rocks including the Claron (?) conglomerate. The Claron (?) and Indianola conglomerates are of late Cretaceous or early Tertiary age. Armstrong (1963, p. 90-t) reports an age of 241 million years (late Permian) for a sample obtained from the Mineral Range pluton. The sample date was supplied by J. A. Whelan of the University of Utah and was obtained by the Pb-alpha method. Whelan and Odekirk (1963, p. 53) suggest that the Permian age obtained for the sample may be anomalous. It is known that age dates obtained by the Pb-alpha method tend to be high because of inherited radiogenic or common lead (Armstrong, 1963).

Geology and Petrography of the Mineral Range Pluton

Except for the granodiorite north of the Beaver County line, earlier writers consider the bulk of the pluton a granite or a granite gneiss. The igneous rocks along the traverse however are mostly quartz monzonites or alaskites according to Bateman's (1963) classification (see Fig. 13).

The pluton is shown on the geologic map as a homogeneous body except for an inclusion zone along its western boundary (Fig. 12). A vague mineralogical and textural zoning across the pluton is suggested though by earlier workers. Condie (1960, p. 39) writes, "Apparently the coarsest granite is located on the western and northern part of the pluton and the finer granite along the eastern portion of the pluton." Earll (1957, p. 11) noted that the biotite content is very low in the bulk of the pluton but increases gradually in the contact zone towards the Precambrian gneiss on the west side. The writer observed no systematic variation in either mineral content or texture across the pluton but the specimens from the western part of the sample traverse contain the largest grains and the most abundant biotite.

The western part of the pluton contains many dark biotite rich inclusions and is shown on the geologic map (Fig. 12).

The mineral proportions and texture within the pluton vary noticeably: for instance, porphyritic granite facies are not uncommon. Condie (1960, p. 39) describes the texture as hypautomorphic granular, and gives an approximate mode of 50% orthoclase, 25% oligoclase (about An_{20}), 15% or more quartz, and 5% or more biotite and magnetite, with accessory sphene, apatite, microcline, and zircon. An average grain size variation from three millimeters to two centimeters is also given. The writer would add that along the sample traverse laths of normally zoned sodic oligoclase generally less than one-third the size of the accompanying alkali feldspar are common in alkali feldspars on the east side of the traverse but uncommon on the west side. The alkali feldspar is most commonly perthitic. The percentage of dark minerals; biotite, iron ore, sphene, and rarely hornblende is estimated visually at 2% or less along the central and eastern part of the sample traverse.

Three lithologically distinct groups of dikes intrude the pluton. (1) A series of northwest trending dellenite porphyry dikes which dip from vertical to the horizontal crop out in the northern part of the pluton. (2) A few small lamprophyre dikes, confined mainly to the Precambrian Wildhorse Canyon series on the west-central side of the range, strike about due north and dip steeply both east and west. (3) Rhyolite porphyry dikes striking northeasterly and dipping either vertically or steeply to the southeast crop out in the southern and southeastern part of the range. A few plugs of rhyolite porphyry which may be related to the rhyolite porphyry dikes crop out in the southern part of the range. The dellenite porphyry dikes, the lamprophyry dikes, and the rhyolite porphyry dikes and plugs intrude and postdate the Mineral Range pluton as shown by their chilled borders.

Contact relations of the Mineral Range pluton

The observations of earlier workers on the contact relations of the pluton with adjacent rocks are not always in agreement. Thus Earll (1957), and Crawford and Buranek (1945) describe crushed, folded, sheared, upturned Paleozoic sedimentary rocks in contact with the southeastern part of the pluton, but Condie (1960, p. 38) writing of the same contact states, "The contacts between the granite and the Paleozoic limestones, on the other hand, are sharp and apparently undisturbed by the granite." Condie (1960, p. 72) suggests that the steep dip of the Paleozoic rocks in contact with the south-eastern part of the pluton is caused by a combination of folding and diagonal slippage on the easterly trending, high angle faults south of Cave Canyon. His evidence is observed strike-slip faulting on some of the easterly trending, high angle faults, and the observed easterly dip of Paleozoic rocks found in contact with the pluton in the west-central part of the range and in the Bradshaw Mining District. Earll's suggestion (1957, p. 69) that the Cave Canyon fault, the largest of the easterly trending, high angle faults, is causally related to the emplacement of the pluton because it trims the southern end of the pluton so cleanly for three and one-half miles is relevant. The steep easterly dip of the Paleozoic rocks is contact with the southeastern part of the pluton suggests intrusion to me.

Rhyolite porphyry dikes, aplite dikes, and pegmatite dikes are common in the granite and in the sedimentary rocks along the southeastern margin of the pluton.

The northern end of the pluton is composed of granodiorite and is in contact with Cambrian limestones which are changed locally to marble. Several large tremolite outcrops occur about one and one-half miles north of the contact (Fig. 13). Crawford and Buranek (1945, p. 22) report that the beds at the northern end of the range, "...are gently arched into an anticline, the limbs of which are inclined at low angles to the west, northwest, and northeast, respectively."

The pluton on the western side grades through an "inclusion zone" into the generally concordant Precambrian Wildhorse Canyon series: gneisses, schists, granodiorites, adamellites, and migmatites. Dark inclusions may occur anywhere in the pluton but they are most abundant in the transitional contact zone of the pluton and the Precambrian Wildhorse Canyon series, and merit delineation on the geologic map. The inclusions range in size from a few inches to over ten feet in diameter, are generally rich in biotite, sphene, and rarely hornblende, but otherwise are texturally and mineralogically similar to the plutonic host rock. Many inclusions though are more like the rocks of the Precambrian Wildhorse Canyon series; i.e., they may be foliated, or possess a granoblastic texture and may be very rich in biotite or more rarely hornblende. In shape the inclusions may be equant or elongate. If elongate they are commonly aligned and may form long streaks in the granite. "These streaks, especially if they are schistose, tend to parallel the gneissic foliation and schistosity in the Wildhorse Canyon series." (Condie 1960, p. 44). The parallelism between the foliation of the oriented inclusions and the foliation in the Wildhorse Canyon series strongly suggests a metamorphic origin for the inclusions. No primary foliation was recognized in the rocks of the pluton.

The gradational contact of the Mineral Range pluton with the Precambrian Wildhorse Canyon series has been emphasized but locally the contact is sharp. In the contact zone, small patches of granite similar petrographically to the pluton are in sharp contact with older rocks and cut across older diagonal structural features without disrupting them. This suggests the formation of granite in place. But in regard to the contact zone of the pluton with some Precambrian gneiss, Earll (1957, p. 11) cites, "The contact zone, ranging up to one-quarter mile in width, contains numerous blocks of gneiss which have been separated from the main mass by the intruding granite and innumerable smaller inclusions of the older metamorphic rock." This observation may suggest forceful intrusion of the granite pluton.

The southern end of the pluton is in fault contact with Palezoic and Mesozoic sedimentary rocks which form an easterly dipping homocline. The main fault, the Cave Canyon fault, strikes about east-west and is downthrown on the south a maximum of 2000 feet. As mentioned on page 28 the long abrupt fault contact cleanly separating the granite from the sedimentary rocks is suggestive of a genetic relation between the pluton and the fault.

Mineralization near the borders of the pluton

The origin of the mineralization associated with the Mineral Range pluton; tactites, tremolite skarn, and marble is pertinent to an understanding of the genesis of the pluton. Unfortunately the descriptions of part of the mineralized areas by earlier writers are not wholly in agreement. Thus in a description of the tactite zones, Condie (1960, p. 36) states, "No tactite zones (over a few inches in width) were found within the Mineral Range pluton where porphyry dikes were more than 500 feet away. Only minor and discontinuous tactite pockets were found along the granite-limestone contacts if porphyry dikes did not occur in the area. Tactite zones were not observed along most of the granite-limestone contacts." But in a description of the limestones in the Granite Mining district where the tactites are well developed, Crawford and Buranek (1945, p. 19) mention, "The limestones have undergone severe metamorphic alteration, due to the intrusion of the main granite mass, and to a lesser degree, from the injection of 'offshoot' silicic dikes." The same writers (1945, p. 26) describe the mineralization in the Granite Mining district accordingly, "The mineralization, where the contact is comparatively regular, ..., and where the ore channels have not been deflected and complicated by too many faults, seems to have followed a consistent pattern. The zonal arrangement going outward from the intrusive indicates (with irregularities and exceptions) a sequence of tactite beds (commonly called dikes by the prospector) showing progressively a diminishing grade of metamorphism." The pattern of the contact of the pluton with the limestone may be idealized as follows: (Crawford and Buranek, 1945, p. 26).

1) Normal Granite.

2) Marginal facies of the granite characterized by an absence of biotite and relative abundance of pyroxenes, amphiboles, and epidote minerals.

3) A narrow, generally crushed zone, locally containing selvage, giving evidence of pneumatolitic and hydrothermal alteration, and characterized by such minerals as fluorite, muscovite, tourmaline, scheelite, and molybdenite along with later hydrothermal minerals such as chlorite, damourite, pyrite, chalcopyrite, and galena.

4) Garnetite; may be hard and massive or soft and crumbly. Diopside is a prominent associate near the intrusive and epidote near the limestone.

5) Calcite-wollastonite marble, locally with fibrous tremolite.

6) Garnet-vesuvianite-epidote tactite band.

7) Crystalline limestone.

8) Epidote-clinozoisite tactite band.

9) Crystalline limestone.

Two large tremolite skarn outcrops occur in the Cambrian limestones about one and one-half miles north of the pluton. Marble occurrences are numerous but not continuous along the margins of the granite pluton. Large, white marble beds crop out in the Granite Mining district, but commonly the marble is restricted to sporadic occurrences along limestone bedding planes, joints, and along rhyolite porphyry dikes.

Condie (1960, p. 37) suggests that the tactites and skarns originated from one or both of the following processes:

1) Contact metamorphism associated with the porphyry dikes.

2) The formation of a "basic front" around the periphery of the Mineral Range pluton as granitization proceeded.

Crawford and Buranek (1945) infer that the tremolite skarn and most of the tactite occurrences resulted from contact metamorphism by the Mineral Range pluton. They describe tactite bodies localized along intrusives which are marginal to the Mineral Range pluton. Those tactite bodies presumably owe their origin to the marginal intrusives.

Origin of the Mineral Range pluton

Condie (1960, p. 69) suggests that the granitization hypothesis most adequately explains the origin of the Mineral Range pluton and its apophyses. His contention results from a comparison of his field and petrographic observations with criteria commonly used to distinguish in his words (1960, p. 64), "granitized granite from magmatic granite." I think that such criteria are equivocal and suggest that the Mineral Range pluton crystallized from a melt as indicated by the contact metamorphism apparently associated with the pluton and by the concentration of the Ab-Qz-Or proportions (Fig. 14), and the modal plagioclase-quartz-alkali feldspar proportions (Fig. 13) near the silicic end of Petrogeny's Residua (data listed in Table 11).

INTERPRETATIONS OF RESULTS

Variations in Degree of Order among the Feldspars from the Mineral Range

This section is devoted almost entirely to a discussion and interpretation of the observed order-disorder relationships recorded from feldspars of the Mineral range.

It is assumed that the degree of order given for plagioclase is more accurate than that for orthoclase (potassium feldspar) because both optical (2Vx) and X-ray techniques were used for order determinations in plagioclase while only 2Vx was used for orthoclase. In addition the An content of plagioclase is calculated directly while the value used for the Or content of the orthoclase phase is the bulk Or content of the alkali feldspar. The Or content of the Or phase is probably higher than the bulk Or content and varies directly with the amount of exsolution which was not estimated.

The interpretations offered rest heavily upon the hydrothermal and dry conversion (inversion) studies of Goldsmith and Laves (1954), and Mackenzie (1957); kinetic studies of McConnell and McKie (1960), McKie and McConnell (1963), and Eberhard (1967); unit-cell volume determinations by Orville (1967); and experimental ternary feldspar studies of Yoder, Stewart and Smith (1957).

Following the usual terminology, the terms plagioclase and alkali feldspar are used to designate the two main feldspar series which are physically, chemically, and genetically distinct. The sodium and potassium rich phases of the alkali feldspars are designated respectively as albite and orthoclase. Every alkali feldspar sample showed both phases with X-rays and nearly all grains examined with the microscope are perthitic. The albite phase is thought to be exsolved from an originally homogeneous alkali feldspar.

Feldspar nomenclature without strict definition is a bit ambiguous because of overlapping chemical, optical, and structural connotations. The feldspar terms will be used within the guidelines offered above.

Variation in degree of order between orthoclase and coexisting plagioclase

Without exception orthoclase (K-rich phase of potassium feldspar) shows a lower degree of order than coexisting plagioclase (Fig. 16). Fig. 16 should be interpreted only in a qualitative manner because there is no established quantitative relationship between 2θ reflection separations and the actual Al, Si distribution (Bambauer and others, 1967). The apparent difference in degree of order is so large that one might expect to find evidence that the orthoclase (alkali feldspar grains) grew under different environmental conditions (and therefore probably at different times) than the plagioclase. But except for isolated occurrences of plagioclase jacketed by alkali feldspar and vice versa, no textural observations indicate distinctly different periods of crystallization for the two feldspars. The positions of bulk An-Ab-Or on the ternary feldspar diagram (Fig. 17) suggest that precipitation of plagioclase preceded that of alkali feldspar by only a short time and that total crystallization time for most samples is relatively short. The average 5 to 10 percent variation in An content between cores and rims of plagioclase grains and the usual type of zoning (normal) observed are consistent with a relatively short and placid crystallization history.

Assuming then that similar crystallization histories prevailed for coexisting plagioclase and alkali feldspar, the observed differences in order may be controlled more by factors peculiar to each feldspar than by environmental conditions which prevailed either during or after crystallization.

The following three possibilities, singly or taken together, may help explain the differences in degree of order.

1. Orthoclase may be less ordered because its effective inversion temperature is lower than that of plagioclase. Physically this means that the temperature or temperature range which accompanies a significant segregation of randomly positioned Al ions into a definite tetrahedral site or set of sites is lower for orthoclase than for plagioclase (Na-rich plagioclase).

Hydrothermal conversions of natural low to high albite and microcline to sanidine may suggest that the latter has the lower inversion temperature (Goldsmith and Laves, 1954; Tuttle and Bowen, 1950; McConnell and McKie, 1960). Presuming that the plagioclase, An_{10-20}, and orthoclase, Or_{70-90}, of this study invert like their purer counterparts above I shall proceed to discuss the observed difference in degree of order between orthoclase and plagioclase on the basis of different reaction rates. That diffusion is the rate controlling mechanism in natural feldspar inversion has been implied or assumed by most workers (Goldsmith and Laves, 1954; McConnell and McKie, 1960; McKie and McConnell, 1963; Fyfe, Turner and Verhoogen, 1958). If diffusion is the rate controlling mechanism then the temperature dependence of the rate process may be explained with the Arrhenius relationship:

$$K = A\, e^{-E/RT}$$

K is the rate constant

A has been called the frequency factor and is a measure of the probability of transformation (inversion) to occur once the transition state is reached. It is identified perhaps with some vibration frequency of the lattice.

e is the base of the natural logarithms

E is the activation energy

R is the fundamental gas constant equal to 1.98 cal/deg mole

T is the absolute temperature

It might be helpful to add Pauling's (1953) explanation for the exponential factor $e^{-E/RT}$: "...The fraction of collisions in which the molecules have enough energy to react."

Note that my application of this equation is superficial and involves assumptions which may be invalid or at least have not been proven. It does help explain the observed differences in order between orthoclase and plagioclase.

Assume that A and E for orthoclase and Na-rich plagioclase are not significantly different, and that E is 75 kcal/mole. Then the expected rate of inversion for plagioclase at 600° will be 1.7×10^3

times faster than that of orthoclase at 500° C. Thus if we may judge from the work of Steiger and Hart (1967) that post crystallization temperatures of 600° obtained for at least 2 X 10^4 years, and that most of the observed ordering in the plagioclase occurred during that time, we might expect the same degree of ordering at 500° C in the orthoclase to occur in 3 X 10^7 years if the temperature held at 500° for that duration. But the temperature would be expected to remain at 500° for about the same length of time as at 600°.

Now the inversion temperatures are inferred from the work of Goldsmith and Laves (1954) and McConnell and McKie (1960). More recent experimental work by Tomisaka (in Wright, 1967) and field data (Steiger and Hart, 1967; Wright, 1967) suggest that the microcline-orthoclase inversion may be lower than 500° C, possibly as low as 350° C. If we assume an inversion temperature of 400° C for orthoclase, and retain the 600° C for plagioclase, then the rate of inversion for plagioclase is expected to be about 3.6 X 10^5 times faster than the orthoclase-microcline inversion.

2. A second explanation of the observed differences in order between orthoclase and plagioclase may lie in differences in the value of E required for ordering.

X-ray studies at elevated temperatures from 100-1500° C on a microcline and on a series of plagioclases from albite to anorthite showed no change in the reciprocal lattice angles of the microcline but a smooth change for each plagioclase (Grundy and Brown, 1967). Perhaps microcline resists inversion more than plagioclase because its energy of activation for ordering is higher. Estimates of E values for ordering of albite vary from 55.9 ±.2 kcal/mole under hydrothermal conditions to 96 ±11 kcal/mole under dry conditions (McKie and McConnell, 1963). I know of no published E values for ordering of orthoclase, but Jagitsch and Mats-Goran (in Fyfe, Turner, and Verhoogen, 1958) record an E value of 167 kcal/mole for homogenization of Na and K in sodium and potassium feldspars. Fyfe, et al. (1958) interpret that high value as the energy required to liberate K or Na from their lattice positions rather than the actual E of diffusion. Lacy (1965, p. 146) suggests E values of 20-30 kcal/mole for movements of divalent cations and values up to 30 kcal/mole for exchange diffusion of Na and K in "...Loosely packed structures where the anionic framework is not seriously disturbed."

The implication is then that E of ordering is greater for orthoclase than for Na-rich plagioclase and therefore in terms of the Arrhenius relationship, the rate of inversion (ordering) for orthoclase is slower. Brown (1965, p. 345) appears to take the opposite view and reasons from a comparison of hypothetical growth and ordering rates that E for ordering of potassium feldspar is about 20-30 kcal/mole, "...So that ordering proceeds very slowly compared with albite at such low temperatures." The statement in quotes is at loggerheads with the arithmetic of the Arrhenius relationship.

3. Orthoclase may be less ordered than the plagioclase because of selective effects of crystallization and/or post-crystallization confining pressure.

Orville (1967) found that the unit cell volumes for the albite-microcline series (Ab_{100-70}) are significantly lower than their high albite-sanidine analogs, but are about the same for both high and low series for remaining compositions (Ab_{70-0}). This implies as Orville suggests that confining pressure favors Al:Si ordering in albite-rich feldspars over orthoclase rich feldspars. He calculates that 1000 bars confining pressure should raise the low albite-high albite transition from 9 to 17° C. If applicable to the natural coexisting orthoclase and Na-rich plagioclase studied, pressure not only favors inversion of plagioclase directly but also indirectly by raising the effective inversion temperature and thereby increasing its rate.

Now if the association found in this study; low (or nearly low) plagioclase with intermediate to minimum microclines (and orthoclase) is mineralogically rather than evironmentally controlled, then structurally similar feldspar associations may be expected to be common or perhaps even widespread in nature. The occurrence of low albite with structurally intermediate forms of potassium feldspar is common as indicated by the alkali feldspar phase diagram of Mackenzie and Smith (1961). Their diagram indicates that the temperatures necessary for the same degree of ordering (inversion) are much lower for potassium than for sodium feldspar. This does not imply that all subsolvus relationships of the alkali feldspars are like those of coexisting but physically separate orthoclase and Na-rich plagioclase. However, the inversion relationships of the latter are expected to parallel in a general way those of their alkali feldspar analogs.

Detailed descriptions of the degree of order in both orthoclase and the coexisting plagioclase are uncommon but some descriptions do invite comparisons with my data. Gay (1961), Marmo (1967), and perhaps Tuttle and Bowen (1958) find that plagioclase is more ordered than coexisting potassium feldspar in a granophyre, in some plagioclase-bearing granites, and in some Tertiary granites from Skye respectively. The work of Wright (1964), Phair and Fisher (1962), and Hall (1966) suggests that coexisting alkali feldspars (potassium feldspar) and plagioclase have reached similar states of order in a shallow grandiorite-quartz monzonite intrusion, in some Front Range, Colorado feldspars, and in some granites respectively. Raguin (1965) states that the plagioclase in many granites is the low temperature variety but the potash feldspar may be orthoclase, microcline or both with a definite proportion of orthoclase to microcline in a given granite.

It would seem then that in granitic plutonic rocks plagioclase is normally as well ordered, or more highly ordered, than coexisting potassium feldspar. The latter prevails in the feldspars of the Mineral Range whether they be igneous or metamorphic.

Variations in degree of order among the potassium feldspars

Significant changes in degree of order in the potassium feldspars appear to be related to two different groups of samples according to their position along the surface of the pluton (See Fig. 16 and Fig. 12). Samples 3721 through 3726 show the lowest order but are taken from the east central part of the pluton and might be considered the central group. The remaining plutonic samples 3727 through 3731 and 3704 through 3720 (excluding metamorphic samples 3705 and 3708) might be considered the boundary group and these show a higher degree of order. The distribution shown, lower order toward the center of the pluton and higher order near the borders was not expected, but similar relationships have been noticed by other workers. Thus Caillere and Kraut (1960) observed a higher degree of order in the border facies than in the center of a granitic pluton and attribute it to deformation (protoclasis) during intrusion. A few of my potassium feldspars show a higher incidence of grid twinning and higher optic angles adjacent to fractures than elsewhere in the grain (Fig. 18). This probably means a higher degree of order near the fracture. However, no significant megascopic or microscopic deformation was recognized in samples showing higher order.

Nilssen and Smithson (1965) found that potassium feldspars near the borders of an intrusion showed a degree of order (structural state) like those near the center. They suggest that perhaps the temperature difference between the intrusion and host rocks is not large enough to cause rapid crystallization and thus a significant change in degree of order. Their observations are especially puzzling when compared with the present study. The east side of the Mineral Range pluton appears to be more epizonal in nature than the west side yet the potassium feldspars from the east side show the highest ordering!

None of the megascopic, microscopic, compositional, or other petrological data (Figs. 19 and 20) collected varies systematically with degree of order in the potassium feldspars. Thus no specific explanation is attempted.

It is worthwhile noting that except for sample 3714, samples 3721 through 3726 show about the same degree of order and the lowest along the traverse. Yet the stage of fractionation as suggested by the temperature of crystallization, the K/Rb ratio, the total An content (Fig. 19), and the absolute amounts of Rb_2O and BaO (Fig. 20) are about the highest for samples 3721-3724, but the lowest for samples 3725 and 3726. This may suggest that the observed degree of order in the potassium feldspars is more dependent on post-crystallization than crystallization phenomena, or that the temperature of inversion is lower than the crystallization temperature.

Variations in degree of order among the plagioclase feldspars

The distribution of the degree of order shown by the plagioclase may be partly related to the plutonic boundaries. The average degree of order of those samples toward the center of the pluton, 3719-3724, is somewhat higher than the average for those samples toward the sides (Fig. 16). The difference however is not great enough to be convincing and the trend of higher order toward the eastern boundary of the pluton is not to be expected perhaps from geologic relationships alone. Even though no strong or at least expected correlations between order and position in the pluton are found, it seems that the conditions which prevailed during plagioclase crystallization controlled the observed variations in degree of order.

Plots of degree of order versus An content of plagioclase (Fig. 21-A), total An percentage of all feldspars (Fig. 21-B), and relative temperatures of crystallization (Fig. 21-C) all seem to indicate a general increase in degree of order with increasing fractionation. (Relative temperatures of crystallization plotted in Fig. 21-C are taken from tie lines joining coexisting ternary feldspars plotted on Fig. 17.) Decreasing temperature and increasing water pressure would be expected to play dominant roles in ordering. Other mineralogic factors affecting the observed degree of order may be superimposed on or accelerated by some of the environmental factors attendant upon increased fractionation. Thus Eberhard (1967) finds that the rate of ordering in the acid plagioclases increases with increasing Ab content. Increased water pressure should promote ordering in the plagioclases studied if their cell volumes like those of albite decrease with ordering (Orville, 1967). The placement of the metamorphic plagioclases in Fig. 21-A, B, and C is consistent with a mineralogic control rather than an environmental control associated with magmatic differentiation.

As is the case with potassium feldspar, there is no good correlation between minor or trace element amounts and degree of order. I had expected a correlation by analogy with the effects of impurities on the High-Low inversion of quartz (Sosman, 1965). However, recent X-ray emission microanalyses of feldspars by Corlett and Ribbe (1967), Smith and Ribbe (1966), and Ribbe and Smith (1966) indicate that bulk methods of analyses for trace or minor elements in the feldspars are suspect. Bulk methods of analysis do not discriminate structurally controlled impurities from those found in mineral inclusions.

Parallel to the preceding discussion on plagioclase ordering is the observation that average order recorded for the rims of plutonic plagioclase grains is significantly higher than that of their cores (Fig. 3-A). In all the samples observed, the average An content of the rim is less than that of the core. Therefore, the higher ordering found in the rims of the plagioclase grains appears to be due mainly to the changing environment of crystallization during fractionation (decrease in temperature and perhaps increase in water pressure) and possibly to certain superimposed mineralogic effects as discussed previously.

Prior to developing any explanations for the observed variation in order among the plagioclase, the writer thought that the higher order recorded for the rims may be related to twinning as many of the rims show a higher frequency of twinning than the associated cores. But frequency of twinning on rims and cores of many grains is similar even though the rim shows the higher ordering. An interesting question arises: Is the greater frequency of twinning due to greater inversion (order) analogous to that associated with the orthoclase-microcline inversion, or is the greater degree of order due to twinning? This question might be reasonably answered if one could distinguish transformation twinning (twinning caused by inversion; Vance, 1961) from other types of secondary twinning. Some of the twinning observed on the rims appears to be deformation twinning. The deformation may be associated with intrusion during crystallization as there is no recorded pervasive deformation of the pluton since emplacement. Well ordered (low) Na-rich plagioclase is said to resist deformation twinning because it involves movement of Al and Si ions while disordered (high) Na-rich plagioclase twins readily under stress because the pattern of Al and Si ions is not disturbed (Smith, 1962). Some of the frequently twinned, highly ordered plagioclase (rims and cores) may have twinned then during crystallization when they were less ordered, and thus the twinning observed may not be related to inversion.

Variation in degree of order among the albite phase of the alkali feldspars

Data on the composition and degree of order of the albite phase are neither precise nor complete. The available data suggest that the degree of order of the albite phase is always higher than that of the coexisting orthoclase phase and is usually higher or about the same as that of the plagioclase. Explanations derived for other feldspar relationships found in this study seem applicable. High water pressures, a relatively high inversion temperature, and possibly lower activation energies for inversion of albite, would singly or in concert favor development of a higher degree of order in the albite.

Thus, on the basis of alkali feldspar phase diagrams (Mackenzie and Smith, 1961; Wright, 1964; Goldsmith and Laves, 1961) a correlation was expected between amount of exsolved albite and degree of order of the orthoclase phase. However, the relative amount of exsolved albite correlates only with the calculated Ab content of the alkali feldspars (Fig. 22). This may suggest that exsolution in the alkali feldspars studied is largely a function of Ab content and may precede or at least may not accompany directly the ordering process.

Summary

1. The observed degree of order for the orthoclase phase of the alkali feldspar appears to be significantly lower than that for coexisting plagioclase. An explanation for this difference is offered in terms of the Arrhenius rate law: $K = A e^{-E/RT}$. Holding A and E constant but assuming that T, the effective temperature of inversion (ordering), is 100° C lower for orthoclase than Na-rich plagioclase results in an inversion (ordering) rate for orthoclase several orders of magnitude lower than that of plagioclase. The result of a larger E is similar to that of a smaller T. If E for

orthoclase is larger than for plagioclase, the rate of orthoclase inversion is again expected to be significantly lower.

The evidence for real and/or significant differences in E and T for orthoclase and Na-rich plagioclase is not definitive but I would judge that variations in T affect the rate of inversion (ordering) more than variations in E.

High water pressures should also favor inversion (ordering) or Na-rich plagioclase over orthoclase because ordering probably leads to significantly smaller unit cell volumes in the former but not in the latter.

2. Degree of order variations in the potassium feldspars show neither systematic nor expectable correlations with recorded geological, petrological, or compositional data and remain inexplicable. Degree of order variations in the plagioclase correlate with inferred conditions of crystallization; order increases with increasing An content of the plagioclase, increasing total An feldspar content, and with relatively lower crystallization temperatures. Thus plagioclase may fingerprint crystallization conditions much better than coexisting orthoclase. The apparent lack of correlation between the inferred conditions of crystallization and ordering in orthoclase may suggest that its effective inversion (ordering) temperature is significantly lower than the inversion temperature of Na-rich plagioclase.

Certain mineralogic factors like decreasing An content and decreasing unit-cell volume may accompany and contribute to plagioclase ordering during progressive fractionation. The parallelism between plutonic and those few metamorphic plagioclases studied on plots of order versus An content suggest that mineralogic factors may effect ordering outside of as well as within the framework of magmatic crystallization.

3. Where it could be recorded, the degree of order of the albite phase of the alkali feldspar is much greater than that of the orthoclase phase and comparable to that of coexisting plagioclase. The average degree of order for the rims of normal zoned plagioclase is greater than their respective cores. Both these observations may be understood or perhaps even expected from the framework of explanations advanced above so will not be amplified.

4. Some plagioclases show a much higher frequency of albite twinning on their rims than on their cores. The rims are usually significantly more ordered than the cores so this may be transformation twinning. However, the appearance of the twinning on some rims is consistent with deformation twinning. Low Na-rich plagioclase resists mechanically caused structural rearrangement such that deformation might cause grain breakage or irregularly shaped, patchy twinning rather than the normal albite twinning. However, broken plagioclase grains and patchy twinning (not looked for specifically) appear to be the exception rather than the rule. Normal albite twinning forms readily in high temperature albite. Presumably then the deformation twinning associated with some of the low temperature plutonic plagioclase rims occurred at or near the time of crystallization.

5. The lack of correlation between trace or minor amounts of Ba, Rb, and Sr, and degree of order in the feldspars studied may be real or may be due to insensitive bulk methods of chemical analyses.

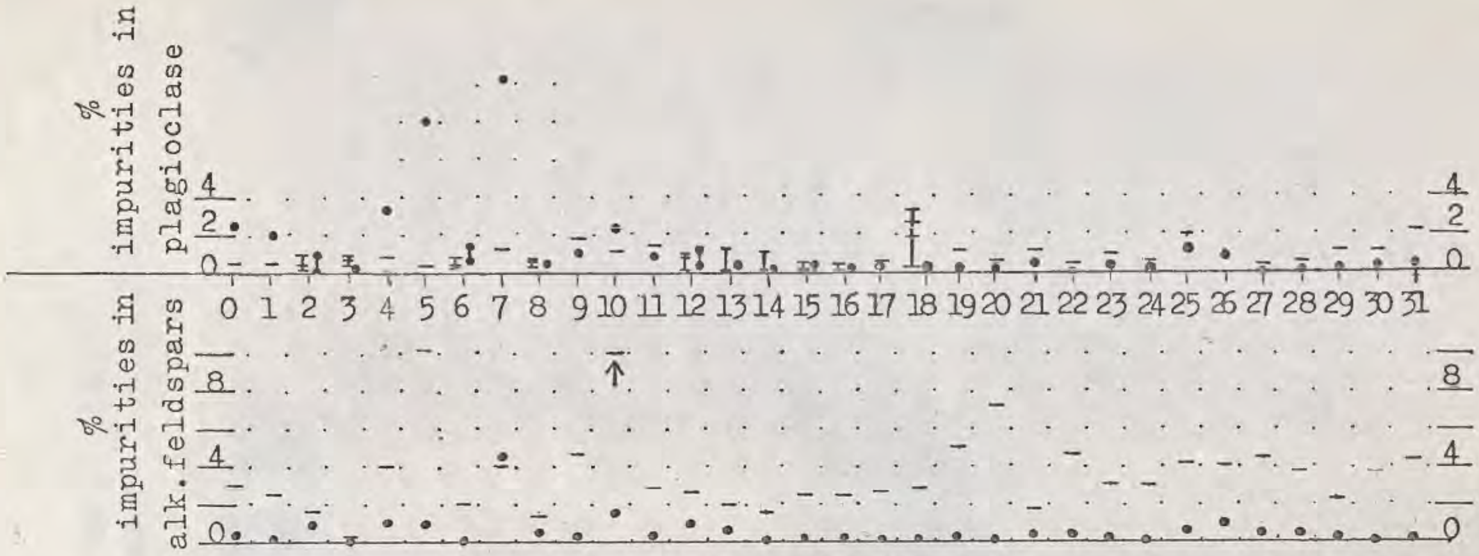
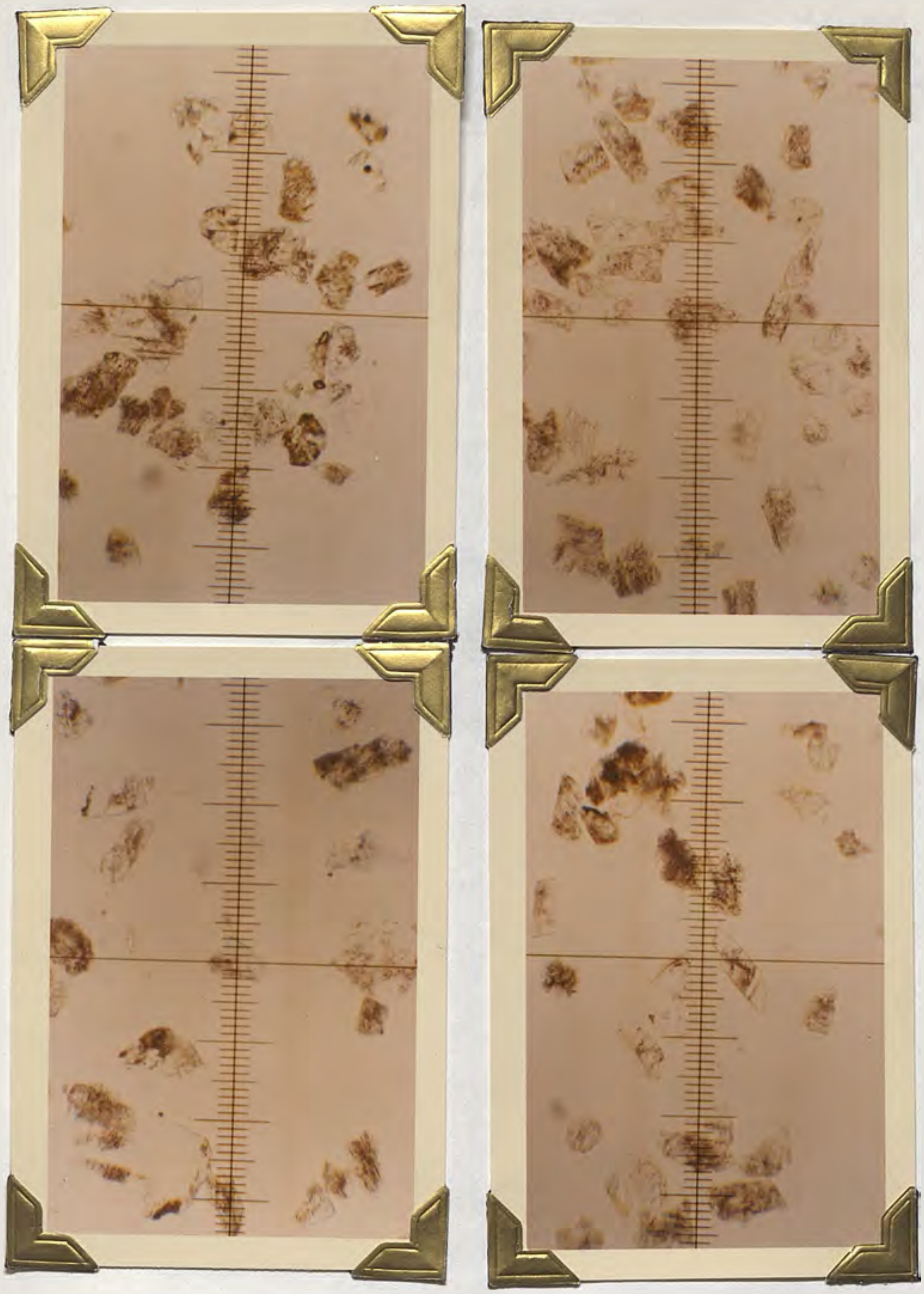


Figure 1 Major impurities in the feldspars observed under the petrographic microscope. Dashes represent plagioclase in the alkali feldspars or orthoclase (potassium feldspar) in the plagioclase. Solid spheres represent chiefly biotite, chlorite, or hornblende; to a lesser extent sericite-like material. Nine plagioclase samples were done in triplicate, one in quadruplicate; the range is represented by the vertical line. The percent impurities was estimated by counting 1000 grains in oil with refractive index 1.530. The relative movement of the Becke line was observed for each grain. Alkali feldspar sample 3710 contains 25% plagioclase

The femic minerals and the sericite are locked with the orthoclase in nearly all cases, but only about 25-50% of the plagioclase is locked with the orthoclase. Most of the femic minerals and sericite are locked in the plagioclase, but the orthoclase occurs as separate grains. Chemical analyses from feldspar fractions of samples 3707 and 3710 were not used in geologic interpretation.



Alkali feldspar Plagioclase

Figure 2 Appearance of feldspars in transmitted light
5 units equal .3 mm.

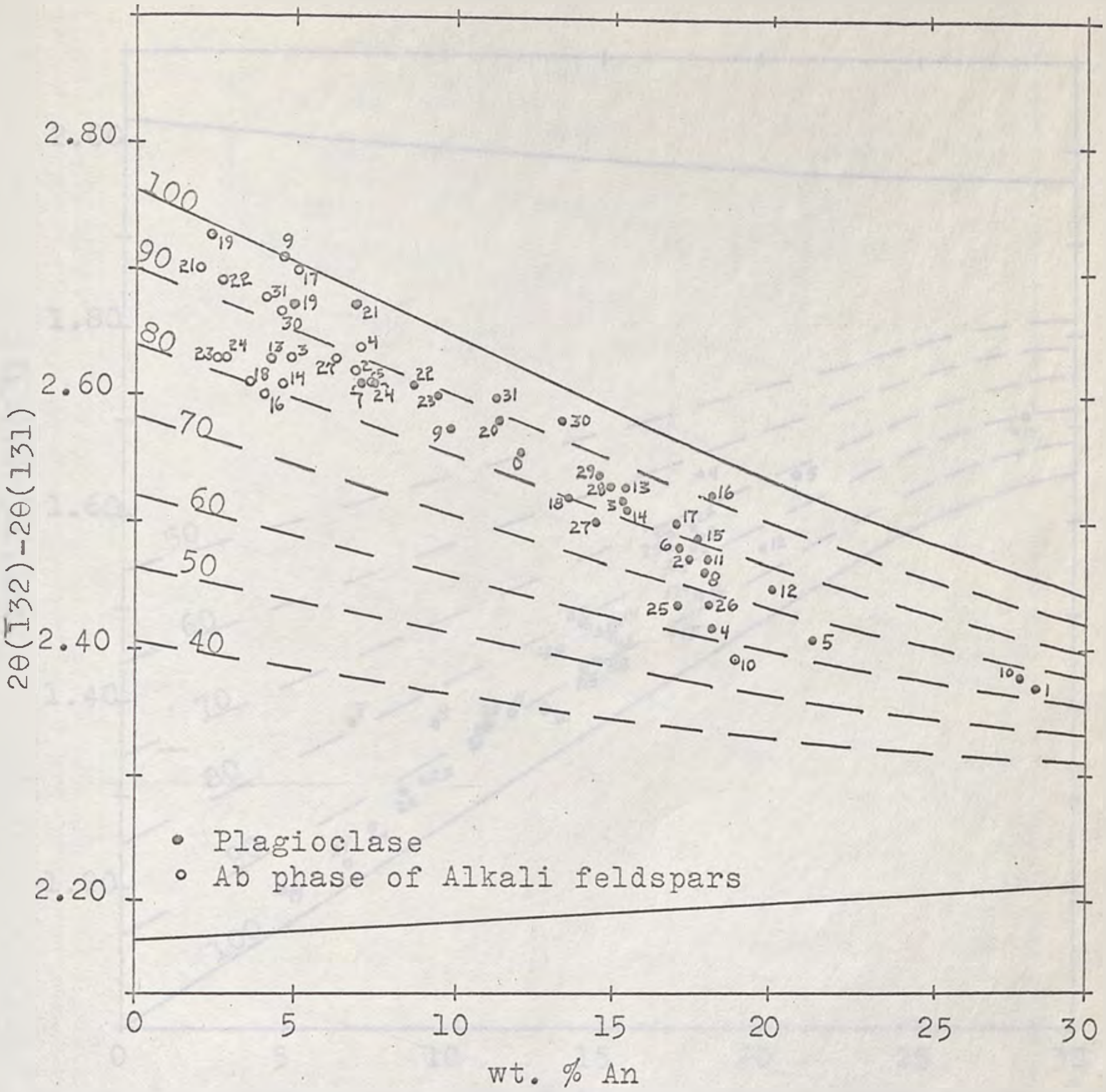


Figure 4 Degree of Order in the plagioclases from the Mineral Range. Diagram enlarged and modified from J. V. Smith (1956). Dashed lines indicate degree of order in percent assuming a linear relationship between the bounding curves.

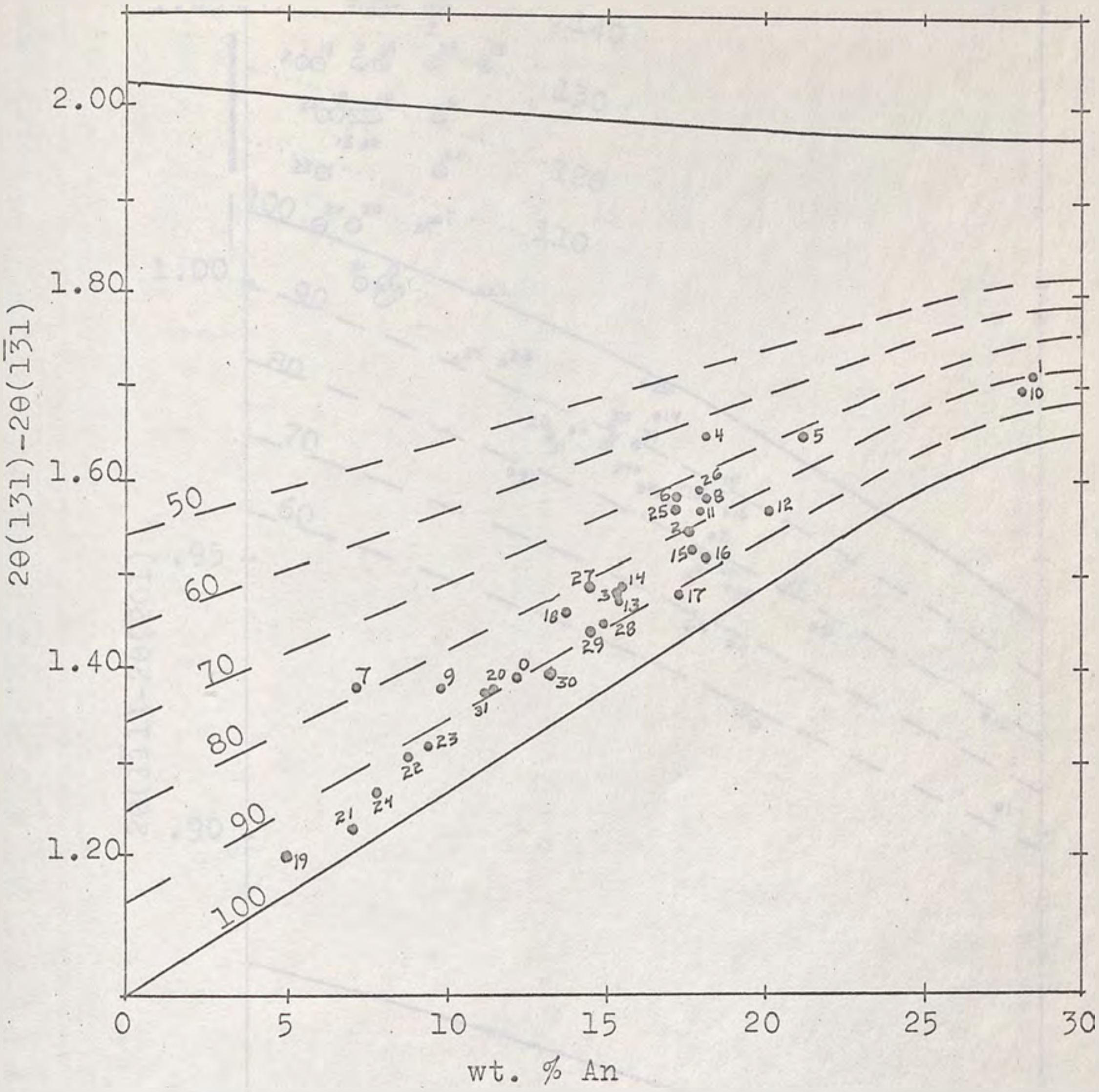


Figure 5 Degree of Order in the plagioclases from the Mineral Range. Diagram enlarged and modified from J. V. Smith (1956). Dashed lines indicate degree of order in percent assuming a linear relationship between the bounding curves.

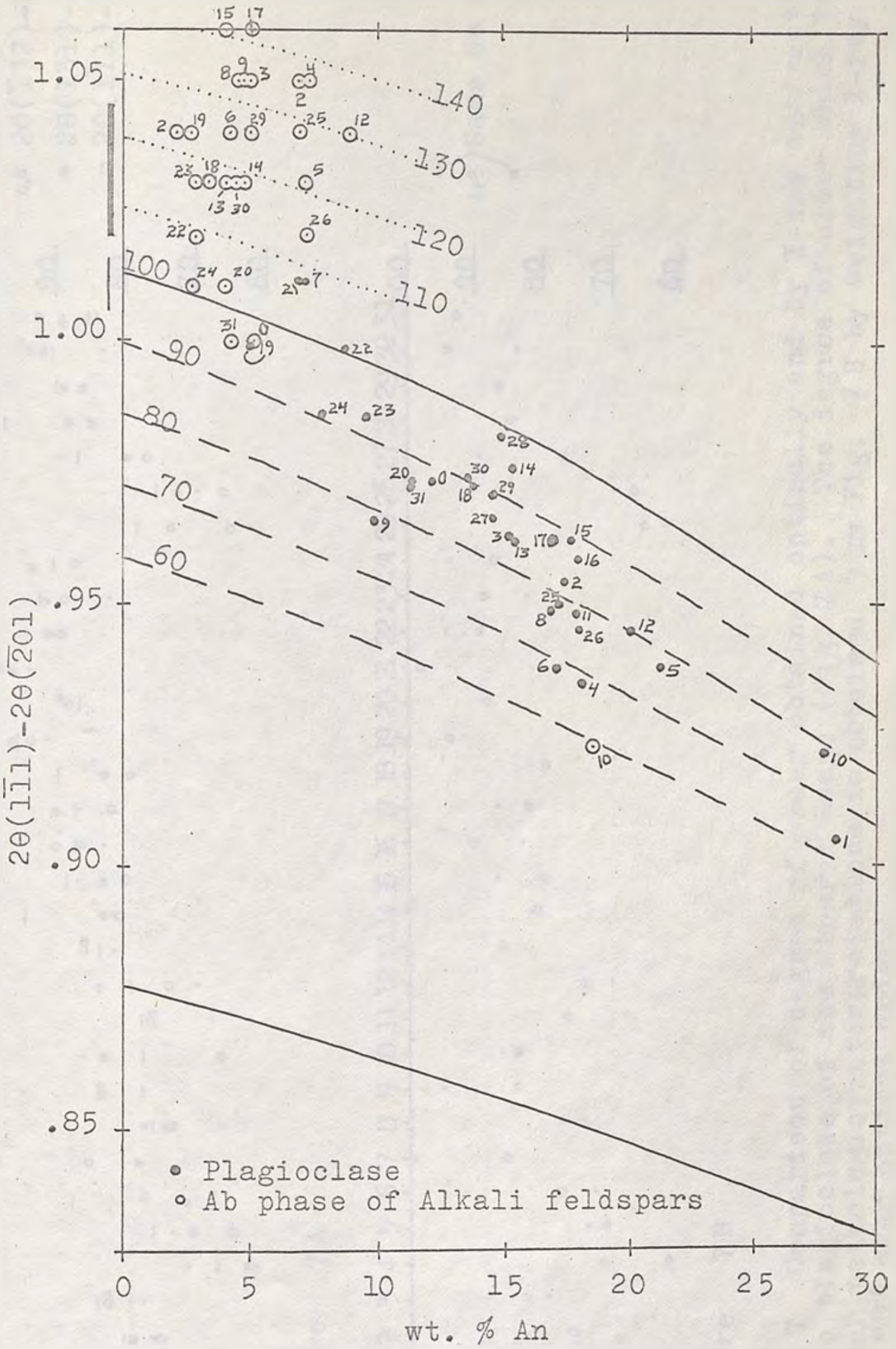


Figure 6 Degree of Order in the plagioclases from the Mineral Range. Diagram enlarged and modified from Smith and Gay (1958). Dashed lines indicate degree of order in percent assuming a linear relationship between the bounding curves. Short dotted lines indicate "degree of order" of the Ab phase in the alkali feldspars and the heavy vertical line is the estimated maximum average deviation of the reflection separations. The short, thin vertical line represents the same deviation for the plagioclase.

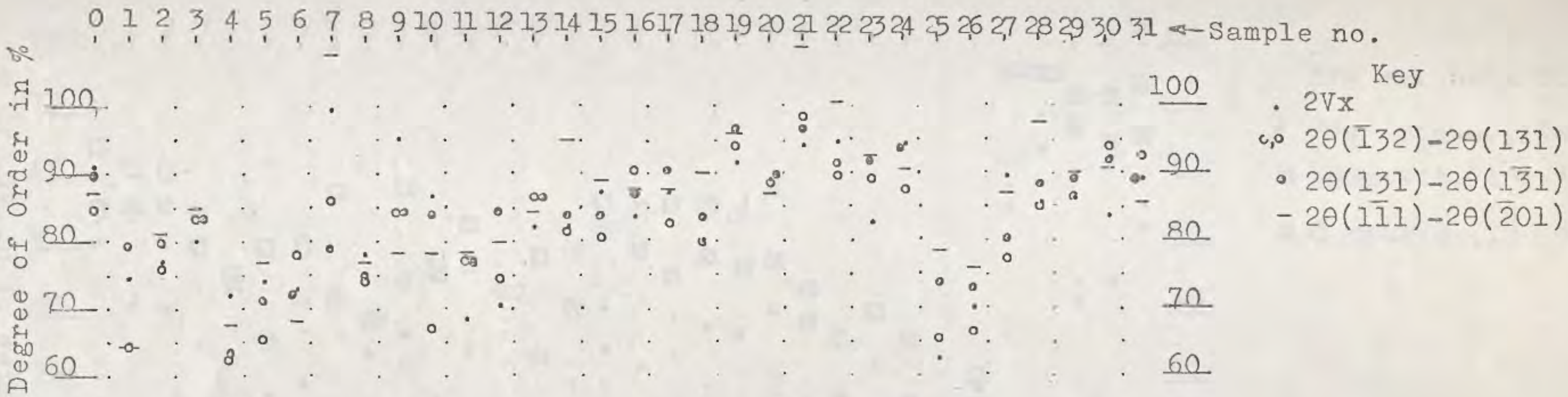


Figure 7 A

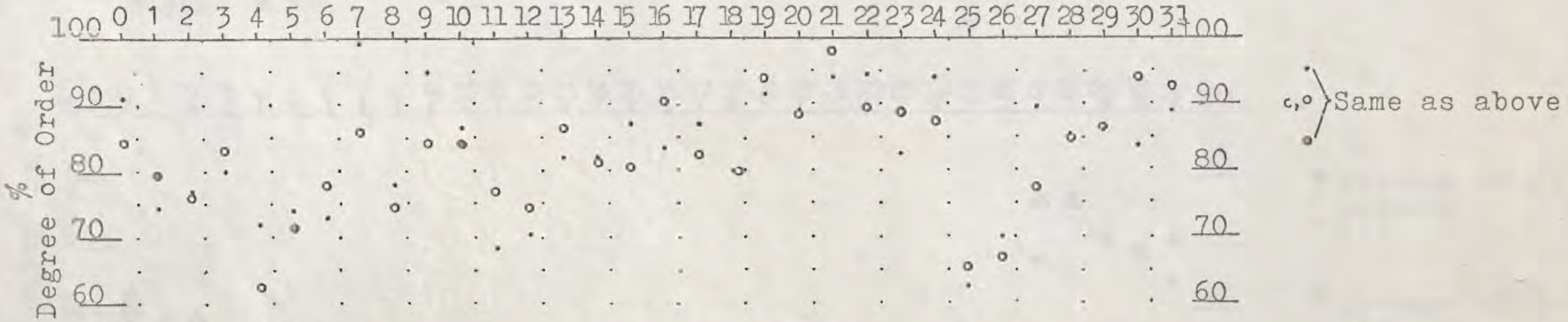


Figure 7 B

Figure 7 Comparison of degree of order obtained optically and by X-ray diffraction for the plagioclase of the Mineral Range (Fig. 7 A). The degree of order which is used for petrologic interpretations is obtained from Fig. 7 B by weighting X-ray order 80% over optical order.

Figure 8 A

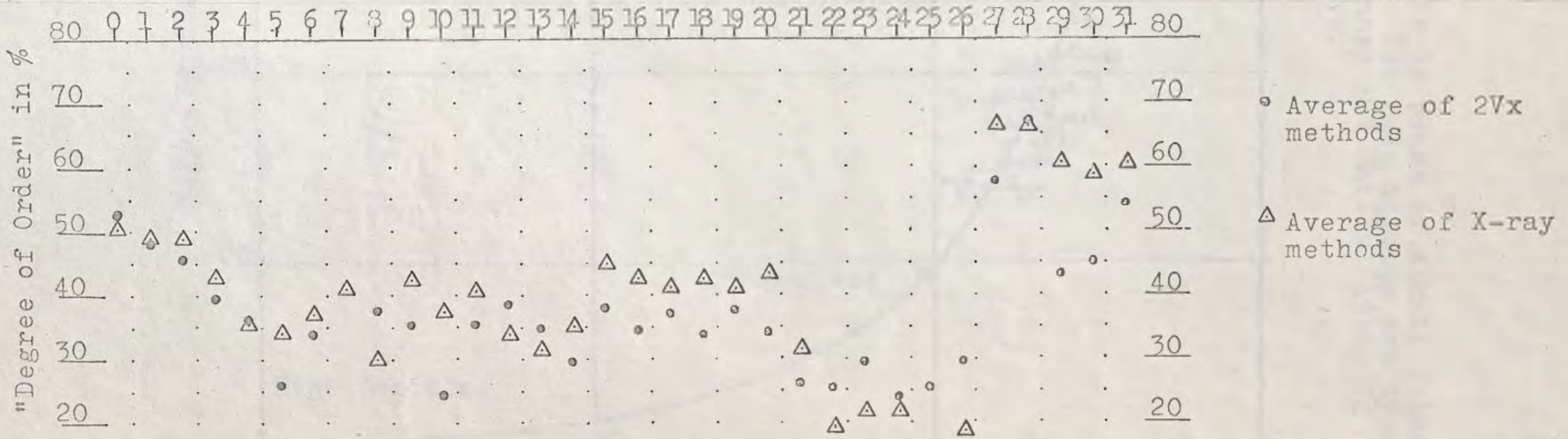
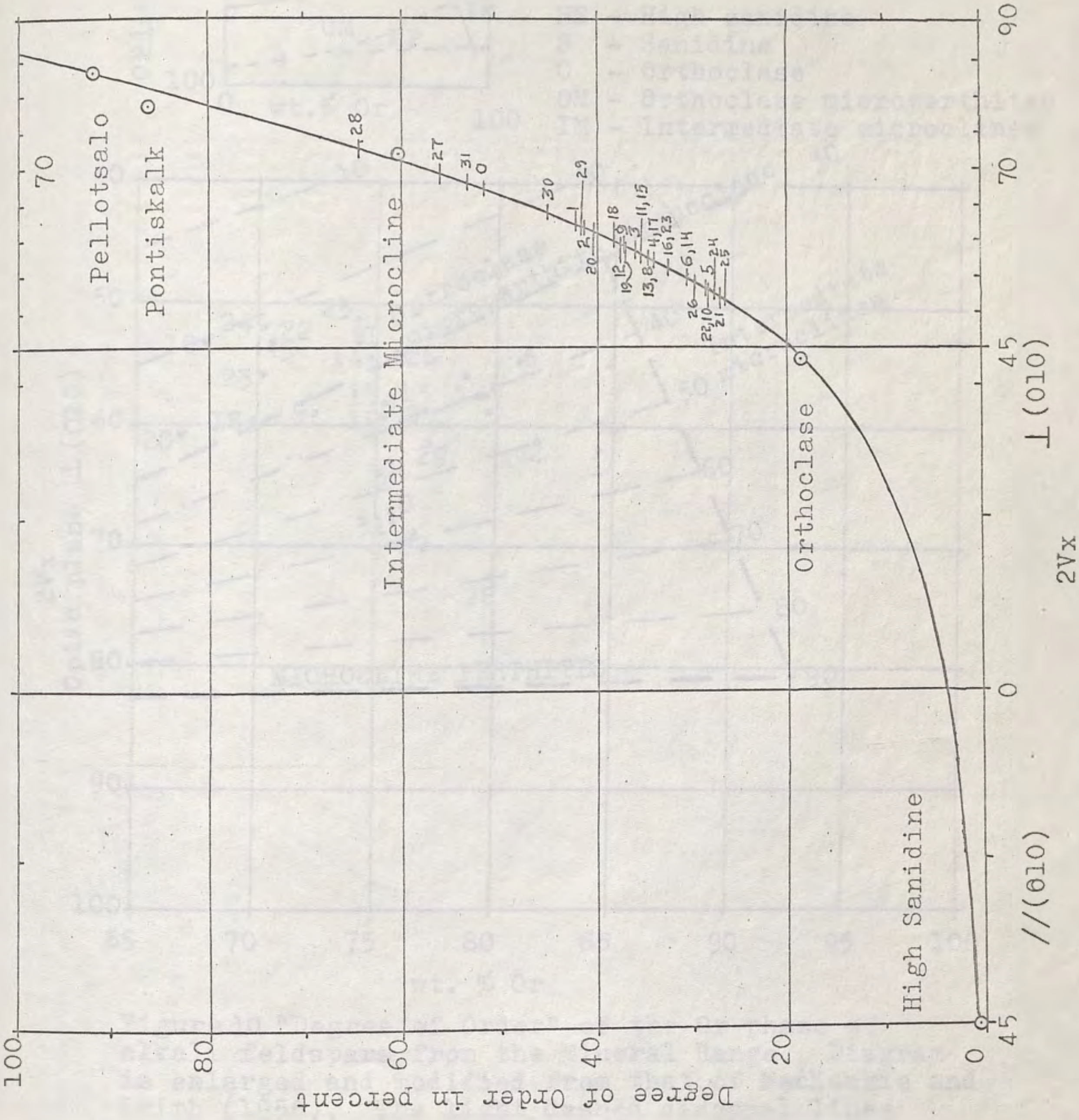
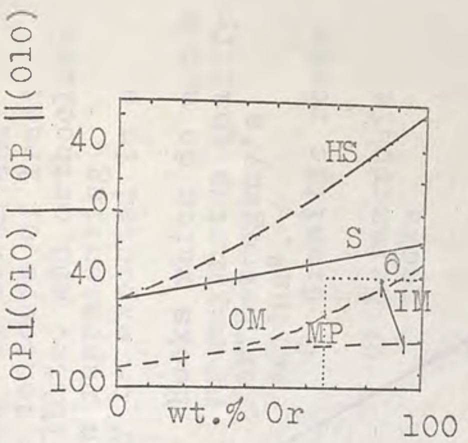


Figure 8B

Figure 8 Comparison of "degree of order" obtained optically and by X-ray diffraction for the Or phase of the alkali feldspars of the Mineral Range.(Fig. 8A). The "degree of order" used for petrologic interpretations is the optical order of Fig. 8B. NOTE THAT THE X-RAY PARAMETERS GIVE ONLY RELATIVE DIFFERENCES; THEY ARE NOT INTENDED TO GIVE ABSOLUTE VALUES.

Figure 9 Degree of order of the Or phase of alkali feldspars. Average 2Vx plotted. The open circles are type specimens used by Finney and Bailey (1964) in constructing the curve.





Key to Figure 10 Reduced from diagram of MacKenzie and Smith (1956). Area within dots includes diagram below.

HS - High sanidine
S - Sanidine
O - Orthoclase
OM - Orthoclase microperthites
IM - Intermediate microclines

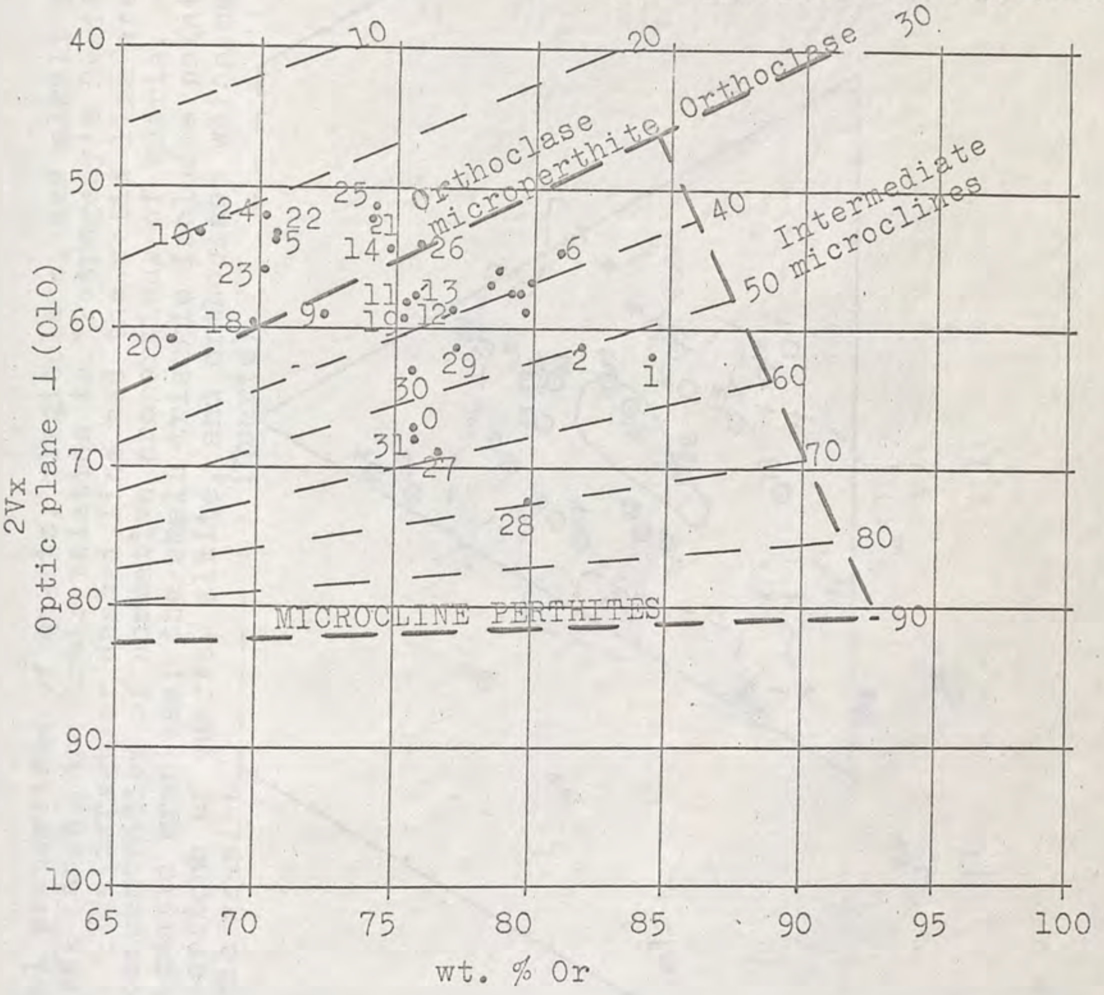
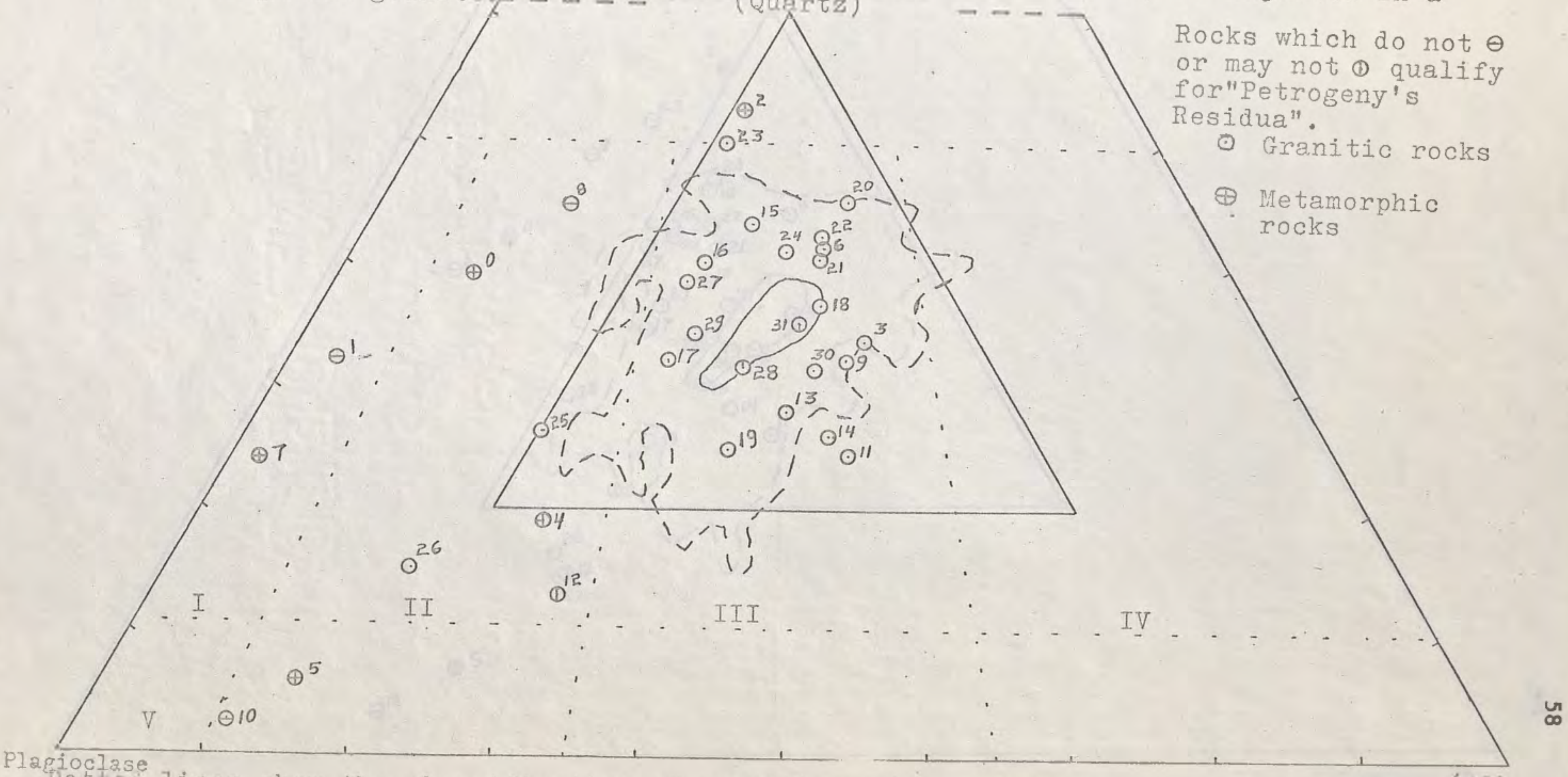


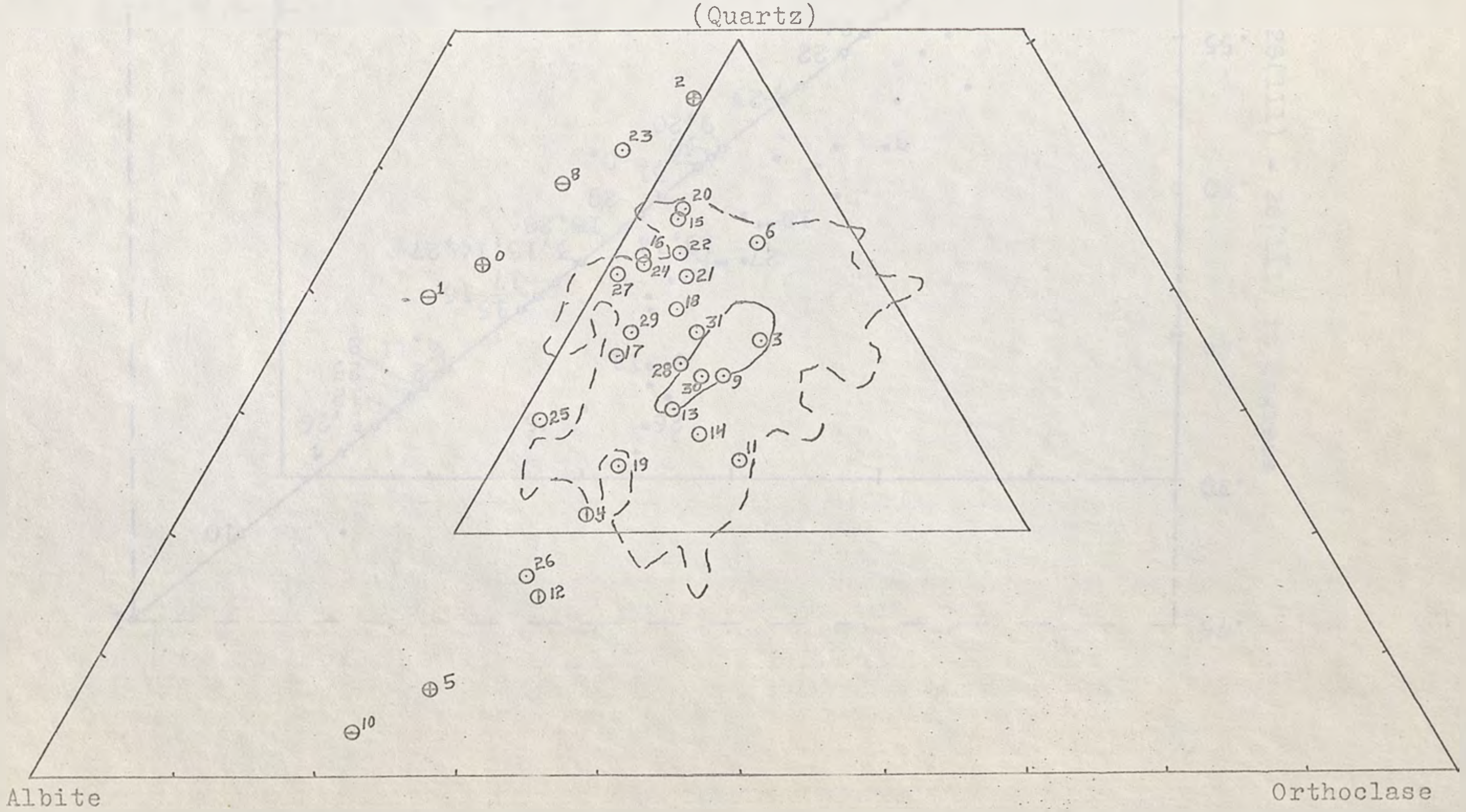
Figure 10 "Degree of Order" of the Or phase of alkali feldspars from the Mineral Range. Diagram is enlarged and modified from that of MacKenzie and Smith (1956). The light dashed diagonal lines represent "degree of order" assuming 0 order for sanidine, 30% order for orthoclase, and 90% order for microcline. 2Vx was measured on the Or phase of the alkali feldspar when perthitic optically but is plotted against bulk Or content. The cluster of unlabeled samples near Or_{80} are from left to right: 4, 16, 8, 15, 3, 17.

Figure 13 Modal proportions of quartz, plagioclase, and alkali feldspar in rocks from the Mineral Range, and their relation to "Petrogeny's Residua" of Bowen and Tuttle (1958). The irregular dashed line and the solid line are contours of least and greatest concentration of normative proportions of quartz, albite, and orthoclase for natural magmatic granites; the small triangle includes points representing normative proportions of quartz, albite, and orthoclase which may be expected in a natural magmatic granite.



Dotted lines show the classification of granitic rocks used by Bateman, et el. (1963). I= Quartz diorite; II= Granodiorite; III= Quartz monzonite and alaskite; IV= Granite; V= Diorite and hornblende gabbro

Figure 14 Proportions of albite, orthoclase, and quartz in rocks from the Mineral Range and their relation to "Petrogeny's Residua" of Bowen and Tuttle (1958). Symbols are like those of Figure 13.



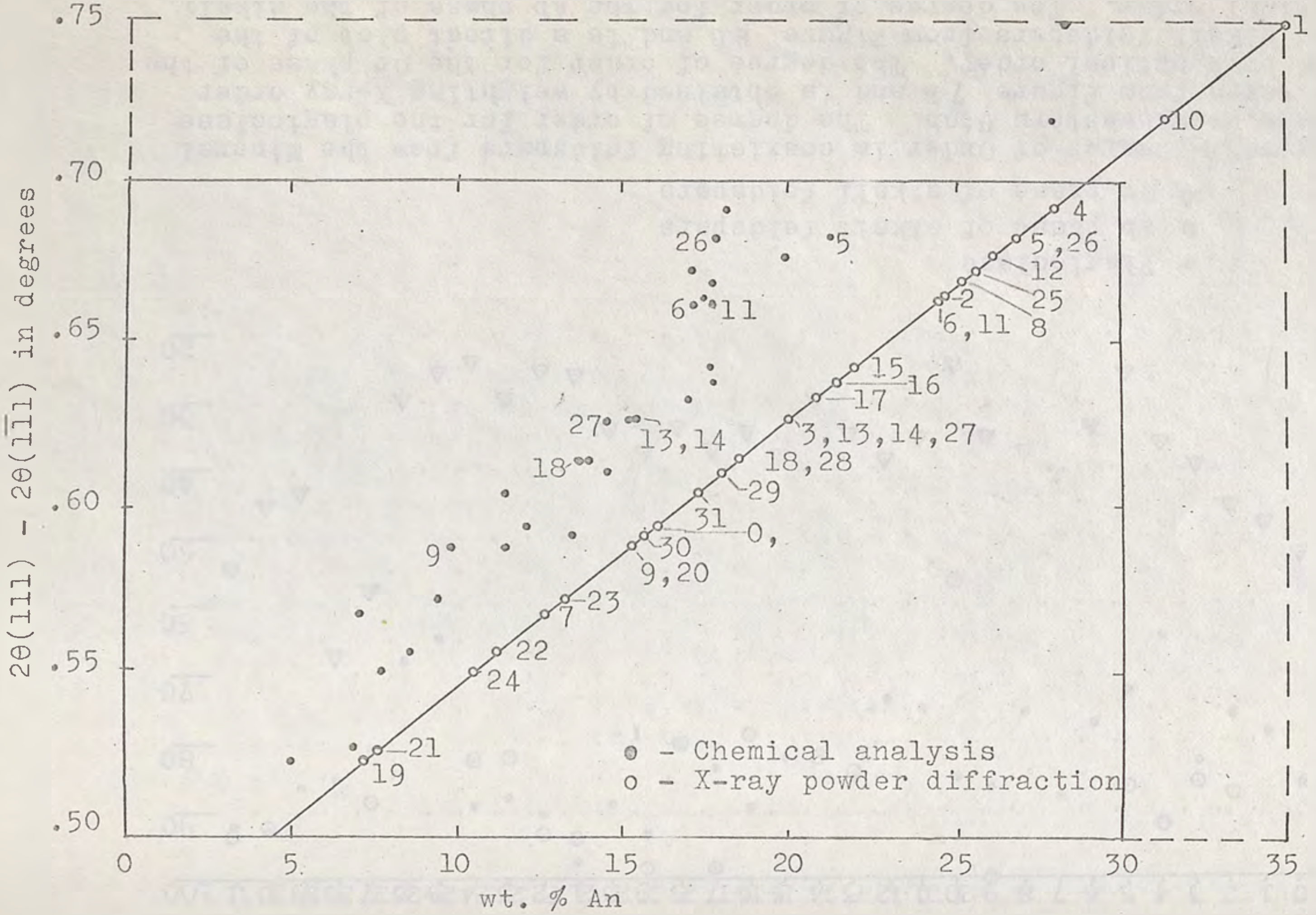


Figure 15 Comparison of An content obtained by chemical analysis with An content obtained by X-ray powder diffraction. Diagram enlarged and extended from J. V. Smith (1956) Smith's curve extends to about An_{24}.

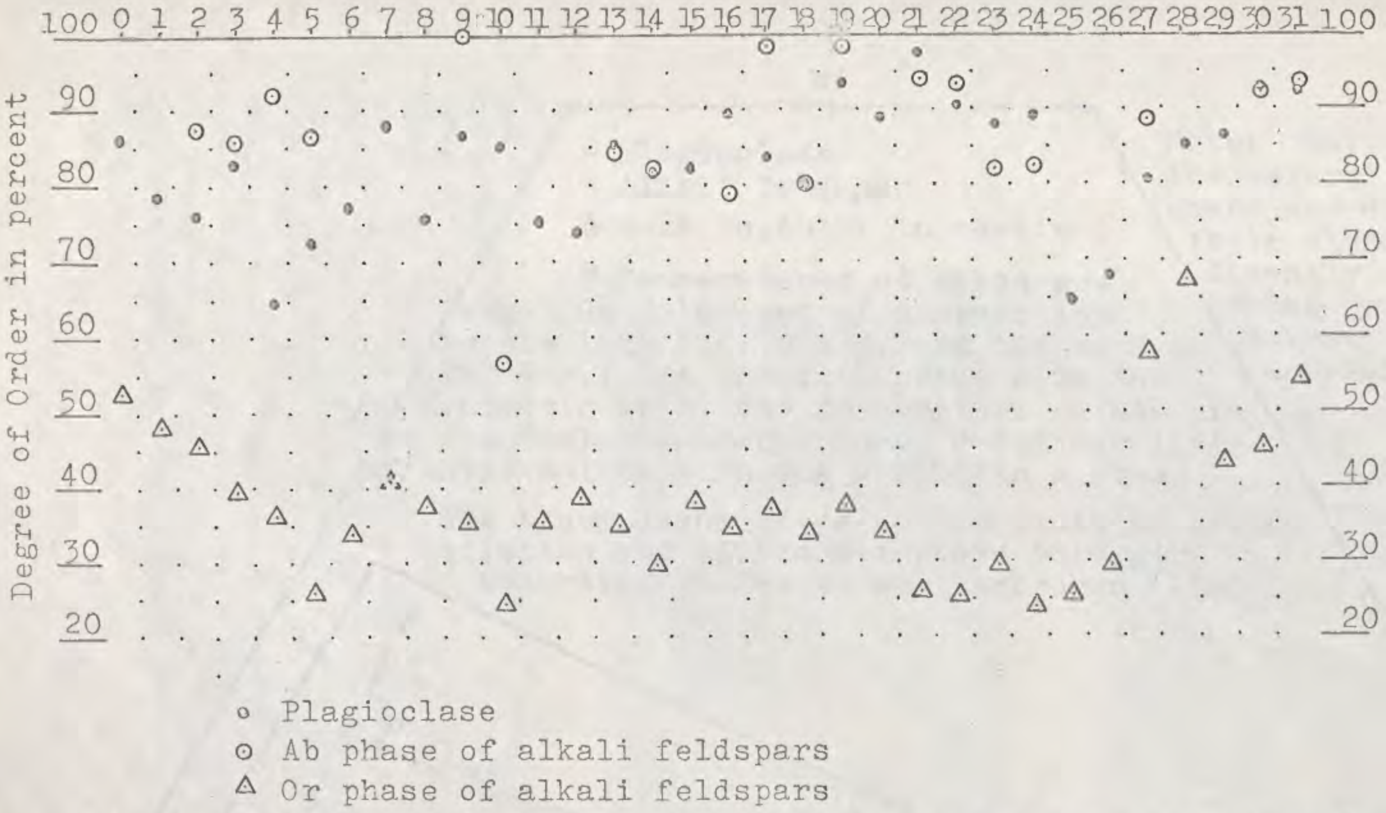
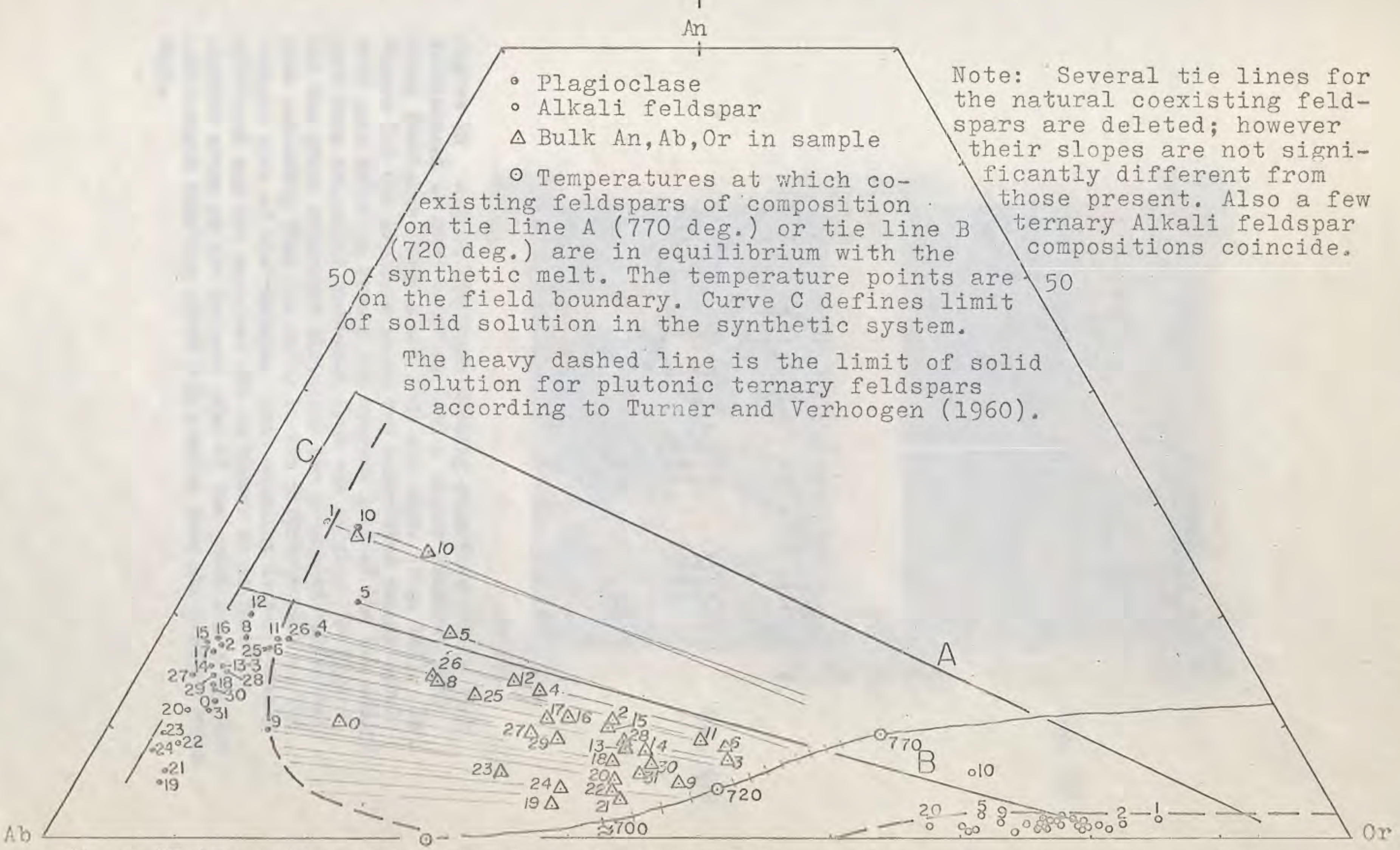


Figure 16 Degree of Order in coexisting feldspars from the Mineral Range, southwestern Utah. The degree of order for the plagioclase is taken from Figure 7 B and is obtained by weighting X-ray order 80% over optical order. The degree of order for the Or phase of the the alkali feldspars from Figure 8 B and is a direct plot of the optical order. The degree of order for the Ab phase of the alkali feldspars is taken from Figure 4 using the reflection separation $2\theta(\bar{1}32)-2\theta(131)$ and assuming that all the An present in the alkali feldspar is in the Ab phase.



⊙ Temperatures at which coexisting feldspars of composition on tie line A (770 deg.) or tie line B (720 deg.) are in equilibrium with the synthetic melt. The temperature points are on the field boundary. Curve C defines limit of solid solution in the synthetic system.

The heavy dashed line is the limit of solid solution for plutonic ternary feldspars according to Turner and Verhoogen (1960).

Note: Several tie lines for the natural coexisting feldspars are deleted; however their slopes are not significantly different from those present. Also a few ternary Alkali feldspar compositions coincide.

Figure 17 Coexisting feldspars from the Mineral Range, Utah, plotted on the projection of the quaternary system $NaAlSi_3O_8$ (Ab) - $KAlSi_3O_8$ (Or) - $CaAl_2Si_2O_8$ (An) - H_2O at 5000 bars H_2O pressure (Yoder, Stewart, and Smith, 1956-1957).

Fig. 18A

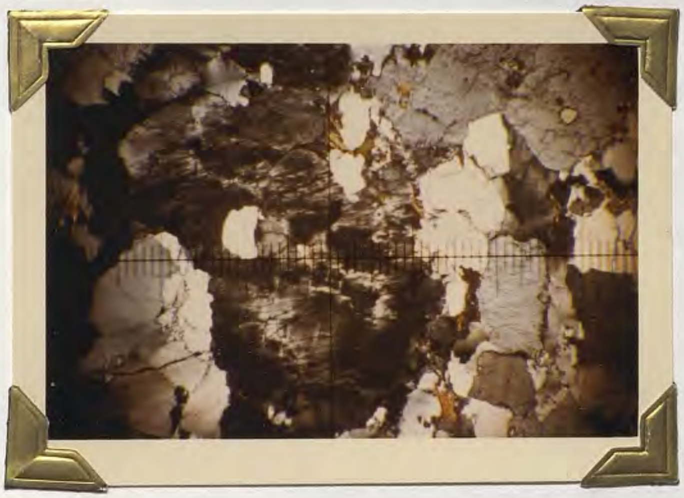


Fig. 18B

Figure 18 Alkali feldspars showing selective though weak development of grid twinning (and a higher measured 2Vx) along fractures (Figs 18A & 18B) and edges (Fig. 18A). In Figure 18B the fracture zones and associated weakly developed grid twinning occupy the western half of the ten square unit area extending southwest from the origin. In Figure 18A the grain concerned straddles the graduated horizontal line extending from the fifth to the fifteenth unit on the eastern side of the picture. Grid twinning is very weakly developed and the measured 2Vx is higher in or near the lighter areas at the western edge of the grain and along the north-south fracture about 2 1/2 units from the western grain edge.

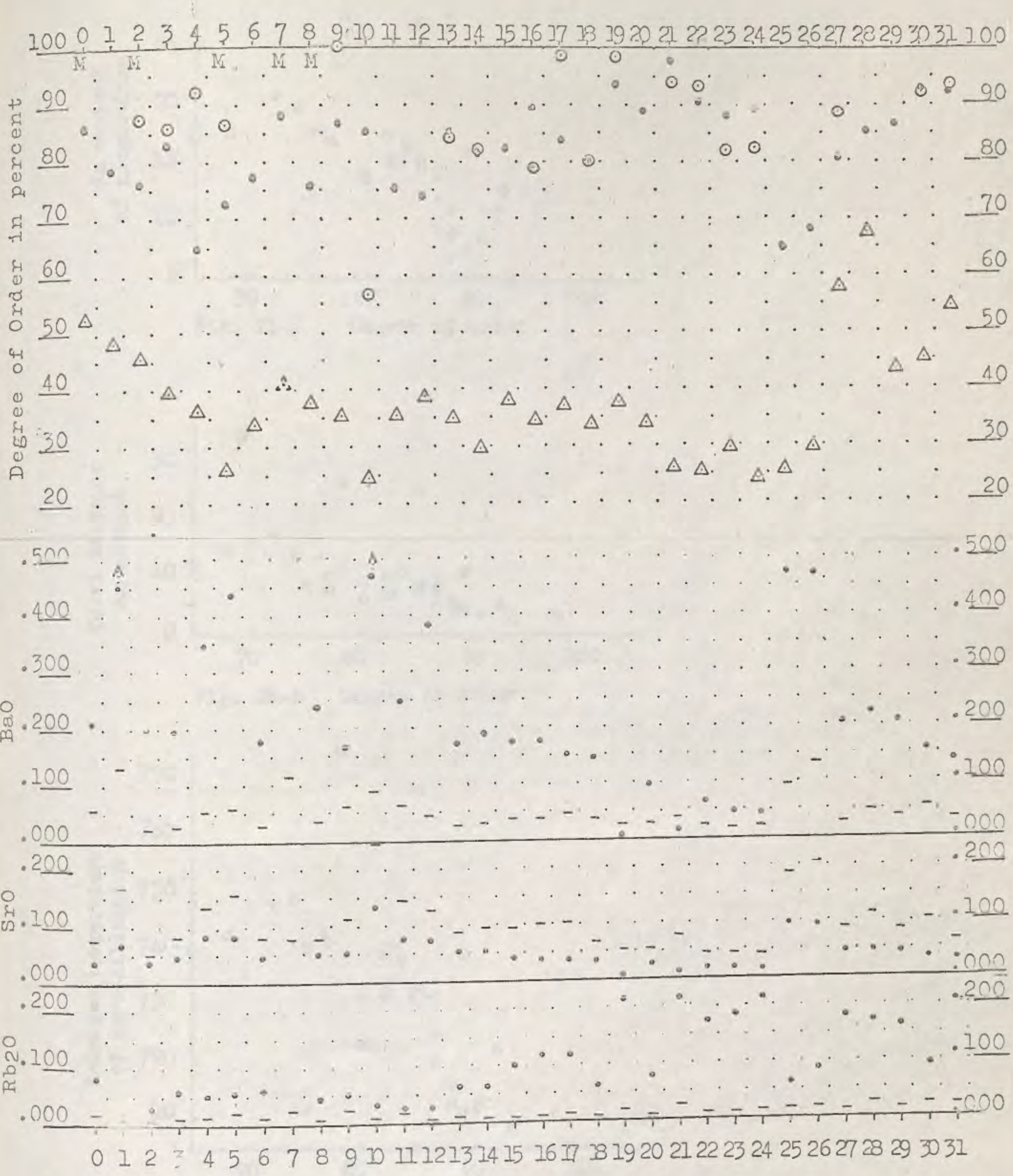


Figure 20 Distribution of Rb_2O, SrO, and BaO in coexisting plagioclase (-) and alkali feldspar (•) and its relation to degree of order in the feldspars from the Mineral Range. Symbols for degree of order are same as Figure 16. BaO in sample 3702 is 1.60 and in sample 3710 is .630. All oxides in weight percent. "M" under top line represents metamorphic samples.

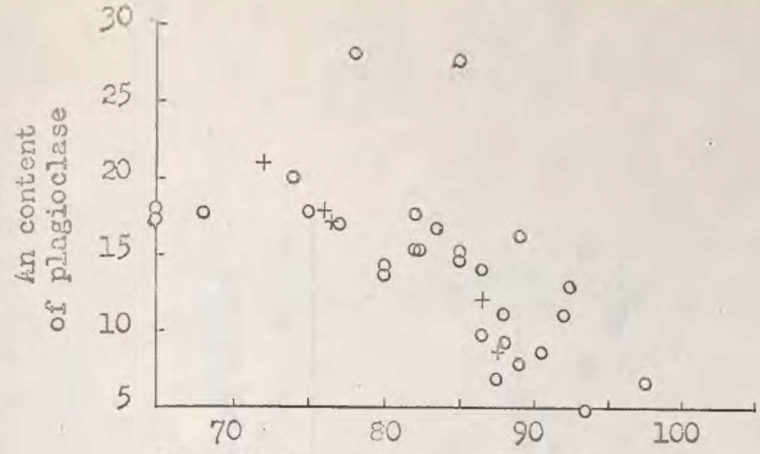


Fig. 21-A Degree of order

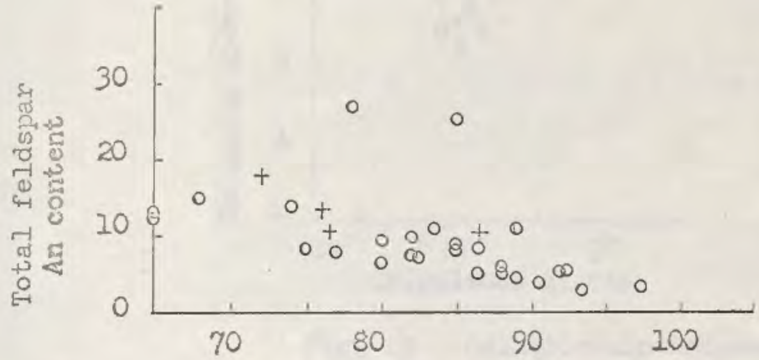


Fig. 21-B Degree of order

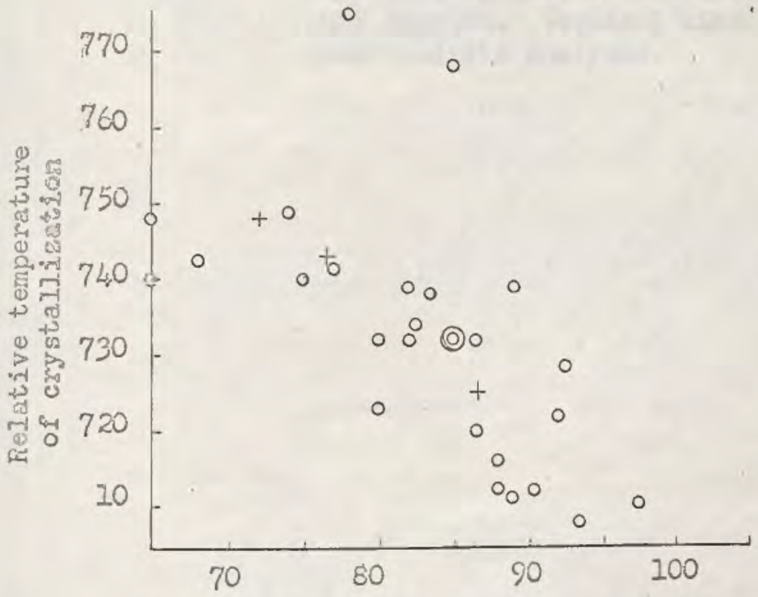


Fig. 21-C Degree of order

Fig. 21 Relationship between degree of order and An content of plagioclase (A), total feldspar An content (B) and relative temperatures of crystallization of plagioclase (C). Circles represent igneous, and plusses, metamorphic samples respectively.

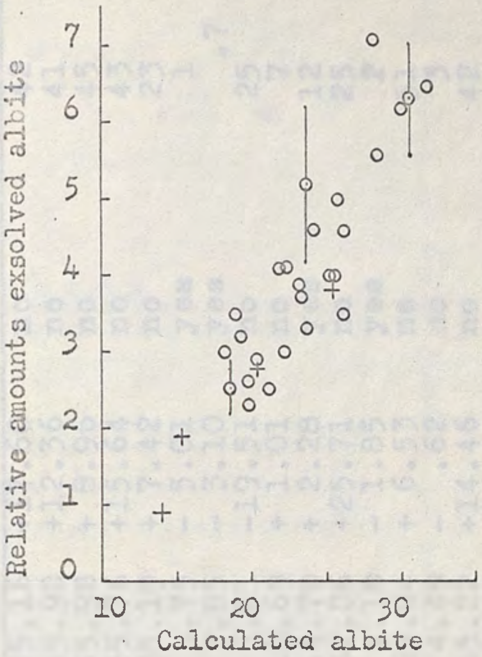


Fig. 22 Relationship between relative amounts exsolved Ab (estimated from the (002) reflection) and Ab calculated from chemical analyses. Circles represent igneous rock samples and plusses metamorphic samples. Vertical lines give range on three quadruplicate analyses.

TABLE 1 -Recalculation of chemical analyses of plagioclase to molecular % and weight % An showing excess (+) or deficient (-) SiO_2 and Al_2O_3. The effectiveness of removing quartz from the plagioclase by flotation is shown.

Sample	Mol. %			Wt. %	+ or -	+ or -	Quartz	% quartz in sample	
	An	Ab	Or	An/An+Ab	SiO_2	Al_2O_3	floated out	detd. by X-ray diffr.	as calcd. from anal.
3700P1	11.5	81.6	6.9	12.9	+55.16	+17.60	no	42	+43.3
3700P1-A	11.3	81.3	7.4	12.6	+55.90	+12.36	no	41	+44.8
3700P1-B	11.4	81.9	6.8	12.7	+55.98	+ 8.96	no	45	+44.6
3700P1-C	11.1	82.1	6.8	12.3	+55.76	+15.64	no	43	+44.1
3701P1	27.1	65.9	7.0	30.1	+35.19	+ 7.42	no	23	+24.4
3702P1	16.5	79.1	4.5	18.0	- 5.75	- 5.01	yes	1	- 3.5
3703P1	14.5	79.9	5.6	15.9	- 3.85	- 3.10	yes	.7	- 2.4
3704P1	14.1	76.6	9.4	16.0	+ 5.61	-19.51	no	25	+ 4.0
3705P1	20.2	66.9	12.9	23.9	+10.69	+ 1.01	no	7	+ 6.9
3706P1	16.2	75.6	8.2	18.4	+14.70	+ 2.28	yes	12	+ 9.7
3707P1	6.7	63.9	29.4	9.7	+32.06	+25.71	no	25	+22.2
3708P1	17.0	76.9	6.1	18.8	- 4.10	- 1.85	yes	2	- 2.5
3709P1	9.4	79.1	11.5	10.8	+59.04	+ 6.53	no	51	+48.7
3710P1	26.8	63.5	9.8	30.4	+ 4.49	- .62	no	3	+ 2.7
3711P1	17.0	74.7	8.3	19.1	+55.22	+14.46	no	42	+43.2
3712P1	19.1	75.4	5.6	20.9	- 2.67	- 4.42	yes	1	- 1.6
3713P1	14.5	80.0	5.4	16.0	- 2.27	- .67	yes	.6	- 1.4
3714P1	14.6	80.6	4.8	15.9	- 6.50	- 4.52	yes	.4	- 4.0
3715P1	16.8	79.9	3.3	18.0	- 2.62	- 2.85	yes	.4	- 1.6
3716P1	17.0	79.2	3.8	18.3	+30.51	+ 5.07	yes	24	+21.4
3717P1	13.0	83.9	3.1	14.0	+35.32	-20.09	no	43	+27.5
3718P1	12.9	81.3	5.9	14.3	- 3.26	- 2.89	yes	.5	- 2.1
3718P1-A	12.9	81.2	5.9	14.3	- 3.28	- 4.70	yes	.6	- 2.1
3718P1-B	13.1	81.2	5.7	14.4	- 3.26	- 4.59	yes	.6	- 2.1
3718P1-C	12.9	81.1	6.0	14.3	- 3.16	- 3.58	yes	.7	- 2.0
3719P1	4.6	89.4	6.0	5.2	+48.00	+ 6.96	no	38	+37.6
3720P1	10.8	84.3	4.9	11.8	+ .89	- 1.00	yes	1	+ .6

TABLE 1-Continued

Sample	Mol. % An	Mol. % Ab	Mol. % Or	Wt. % An/An+Ab	+ or - SiO_2	+ or - Al_2O_3	Quartz floated out	% quartz in sample detd. by X-ray diffr.	% quartz in sample as calcd. from anal.
3721Pl	3.4	93.7	2.9	3.6	+31.39	-85.95	no	59	+26.5
3722Pl	8.1	86.2	5.7	9.0	+ 2.80	- .82	yes	2	+ 1.8
3723Pl	8.9	86.9	4.1	9.7	+ 3.32	- 5.20	yes	3	+ 2.2
3724Pl	7.4	88.5	4.1	8.0	- 3.46	- 4.89	yes	.8	- 2.2
3724Pl-A	7.5	88.4	4.2	8.1	- 4.10	- 5.85	yes	.6	- 2.6
3724Pl-B	7.4	88.5	4.1	8.0	- 4.85	- 5.37	yes	.6	- 3.1
3724Pl-C	7.4	88.4	4.2	8.0	- 5.31	- 3.13	yes	.8	- 3.4
3725Pl	16.2	75.9	7.9	18.0	+40.29	+ 3.10	no	33	+30.3
3726Pl	17.1	73.9	9.1	19.2	+21.90	+ 1.49	no	18	+15.0
3727Pl	13.7	82.3	4.0	14.8	- 7.31	- 8.73	yes	.7	- 4.6
3728Pl	14.2	79.7	6.1	15.6	+55.55	+ .92	no	46	+44.3
3729Pl	13.7	80.9	5.4	15.0	- 3.23	- 5.82	yes	.8	- 2.1
3730Pl	12.7	81.1	6.3	13.9	+60.37	+12.23	no	49	+48.9
3731Pl	9.8	84.2	6.0	10.8	-11.99	-13.08	yes	.8	- 7.7

(+ or -) SiO_2 and (+ or -) Al_2O_3 is in percent of amount SiO_2 or Al_2O_3 present in chemical analyses.

TABLE 2 -Recalculation of chemical analyses of alkali feldspars to molecular % and weight % Or showing excess (+) or deficient (-) SiO_2 and Al_2O_3.

Sample	Mol. %			Wt. %	+ or -	+ or -	Quartz	Quartz in sample	
	An	Ab	Or	Or	SiO_2	Al_2O_3	floated out	amt. detd. by X-ray diffr.	% calcd. from anal.
3700Ks	1.3	20.4	78.3	74.7	+ 3.80	+ 6.10	no	2	+ 2.5
3701Ks	1.7	8.8	89.5	80.4	+ 4.48	+ 8.32	no	2	+ 2.8
3702Ks	1.1	16.6	82.3	81.2	- .16	+ 2.85	yes	2	- .1
3703Ks	.9	19.4	79.7	78.7	+ .31	+ 2.74	yes	2	+ .2
3704Ks	1.2	36.2	62.6	77.5	-26.20	-22.26	no	1	-16.7
3705Ks	2.0	27.2	70.8	69.3	- 2.08	+ 2.91	no	3	- 1.3
3706Ks	.8	23.5	75.8	80.6	- 8.75	- 3.79	yes	2	- 5.6
3706Ks-A	.8	23.6	75.7	80.4	- 9.12	- 2.92	yes	2	- 5.8
3706Ks-B	.8	23.6	75.7	80.4	- 8.71	- 3.03	yes	2	- 5.5
3706Ks-C	.8	23.7	75.5	79.5	- 8.67	- 1.80	yes	1	- 5.5
3707Ks									
3708Ks	1.0	15.8	83.2	77.9	+ 3.91	+ 8.69	yes	2	+ 2.5
3709Ks	1.3	22.8	75.9	71.7	+ 3.43	+ 7.26	no	2	+ 2.2
3710Ks	6.3	22.4	71.3	66.2	+ 3.54	+ 5.97	no	3	+ 2.2
3711Ks	1.4	29.4	69.2	74.7	- 9.48	- 7.13	no	3	- 6.1
3712Ks	2.1	16.5	81.5	75.9	+ 4.98	+ 7.41	yes	3	+ 3.2
3713Ks	1.1	25.9	73.1	75.1	- 3.14	+ .26	yes	3	- 2.0
3714Ks	1.2	26.5	72.3	73.8	- 3.04	+ 1.21	yes	2	- 2.0
3715Ks	.8	24.0	75.3	78.4	- 5.70	- 2.64	yes	2	- 3.7
3716Ks	.8	23.9	75.4	77.9	- 4.76	- 1.99	yes	1	- 3.1
3717Ks	.8	39.5	59.8	78.8	-33.01	-30.17	no	3	-21.3
3718Ks	1.0	31.4	67.6	69.2	- 4.29	- 1.85	yes	2	- 2.7
3718Ks-A	1.1	31.5	67.5	69.0	- 4.47	+ .79	yes	2	- 2.8
3718Ks-B	1.1	31.6	67.4	68.8	- 4.64	+ .21	yes	2	- 2.9
3718Ks-C	1.1	31.7	67.2	68.3	- 4.27	+ .85	yes	2	- 2.7
3719Ks	.5	36.7	60.9	74.5	-24.23	-20.43	no	3	-15.6
3720Ks	1.1	36.0	62.9	66.4	- 7.68	- 4.09	yes	3	- 4.9

TABLE 2 -Continued

Sample	Mol. %			Wt. %	+ or -	+ or -	Quartz	Quartz in sample	
	An	Ab	Or	Or	SiO_2	Al_2O_3	floated out	amt. detd. by X-ray diffr.	% calcd. from anal.
3721Ks	.4	42.0	57.6	73.2	-28.17	-24.81	no	2	-18.2
3722Ks	.8	30.8	68.4	69.9	- 4.28	- 1.64	yes	2	- 2.7
3723Ks	.7	30.0	69.3	69.3	- 2.08	+ .87	yes	1	- 1.3
3724Ks	.8	29.8	69.5	69.3	- 1.91	+ 1.67	yes	2	- 1.2
3725Ks	1.7	25.1	73.2	72.7	- 1.92	+ .86	no	2	- 1.2
3726Ks	1.7	23.4	74.9	74.4	- 2.75	+ 3.38	no	2	- 1.7
3727Ks	1.5	23.1	75.5	75.3	- 2.49	+ 1.70	yes	2	- 1.6
3728Ks	1.0	20.0	79.0	78.7	- 1.76	+ 1.24	no	2	- 1.1
3729Ks	1.1	23.3	75.6	76.1	- 3.38	+ 1.12	yes	2	- 2.2
3730Ks	1.1	24.6	74.3	74.7	- 2.25	+ 2.18	no	2	- 1.4
3731Ks	.9	24.5	74.6	75.5	- 2.83	+ 1.54	yes	1	- 1.8
3731Ks-A	1.0	24.5	74.5	75.3	- 3.78	+ .38	yes	1	- 2.4
3731Ks-B	1.0	24.6	74.4	74.9	- 3.11	+ .91	yes	1	- 2.0
3731Ks-C	1.0	24.7	74.3	74.7	- 3.06	+ 2.53	yes	2	- 2.0

(+ or -) SiO_2 and (+ or -) Al_2O_3 is in percent of amount SiO_2 or Al_2O_3 present in chemical analyses.

Weight percent Or not calculated to 100 percent.

Amount of quartz is estimated by comparing intensities of the quartz reflections (100) and (101) in the alkali feldspar sample to the same quartz reflections in the plagioclase feldspars. Interference of quartz reflections (100) and (101) by potassium feldspar reflections (20$\bar{1}$)and (220) respectively occurs in every sample. The maximum amount of quartz present in any sample is believed to be about 3 percent. It may be less. The maximum value of 3 is broken into 1, 2, or 3 percent for a given sample depending on the height of the quartz reflection plateau (more rarely peak) and the width of the adjacent potassium feldspar reflection profiles. The position and line profile of the potassium feldspar reflection (20$\bar{1}$) changes less from sample to sample than the reflection (220), and was used in most of the quartz determinations.

TABLE 3-Chemical analyses of plagioclase from the Mineral Range, Utah, calculated to weight percent feldspar[1]

Sample	An	Ab	Or	(Ba)	(Sr)	(Rb)	Total
3702Pl	17.36	79.04	4.69	.05	.16	.03	101.33
3703Pl	14.98	79.12	5.80	.06	.26	.04	100.26
3708Pl	17.56	75.90	6.32	.09	.24	.03	100.15
3710Pl	25.85	59.23	9.46	.21	.75	.04	95.53
3712Pl	19.45	73.70	5.66	.11	.40	.02	99.35
3713Pl	14.64	77.09	5.45	.06	.28	.04	97.55
3714Pl	15.13	80.14	5.01	.07	.30	.03	100.68
3715Pl	17.07	77.77	3.36	.09	.30	.02	98.61
3718Pl	13.40	80.56	6.09	.09	.22	.03	100.38
3718Pl-A	13.40	80.56	6.21	.09	.22	.03	100.49
3718Pl-B	13.54	80.56	5.97	.09	.22	.04	100.41
3718Pl-C	13.44	80.56	6.15	.11	.23	.13	100.61
3720Pl	10.77	80.56	4.88	.07	.17	.03	96.46
3722Pl	7.94	80.56	5.56	.05	.14	.04	94.28
3723Pl	8.93	82.93	4.13	.04	.14	.04	96.21
3724Pl	7.64	88.17	4.27	.05	.14	.05	100.31
3724Pl-A	7.79	88.17	4.33	.05	.14	.05	100.52
3724Pl-B	7.69	88.17	4.29	.04	.14	.04	100.38
3724Pl-C	7.69	88.17	4.24	.06	.17	.14	100.48
3727Pl	14.64	84.03	4.29	.07	.28	.04	103.34
3729Pl	14.24	80.73	5.64	.10	.27	.06	101.02
3731Pl	11.01	90.80	6.74	.09	.20	.07	108.91

(Ba) = $BaAl_2Si_2O_8$
(Sr) = $SrAl_2Si_2O_8$
(Rb) = $RbAlSi_3O_8$

[1] Only those samples with three percent quartz or less (as determined by X-ray diffraction) are calculated to weight percent feldspar.

TABLE 4 -Chemical analyses of the alkali feldspars from the Mineral Range, Utah, calculated to weight percent feldspar

Sample	Or	Ab	An	(Ba)	(Sr)	(Rb)	Total
3700Ks	74.70	18.53	1.13	.52	.12	.29	95.28
3701Ks	80.37	7.70	1.38	3.92	.22	.08	93.67
3702Ks	81.20	15.49	1.04	.50	.12	.10	98.45
3703Ks	78.72	18.19	.81	.47	.15	.21	98.55
3704Ks	77.54	42.65	1.29	.85	.26	.18	122.77
3705Ks	69.32	25.39	1.81	1.07	.26	.20	98.04
3706Ks	80.61	23.69	.70	.44	.14	.21	105.79
3706Ks-A	80.37	23.69	.69	.42	.14	.20	105.52
3706Ks-B	80.37	23.69	.66	.43	.14	.21	105.51
3706Ks-C	79.55	23.69	.69	.45	.16	.26	104.79
3707Ks							
3708Ks	77.95	14.05	.83	.58	.16	.16	93.72
3709Ks	71.74	20.48	1.14	.42	.17	.18	94.12
3710Ks	66.25	19.97	5.55	1.54	.41	.12	93.84
3711Ks	74.70	30.04	1.29	.61	.24	.09	106.96
3712Ks	75.88	14.56	1.77	.94	.23	.10	93.47
3713Ks	75.11	25.22	.96	.42	.16	.23	102.09
3714Ks	73.81	25.64	1.12	.46	.17	.22	101.42
3715Ks	78.42	23.69	.72	.43	.12	.38	103.76
3716Ks	77.95	23.44	.72	.43	.12	.41	103.07
3717Ks	78.78	49.50	.95	.37	.11	.41	130.12
3718Ks	69.20	30.55	.98	.36	.11	.22	101.41
3718Ks-A	69.03	30.55	1.01	.36	.10	.21	101.25
3718Ks-B	68.79	30.55	1.01	.36	.11	.22	101.03
3718Ks-C	68.32	30.55	1.03	.38	.13	.26	100.67
3719Ks	74.52	44.93	.56	.02	.03	.74	120.80
3720Ks	66.43	36.05	1.14	.24	.09	.27	104.20
3721Ks	73.16	50.60	.47	.03	.04	.74	125.04
3722Ks	69.91	29.96	.76	.15	.06	.60	101.45
3723Ks	69.32	28.52	.67	.11	.05	.63	99.30
3724Ks	69.32	28.26	.76	.11	.05	.74	99.24
3725Ks	72.69	23.78	1.48	1.15	.31	.21	99.62
3726Ks	74.40	22.17	1.44	1.15	.29	.30	99.76
3727Ks	75.29	21.92	1.34	.51	.15	.62	99.83
3728Ks	78.72	18.96	.92	.54	.15	.60	99.89
3729Ks	76.06	22.34	1.02	.51	.15	.56	100.64
3730Ks	74.70	23.44	1.02	.38	.11	.32	99.97
3731Ks	75.47	23.61	.87	.34	.10	.72	101.11
3731Ks-A	75.29	23.61	.94	.33	.10	.72	100.98
3731Ks-B	74.94	23.61	.89	.34	.10	.72	100.60
3731Ks-C	74.70	23.61	.92	.35	.12	.69	100.39

(Ba) = $BaAl_2Si_2O_8$
(Sr) = $SrAl_2Si_2O_8$
(Rb) = $RbAlSi_3O_8$

TABLE 5 -Final An-Or-Ab weight percents for plagioclase and alkali feldspars from the Mineral Range. Or includes Rb and Ba feldspar, and An includes Sr feldspar. See page 1 for explanation.

	Plagioclase			Alkali feldspars		
	An	Ab	Or	Or	Ab	An
3700	12.1	80.7	7.2	75.5	23.3	1.3
3700-A	11.8	80.3	7.9			
3700-B	12.0	80.9	7.1			
3700-C	11.7	81.0	7.3			
3701	28.2	64.4	7.4	84.4	14.0	1.6
3702	17.3	78.0	4.7	81.8	15.5	1.2
3703	15.2	78.9	5.9	79.4	18.2	1.0
3704	18.0	69.9	12.0	78.6	19.9	1.6
3705	21.1	65.5	13.5	70.6	25.4	2.1
3706	17.0	74.4	8.6	81.3	17.9	.8
3706-A				81.0	18.2	.8
3706-B				81.0	18.2	.8
3706-C				80.3	18.9	.9
3707	7.0	62.5	30.5			
3708	17.8	75.8	6.4	78.7	20.3	1.0
3709	9.8	78.0	12.2	72.3	26.4	1.3
3710	27.8	62.0	10.2	67.9	26.1	6.0
3711	17.8	73.5	8.7	75.4	23.1	1.5
3712	20.0	74.2	5.8	76.9	21.1	2.0
3713	15.3	79.0	5.7	75.8	25.2	1.1
3714	15.3	79.6	5.1	74.5	25.6	1.3
3715	17.6	78.9	3.5	79.2	19.9	.8
3716	17.9	78.1	4.0	78.8	20.4	.8
3717	16.9	79.0	4.1	79.6	19.4	1.1
3718	13.6	80.3	6.2	69.8	30.6	1.1
3718-A	13.6	80.2	6.3	69.6	30.6	1.1
3718-B	13.7	80.2	6.1	69.4	30.6	1.1
3718-C	13.6	80.1	6.3	69.0	30.6	1.2
3719	5.0	88.6	6.4	75.3	24.1	.6
3720	11.3	83.5	5.2	67.0	31.9	1.2
3721	6.9	87.2	5.9	73.9	25.6	.5
3722	8.6	85.5	6.0	70.7	30.0	.8
3723	9.4	86.2	4.4	70.1	28.5	.7
3724	7.8	87.9	4.3	70.2	28.3	.8
3724-A	7.9	87.7	4.4			
3724-B	7.8	87.8	4.4			
3724-C	7.8	87.8	4.4			
3725	17.0	74.7	8.4	74.1	23.8	1.8
3726	17.9	72.5	9.6	75.9	22.2	1.7
3727	14.4	81.3	4.3	76.4	21.9	1.5
3728	14.9	78.7	6.4	79.9	19.0	1.1
3729	14.4	79.9	5.7	77.1	22.3	1.2
3730	13.3	80.1	6.6	75.4	23.4	1.1
3731	11.2	81.9	6.9	76.5	23.6	1.0
3731-A				76.3	23.6	1.0
3731-B				76.0	23.6	1.0
3731-C				75.7	23.6	1.0

TABLE 6 -X-ray powder diffraction data on plagioclase feldspars from the Mineral Range

	$2\theta(\bar{1}32)-2\theta(131)$			$2\theta(131)-2\theta(1\bar{3}1)$			$2\theta(111)-2\theta(\bar{1}11)$			$2\theta(1\bar{1}1)-2\theta(\bar{2}01)$		
	Fwd.	Rev.	Avg.	Fwd.	Rev.	Avg.	Fwd.	Rev.	Avg.	Fwd.	Rev.	Avg.
3700Pl	2.539	2.564	2.551	1.412	1.404	1.408	.597	.598	.597	.973	.960	.966
3700Pl-A	2.582	2.549	2.565	1.380	1.367	1.373	.600	.574	.587	.968	.985	.976
3700Pl-B	2.578	2.555	2.566	1.417	1.386	1.401	.616	.586	.601	.982	.974	.978
3700Pl-C	2.576	2.554	2.565	1.378	1.374	1.376	.603	.612	.607	.970	.957	.963
3701Pl	2.370	2.374	2.372	1.698	1.720	1.709	.755	.745	.750	.890	.920	.905
3702Pl	2.479	2.465	2.472	1.548	1.561	1.554	.664	.663	.663	.953	.956	.954
3703Pl	2.537	2.504	2.520	1.478	1.473	1.475	.619	.637	.628	.961	.963	.962
3704Pl	2.420	2.409	2.415	1.645	1.650	1.647	.701	.682	.691	.924	.947	.935
3705Pl	2.415	2.410	2.412	1.661	1.648	1.654	.680	.685	.682	.939	.937	.938
3706Pl	2.478	2.483	2.480	1.590	1.565	1.577	.654	.670	.662	.938	.935	.937
3707Pl	2.641	2.583	2.612	1.376	1.387	1.381	.570	.566	.568	1.039	.985	1.012
3708Pl	2.460	2.461	2.460	1.572	1.590	1.581	.668	.669	.668	.948	.950	.949
3709Pl	2.580	2.569	2.574	1.410	1.354	1.380	.602	.576	.589	.956	.975	.965
3710Pl	2.369	2.385	2.377	1.696	1.697	1.696	.729	.716	.722	.917	.928	.922
3711Pl	2.456	2.475	2.465	1.576	1.560	1.568	.672	.653	.662	.947	.950	.948
3712Pl	2.453	2.443	2.448	1.574	1.575	1.574	.682	.670	.676	.946	.945	.945
3713Pl	2.534	2.522	2.528	1.473	1.470	1.471	.613	.643	.628	.973	.951	.962
3714Pl	2.508	2.512	2.510	1.488	1.482	1.485	.616	.641	.628	.979	.972	.975
3715Pl	2.508	2.480	2.494	1.554	1.505	1.530	.645	.639	.642	.961	.963	.962
3716Pl	2.510	2.521	2.515	1.536	1.513	1.524	.647	.632	.639	.955	.961	.958
3717Pl	2.520	2.483	2.501	1.466	1.490	1.478	.642	.626	.634	.948	.978	.963
3718Pl	2.525	2.520	2.522	1.475	1.476	1.475	.616	.615	.615	.970	.973	.971
3718Pl-A	2.522	2.509	2.516	1.478	1.453	1.465	.624	.621	.622	.976	.962	.969
3718Pl-B	2.520	2.540	2.530	1.460	1.446	1.453	.607	.609	.608	.973	.984	.978
3718Pl-C	2.519	2.498	2.508	1.447	1.460	1.453	.620	.631	.625	.978	.968	.973
3719Pl	2.664	2.678	2.671	1.220	1.179	1.199	.525	.522	.523	.997	1.001	.999
3720Pl	2.593	2.569	2.581	1.370	1.380	1.375	.579	.598	.589	.971	.976	.973
3721Pl	2.678	2.650	2.666	1.217	1.240	1.228	.519	.532	.525	1.018	1.007	1.012
3722Pl	2.602	2.611	2.607	1.322	1.303	1.312	.548	.563	.555	1.012	.986	.999
3723Pl	2.595	2.606	2.600	1.322	1.320	1.321	.566	.579	.572	.981	.989	.985
3724Pl	2.619	2.593	2.606	1.243	1.279	1.261	.546	.554	.550	.990	.994	.992

TABLE 6 -Continued

	$2\theta(\bar{1}32)-2\theta(131)$			$2\theta(131)-2\theta(1\bar{3}1)$			$2\theta(111)-2\theta(1\bar{1}1)$			$2\theta(1\bar{1}1)-2\theta(\bar{2}01)$		
	Fwd.	Rev.	Avg.	Fwd.	Rev.	Avg.	Fwd.	Rev.	Avg.	Fwd.	Rev.	Avg.
3724P1-A	2.607	2.612	2.609	1.301	1.256	1.279	.552	.545	.548	.982	.999	.990
3724P1-B	2.616	2.632	2.624	1.278	1.272	1.275	.572	.564	.568	.974	.983	.978
3724P1-C	2.603	2.619	2.611	1.270	1.253	1.262	.547	.558	.553	1.000	.984	.992
3725P1	2.454	2.428	2.441	1.569	1.567	1.568	.669	.673	.671	.946	.954	.950
3726P1	2.422	2.454	2.438	1.603	1.579	1.591	.696	.669	.682	.930	.960	.945
3727P1	2.504	2.500	2.502	1.501	1.483	1.492	.623	.633	.628	.973	.959	.966
3728P1	2.531	2.519	2.525	1.454	1.445	1.449	.610	.621	.615	.987	.976	.981
3729P1	2.533	2.543	2.538	1.453	1.430	1.441	.602	.621	.611	.967	.973	.970
3730P1	2.574	2.585	2.579	1.376	1.400	1.387	.587	.598	.592	.975	.972	.973
3731P1	2.606	2.592	2.599	1.356	1.380	1.368	.579	.632	.605	.979	.964	.972
FD156	2.580 2.561	2.562	2.568	1.381 1.379	1.384	1.381	.631 .604	.593	.609	.959 .982	.970	.970
FD156			2.595*			1.390*			.615*			.98**

*-Values obtained by J. V. Smith (1956).
**-Value obtained by J. V. Smith and P. Gay (1958).

TABLE 7 -X-ray powder diffraction data on alkali feldspars from the Mineral Range: the Or phase[1]

	$(1\bar{3}1)$ (131) pk/width			$(1\bar{3}0)$ (130) pk/width		
	Fwd.	Rev.	Avg.	Fwd.	Rev.	Avg.
3700Ks	3.1	2.7	2.9	5.1	4.5	4.8
3701Ks	3.5	3.7	3.6	4.5	4.8	4.7
3702Ks	3.6	3.8	3.7	4.8	4.5	4.7
3703Ks	3.5	6.3	4.9	4.9	6.9	5.9
3704Ks	6.8	6.5	6.7	6.6	7.3	7.0
3705Ks	5.7	6.1	5.9	8.3	9.1	8.7
3706Ks	4.8	4.8	4.8	7.0	6.9	7.0
3706Ks-A	5.4	7.5	6.5	6.7	9.8	8.3
3706Ks-B	6.3	7.2	6.8	7.7	7.5	7.6
3706Ks-C	5.6	5.2	5.4	6.8	7.1	7.0
3707Ks *	4.3	4.3	4.3	7.7	7.3	7.5
3708Ks	7.4	8.5	8.0	8.3	7.9	8.1
3709Ks	4.4	3.9	4.2	6.3	7.4	6.9
3710Ks	6.7	5.8	6.3	6.4	6.9	6.7
3711Ks	5.1	5.3	5.2	6.3	6.4	6.4
3712Ks	7.7	6.8	7.3	7.4	7.1	7.3
3713Ks	6.0	6.4	6.2	9.9	8.2	9.1
3714Ks	5.6	6.6	6.1	7.7	7.9	7.8
3715Ks	4.4	4.7	4.6	5.5	5.2	5.4
3716Ks	5.2	4.3	4.8	6.4	5.7	6.1
3717Ks	4.9	4.5	4.7	6.5	7.1	6.8
3718Ks	5.5	4.4	5.0	5.7	5.5	5.6
3718Ks-A	4.5	5.5	5.0	7.8	5.8	6.8
3718Ks-B	4.0	5.2	4.6	6.8	6.4	6.6
3718Ks-C	4.0	4.8	4.4	6.2	6.0	6.1
3719Ks	6.0	3.9	5.0	7.1	6.1	6.6
3720Ks	4.4	3.9	4.2	6.8	6.0	6.4
3721Ks	7.3	7.0	7.2	8.4	8.0	8.2
3722Ks	8.7	8.7	8.7	11.3	12.3	11.8
3723Ks	7.7	8.1	7.9	11.4	11.4	11.4
3724Ks	7.4	10.0	8.7	9.3	12.1	10.7
3725Ks	9.6	12.4	11.0	11.9	14.6	13.3
3726Ks	9.4	10.2	9.8	10.0	11.3	10.7
3727Ks	.7	.7	.7	.7	.7	.7
3728Ks	.8	.8	.8	.8	.7	.8
3729Ks	1.4	1.6	1.5	2.3	2.5	2.4
3730Ks	1.3	1.6	1.5	3.2	2.7	3.0
3731Ks	1.2	1.4	1.3	2.6	3.2	2.9
3731Ks-A	1.2	1.4	1.3	2.6	2.9	2.8
3731Ks-B	1.0	1.3	1.2	2.7	2.8	2.8
3731Ks-C	1.1	.9	1.0	2.3	2.4	2.4

1-The reflection pairs $(1\bar{3}1)$-(131), and $(1\bar{3}0)$-(130) for the Or phase of most samples are not resolved. A relative estimate of the degree of order was obtained by determining the ratio: $\frac{\text{peak height}}{\text{profile width at } \frac{1}{2} \text{ peak height}}$.

*-Smear mount on glass slide.

TABLE 8 -X-ray powder diffraction data on alkali feldspars from the Mineral Range: the Ab phase[1]

	$2\theta(1\bar{1}\bar{1})-2\theta(\bar{2}01)$			$2\theta(\bar{1}32)-2\theta(131)$			(002)		
	Fwd.	Rev.	Avg.	Fwd.	Rev.	Avg.	Fwd.	Rev.	Avg.
3700Ks	.99	1.02	1.00				35	39	37
3701Ks	1.08	1.12	1.10				11	8½	9½
3702Ks	1.03	1.08	1.05	2.63	2.61	2.62	20	18½	19
3703Ks	1.05	1.06	1.05	2.60	2.67	2.63	33	26½	30
3704Ks	1.04	1.07	1.05	2.70	2.57	2.64	25½	21	23
3705Ks	1.05	1.02	1.03	2.67	2.56	2.61	39	36½	38
3706Ks	1.09	1.05	1.07				22	22	22
3706Ks-A	1.02	1.03	1.02				30	29	29½
3706Ks-B	1.03	1.01	1.02				23	18	20½
3706Ks-C	1.04	1.04	1.04				24	23	23½
3707Ks*	1.00	.99	.99	2.62	2.61	2.61	38	40½	39
3708Ks	1.06	1.05	1.05				29½	27½	28½
3709Ks	1.05	1.06	1.05	2.72	2.71	2.71	47	45	46
3710Ks	.92	.92	.92	2.39	2.39	2.39	30	40	35
3711Ks							37	41	39
3712Ks	1.04	1.04	1.04				24	26	25
3713Ks	1.03	1.03	1.03	2.61	2.66	2.63	40	40	40
3714Ks	1.03	1.03	1.03	2.62	2.60	2.61	40½	40½	40½
3715Ks	1.05	1.07	1.06				23½	29	26
3716Ks				2.63	2.58	2.60	31	27	29
3717Ks	1.08	1.04	1.06	2.69	2.7	2.7	31	34	32½
3718Ks	1.01	1.02	1.01	2.63	2.61	2.62	68	61	64½
3718Ks-A	1.03	1.03	1.03	2.58	2.64	2.61	57	59	58
3718Ks-B	1.02	1.04	1.03	2.63	2.60	2.61	82	61	71½
3718Ks-C	1.04	1.04	1.04	2.55	2.67	2.61	55	57	56
3719Ks	1.06	1.03	1.04	2.72	2.75	2.73	47	45	46
3720Ks	1.03	.99	1.01				62½	67	65
3721Ks	1.05	1.03	1.04	2.72	2.7	2.7	54	46	50
3722Ks	1.03	1.02	1.02	2.73	2.66	2.69	59	65	62
3723Ks	1.04	1.03	1.03	2.63	2.63	2.63	55	57	56
3724Ks	1.02	1.01	1.01	2.63	2.64	2.63	62	80	71
3725Ks	1.05	1.03	1.04				28	38	33
3726Ks	1.01	1.03	1.02				25	35	30
3727Ks				2.67	2.59	2.63	42	40½	41
3728Ks							34	36	35
3729Ks	1.04	1.05	1.04				44	38	41
3730Ks	1.03	1.03	1.03	2.66	2.69	2.67	62	59	60½
3731Ks	1.02	.99	1.00	2.72	2.67	2.69	48	69	58½
3731Ks-A	1.03	1.03	1.03				54	56	55
3731Ks-B	.99	1.03	1.01	2.72	2.63	2.67	60	65	62½
3731Ks-C							41	44	42½

1-The values given for the reflection (002) are estimated intensities determined by peak height as recorded in chart units on the diffractogram.

*-Smear mount on glass slide.

TABLE 9 -An content, 2Vx and grain size (mm) of some plagioclases from the Mineral Range[1]

Sample		Core		Rim		Others		Grain size
		An	2Vx	An	2Vx	An	2Vx	
3700	A	19.2	93.5	16.2	89			NR
	B	24	86.5	19.5	82.5			2.5X2.5
	C					15.2	88	NR
	D	16.7	92	18	89.7			2.2X1.7
	E	16.2	91	8.7	97.5			2X1
Avg.		19*		15.5*				
3701	A	29.2	84.5	26.2	83.7			2.5X1
	B	28.7	89					2.5X2.5
	C	31.5	89	27.2	84			1.2X1.2
				26.7	86			
	D	29	84.2	29	84.5			.7X.7
	E	30.7	86.5	29	84			.5X.5
	F	30.5	92.5	30	90.7			.7X.7
Avg.		30.2		28.2				
3702	A			17.7	86.5			1X1.7
				19.5	83.2			
	B	18.5	83.5	19.5	82.7			1X1
	C	17.5	82.5	18.5	76.5			1.5X1
	D	17	82	19.7	85.5	16.7	87.2**	1.7X1.2
		21.5	81	18.5	82.7			
	E	18.5	85.5	20	86			1.2X1.2
Avg.		18.5		19.2				
3703	A	23.5	85.5	15	82			2X1
	B	31.2	86.5	22	83.7			3X7
						24.2	81.5**	
		20	89					
	C	21	86	20	86.2			NR
	D	20	83	19.5	79.7			2X.7
	E					14	93[I]	NR
Avg.		22.5		19				
3704	A	27.5	87.5	23	81.7			.5X.2
	B	25	82.5	26.5	86.5			2.5X1.5
	C					30	86.5	.5X.2
	D	27.5	83.5	23.5	81			3X1.2
	E	25.2	82	27.7	83.7			2.5X1.2
Avg.		26.2		25.2				
3705	A	29	86.2					.7X.7
	B	28	87.5					NR
	C	30.2	86					.3X.3
	D	31	84.7	33.7	82			1X1
	E	29.2	85					.3X.2
Avg.		31		33				

TABLE 9 -Continued

Sample		Core		Rim		Others		Grain
		An	2Vx	An	2Vx	An	2Vx	size
3706	A	22.7	79.5	19	80.7			4X4
	B	22.2	77	19	83			.5X.5
	C	20	79	22	81			2.5X2.5
	D	21.5	80.5	21	82.2			1.2X1
	E	10.5	87.7	11.5	89.5			.7X.7
Avg.		19.5		18.5				
3707	A	8	99.5	8.7	96			.2X.2
	B	10	95.7	10	96.2			.3X.2
	C	9.7	94.7	9.5	93.2			.3X.2
	D	12.5	95	12	95			.7X.5
	E			7.7	92.5			.3X.3
				10.5	93.2			
				8	96			
Avg.		10		10				
3708	A	20.5	83.2					1.5X1.5
	B	23	80.5					1X.3
	C	23.5	82					1.7X.7
Avg.		22.2						
3709	A	20	87.5	20	87.7			2.5X1
	B	6	94.5					.7X.2
	C	3	95.5					.7X.2
	D	19.5	82					2.5X1.5
	E					18.5	81.5	15X10
						23	82.5	
						18.5	86.5	
						22	83	
	F	10.5						2.5X.5
	G	19.5	84					1X.7
Avg.		20		20				
3710	A	27.7	86.7	25.5	84.7	36	94.7^R	.7X.5
	B	28	91.2	29	92.2			1X1.5
				28	88.5			
	C	50	105	34	89.5			.7X.7
	D	34.7	89.2					NR
Avg.		35		29.2				
3711	A	17	80.5					1X.7
	B	22.7	78.5	19.5	82.5			2X2.5
	C	21.5	79.2	19	79			.7X.7
	D	21	80^2					NR
		12.7	87.7					
		19	79.5					
	E	18	84.7					1X.7
	F					16.5	83.5^I	.7X.5
	G					17.5	82.5^I	1.5X.5
Avg.		22.2		19.2				

TABLE 9 -Continued

Sample		Core		Rim		Others		Grain size
		An	2Vx	An	2Vx	An	2Vx	
3712	A	21.5	80.7	16	83.7			1X.7
	B	40	98					NR
	C	19.5	81.5	21	78.2			4X2
	D	42		12				2.5X2.5
	E	29.5	82.5					6X2.5
Avg.		20.5		18.5				
3713	A	16	84	14.7	87.5			2X1
	B	15.5	84.5	19.5	85.7			2.2X.7
	C	21	88	11	83.5			4X2
	D	20	84.5	17.7	87			.7X.7
	E	19.5	82	16.5	83.2			3X2
	F	17.5	83^{I}					NR
	G	20	82^{I}					2.5X1
	H	18	81^{I}					2.5X.5
Avg.		18.5		16				
3714	A	29	22					3X3
	B	17	22					.5X.5
	C	20	83.2	13.5	87			NR
	D	19.5	81.5	20	86			.5X.5
	E	19.5	81	12.2	89.5			.5X.5
Avg.		19.7		15.2				
3715	A	22.5	83	14.7	90			2X1.5
	B	18.5	85.2	0	105^{I}			1X.5
		20.5		7				
	C	14.5	81.2	8.5	93.2			2.5X1
	D	23.7	79.5	20	95			NR
Avg.		18.5		11.5				
3716	A	26.5	82	10.5	87.2			7X7
		29	88.5	6.7	90.7			
	B	20.5	83.5	11.5	89			NR
	C	29.2	87	23	85.5	34^{R}		NR
	D	21	84.5	20	86.2			NR
Avg.		24.5		15.7				
3717	A	38		8				NR
	B	19.5	81.2	13	91.7			3.5X1
	C	22.5	82	15.5	91.5			1.2X.7
	D	22	81.5	16	89.2			NR
	E	27.2	83.7	9	90			1.2X1.2
Avg.		22.7		13.5				
3718	A	17.5	85	9	96			2.5X2
	B	23.2	81	9.7	88.5			2.5X2
	C	20	80.2	18.5	84.5			2.5X2
	D	20	79	15.5	83.5			7X3.5
		11.5	85.5	10.7	91.7			
	E	20	81.5		81			NR
Avg.		19.2		14				

TABLE 9 -Continued

Sample		Core		Rim		Others		Grain size
		An	2Vx	An	2Vx	An	2Vx	
3719	A	4.5	95	8.5	92.7			2.5X2.5
				4	94			
	B	2	91	4.5	92.7			1X1
	C	5	96.5	5	97.5			NR
	D	8.2	94.7	3	97.2			1X.7
	E	10.5	93	10.7	94.5			NR
Avg.		6		6				
3720	A	14.2	87	13	95			2.7X2
	B	10	87.5	11	92.2			15X4
		14	91.5	2.5	91.2			
	C	15.5	84	9	91.7			4X.7
	D	8.5	90.5	9.7	89.5			1.2X1.2
Avg.		12.5		9.5				
3721	A	11	92	8	95			NR
	B	13.2	88.7	12.5	92			1X2
				15.7	90.5			
	C			8.2	95			NR
				5	103			
	D	11.5		11				NR
				13				
				14				
	E	10.5		5.5				3X.2
				11				
	F	10		10				NR
Avg.		12		11				
3722	A	14	87	3.5	100.5	1	98**	2.5X.7
	B	7.7	97.2	8.2	97			1X1.3
	C	5	88	9	95			2.5X.5
	D	14.5	89.5	7.5	96			.5X.7
	E	17	87.2	10.5	91			4X3
	F	15.5	81.2	7.5	92.5^{I}			NR
Avg.		11.5		7.7				
3723	A	16	79.7	10	95			2.5X2
	B	19.5	79	10	89.5			6X2
	C	13.7	83.5	6.5	96.5			.7X.5
	D	5	86	1.5	93.7			2.5X2
	E	16	78	15.7	83.2			2.2X2.2
	F	13.2	81	10.2	92.2			1.2X1.2
		9.2	91^{I}					.7X.7
Avg.		14		8.7				

TABLE 9 -Continued

Sample		Core		Rim		Others		Grain size
		An	2Vx	An	2Vx	An	2Vx	
3724	A			5.5	96			NR
				10.2	95			
	B					12		NR
						12		
						10		
	C	13.7	93	8.7	97[I]			1X1
	D	6.7	97.7	5.2	94.5[I]			NR
	E	16	89	6.7	100			1.5X.5
	F	15.7	94	11				1X.3
	G	16.5	83.2	6.7	93.5			3X3
	H	14	86	10.2	97.2			2.5X1
	I	12		10				NR
	J	17		10.5				NR
				13				
Avg.		15.7		8				
3725	A	22.7	76	17.5	79			1.5X1.5
	B	22.2	78	22.5	77.5			10X4
	C	27.2	80.5	25	80.5			NR
				17.2	76.2			
	D	22.7	80	8.5	87			.7X.5
	E	29.5	81.2	13.2	83			.7X.7
Avg.		25		16.5				
3726	A	27.7	82.5	23.7	77.5			1X.7
	B	20.7	77.2	9	83			.5X.5
	C	24.5	79.5	21.5	80.5			1X.7
	D	26	87.2	14	81			1.5X1.2
	E	30.2	89.7	19.5	84.5			.2X.5
	F	34	87	25.7	78.2[I]			.7X.7
	G	19.5	78.5	20.2	76.2[I]			1X1.5
	H	27.5	82	22	79.5[I]			.7X.5
		26	79	22	80.2			
Avg.		25.7		17.5				
3727	A	5.7	97.5	0	100			.3X.5
	B	23	76.7	27	94.7			NR
	C	25	90.2	16	96.2			.3X.5
	D	13.2	90.5	15	89.2	25	84.2[R]	NR
	E	17	80.7	6.2	94			1.2X.5
	F	19	80.7	20.5	83			2.5X1.2
	G	20	79	11.2	90			1X.7
Avg.		17.5		13.7				
3728	A	29.7	90.5	6.5	99	17	87**	.7X.2
	B	19	80	19	89.2			1.5X1
	C	20	76.7	14.7	88.7			2.5X1
	D	21.5	81.7	20	80.5			10X5
	E	21		17[I]		27[R]		1X.5
Avg.		22.5		15				

TABLE 9 -Continued

Sample		Core		Rim		Others		Grain size
		An	2Vx	An	2Vx	An	2Vx	
3729	A	16.2	87	7.2	90.5			2.2X2.2
				20.2	85.7			
				13.2	84.2			
	B	15	83.7					3X3
		18	83					
	C	20	84.5	16.2	87.2			2.5X1
	D	22	82	20	87.5			1X.5
	E	17[I]						.7X.3
	F	19	84.5[I]					1X1.5
Avg.		19.5		16.5				
3730	A	3	90.5	15.2	87.2			.2X.2
	B	18.5	83.5	14.2	88.7			1X.5
	C	34	90	12	91			2X1
	D	14.2	85.2	14	86.5			NR
Avg.		17.5		14				
3731	A	25	89	12.2	90.7			3.5X5
	B	20	83.2	9.7	87.2			2X1.5
	C	22	83.2	14.2	88			2.5X1
	D	11.7	86.7	14.7	93.7	17.2	88[R]	1X.5
Avg.		19.7		12.7				

1-The An content was obtained with the Universal stage using the a-normal method and the curves of Tobi (1963). See page for explanation.

2-Measurements made on three distinct extinction zones within crystal

* -Only grains which include core and rim measurements (An content and 2Vx) are used in the averages. Inclusions are not included in the averages.

**-Intermediate zone

I-Inclusion

NR-Not recorded

R-Reverse zone

TABLE 10 -2Vx and associated petrographic features of some alkali feldspars from the Mineral Range[1]

Sample		2Vx	Avg. 2Vx	Avg. per grain	Grid twinning	Grain size (mm)	% p-plag.
3700	1	50.5, 57.7, ≈69		59	none	1X.7	25
	2	76.5, 82, 80		79.5	none	2.5X1	4
	3	57.7, 61, 65.2		61.2	none	1X1	0
	4	61.7, 54.5, 60.7		59	none	1X.5	1
	5	76.2, 63.7, 63.5, 73		69	none	1X1	3
	6	82.5, 55.2, 81.7		73.2	NR	NR	NR
			67				
3701	1	70, 66.7, ≈78, 68.7		70.7	none	10X3	1
	2	52.7, 50, 52.5		51.7	none	2X.7	0
	3	62.7, 59.5, 59.2		60.5	none	.5X.7	0
			62				
3702	1	57.7, 57.5, 59		58	none	1.2X1	1
		a b c d					
	2	59.2, 81.2, 80, 56.7		69.2	a,no; b,c,d mod.	NR	1
	3	61.5, 64, 59.5		61.5	none	1X1.5	0
	4	53.5, 59.5, 59.5		57.5	none	NR	0
	5	55.7, 58, 56.7		56.7	none	NR	1
			61.2				
3703	1	61, 61.5, 58.5		60.2	none	2.2X1	4
	2	57.2, 58.7, 58		58	none	1X1	2
	3	59.7, 60.7, 60		60.2	weak?	6X4	8
	4	58.2, 54, 55.5		56	NR	2.5X1.5	5
			58.5				
3704	1	50.2, 58, 50		52.7	none	9X4	5
	2	60, 59.5, 60.5		60	none	NR	NR
	3	52.5, 52.2, 56.2		53.5	none	NR	0
		a b c d					
	4	59.7, 57.2, 60, 68.7		61.5	a,b,c,no; d weak	2.2X1.2	1
	5	53, 56.5, 56.5		55.2	none	1.2X1.2	0
			57				

TABLE 10 -Continued

Sample		2Vx	Avg. 2Vx	Avg. per grain	Grid twinning	Grain size (mm)	% p-plag.
3705	1	56.5, 55.5, 53		55	none	1.2X1	0
	2	53, 54, 55.2		54	weak	2X1	0
	3	54, 54, 54.7		54.2	none	.7X.7	7
	4	54.7, 50, 50.2		51.7	none	.5X.5	7
	5	50.2, 57, 50.5		52.5	none	.7X.7	0
			53.5				
3706	1	51, 45, 53.5		49.7	none	5X5	7
	2	54.5, 52.2, 53.5		53.5	none	12X5	5
	3	54.7, 57, 51		54.2	none	NR	5
	4	≈65, ≈59, ≈52.7		59.2	NR	12X15	10
	5	58.5, 57.5, 55.5		57.2	none	5X2.5	5
			54.7				
3707		No K-spar found in thin section					
3708	1	59.5, 58.7, 58.5		59	none	1X.2	5
	2	54.5, 54.2, 53.5		54	none	1.5X3	5
	3	59.5, 57.2		58.5	none	.7X.5	3
	4	58, 59.5		58.7	none	1X1	3
	5	60, 56		58	none	1X1.5	0
			57.5				
3709	1	65.7, 63.5, 57.7		62.2	none	.5X.5	0
	2	61.5, 54.5, 56.5, 54.5		56.7	NR	NR	NR
	3	60, 54.7, 67, 62.2, 59		60.5	weak?	5X5	18
	4	59.5, 57.5, 57.5		58.2	none	3X3	5
	5	62, 58, 54.5		58.2	weak	12X12	17
			59.2				
3710	1	52.7, 49.5, 55.5, 54		53	none	1X1	0
	2	49, 44.5		46.7	none	.5X.2	0
	3	60, 60.7		60.5	none	1.7X1	0
	4	51.2, 49.7		50.5	none	NR	0
	5	53.5, 55.2		54.5	none	.2X.5	0
			53				

TABLE 10 -Continued

Sample		2Vx	Avg. 2Vx	Avg. per grain	Grid twinning	Grain size (mm)	% p-plag.
3711	1 A*	55.7, 55, 54.7		55.2	none	5.5X3.5	10
	B	53.2, 60.5, 55		56.2	none	.5X.5	5
	C	65.2, 71, 52		62.7	none	3X2.5	5
		a b c					
	2	56, 55.5, 79.7		63.7	a,b,no; c, mod.	1.2X.5	2
	3	52, 56.5, 62		56.7	none	15X7	15
	4	56, 56, 56		56	weak?	12X5.5	20
	5	54, 55.2, 56.2		55.2	NR	2X1.2	3
			58				
3712	1	58.2		58.2	none	.5X.3	0
	2	60.2, 60, 56.5		59	none	1X.5	1
	3	53.5		53.5	none	.5X.5	1
	4	55.7, 59, 60		58.2	weak?	2X.3	2
	5	55, 63.7, 74		64.2	weak?	1X.7	1
			59.5				
3713	1	63, 61.5, 61.5, 61.5		61.7	none	1X1.5	8
	2	56.5, 55, 57.2		56	none	1X1.2	5
	3	54.2, 48.7, 47		50	none	2.2X1	3
	4	61, 56, 57, 60.2, 54.7, 58		57.7	none	10X15	7
	5	60, 66.5, 59.5, 55.5, 52.2 57		58.5	none	10X9	20
			57.5				
3714	1	53, 55.7, 50.5		53	none	12X8	15
	2	52.5, 53.7, 55		53.7	none	3X2	5
	3	55, 54.5, 56		55.2	weak?	2.2X1	10
	4	57, 57.5, 57.5		57.2	none	15X5	10
			54.7				

* - A,B, and C are three individuals of one twinned grain.

TABLE 10-Continued

Sample		2Vx	Avg. 2Vx	Avg. per grain	Grid twinning	Grain size (mm)	% p-plag.
3715	1	50.5, 50.7, 44.5		48.5	none	.5X.3	0
	2	52.2, 52.7, 53.5		52.7	none	1X1.5	0
	3	55, 67.2, 58.5		60.2	none	.5X.7	0
	4	62.7, 53.2, 58.5, 60.2		58.7	none	10X20	17
	5	75.2, 65.5, 72.7		71.2	weak	large	15
	6	62, 48.5, 53.2		54.5	none	2.2X1.2	7
	7	60.7, 53.7, 63.2, 57		58.5	NR	NR	NR
			58				
3716	1	45.5, 49.5, 46		47	none	5.2X2	1
	2	52.7, 53, 54		53.2	none	3X2.5	3
	3	56.2, 54.5, 55		55.2	none	NR	5
	4	67, 71.5, 73.7, 67.5		69.7	weak?	15X10	10
	5	55, 45, 49		49.5	none	NR	3
			56				
3717	1	54.5, 55.5, 56		55.2	none	2X2	0
	2	54.5, 63.5, 55.2		57.7	none	NR	1
	3	55, 55, 57.5		55.7	none	NR	10
	4	53, 53.5, 53.7		53.5	none	5X3	8
	5	58.5, 58.7, 56		57.7	weak?	1X1	5
	6	57.5, 53, 74.7, 56.5		60.5	none	4.3X3	0
			57				
3718	1	59, 60.7, 61.5		60.5	none	15X7	10
	2	49, 49.2, 53.5		50.5	none	2X1	7
	3	70.5, 67.7, 71.5, 72.5		70.5	weak to moderate	7.5X5	25
	4	50, 52.5, 48.5		50.2	none	1.5X.5	8
	5	64.5, 61.2, 62.5		63	none	2.5X2	12
			59.7				

TABLE 10-Continued

Sample		2Vx	Avg. 2Vx	Avg. per grain	Grid twinning	Grain size (mm)	% p-plag.
3719	1	53, 48.7, 50.7, 48.5		50.2	none	2X2	12
		a b c d					
	2	58, 59.2, 79.5, 55.2		63	a,b,d,no;c weak	2X1.2	15
	3	72, 72.2, 65.5		70.2	none	2.5X4	15
	4	50, 47.5, 61		52.7	NR	3X3	18
	5	50, 57.5, 56.5		54.5	none	2X2	5
	6	60.7, 70.7, 63		64.5	none	1.5X.5	3
			59				
3720	1	63.2, 76, 63		67.5	none	15X10	27
	2	55.5, 53, 62		56.7	none	2.2X2.2	5
	3	61.2, 66.2, 52.7		60	none	NR	25
	4	59, 61.5, 60.7		60.5	none	NR	8
	5	57.5, 62, 60		59.7	none	5X2.5	15
			61				
3721	1	50.2, 51.5, 54.5, 51.7, 48.5 43		50	NR	2.5X.5	20
	2	50.5, 48.7, 53.5		51	NR	1.5X1.5	8
	3	48.2, 51.5, 57		52.2	none	1.7X.7	25
	4	56.5, 51.5, 55.5		54.5	none	.7X.5	5
	5	59.5, 51, 52.2		54.2	none	NR	5
			52				
3722	1	68.5, 61, 60.7		63.5	none	7X5	25
	2	51.7, 49.2, 51		50.5	none	5X7	25
	3	48.2, 50.5, 44.2		47.5	none	.7X.7	30
	4	53, 50.5, 48.2		50.5	none	2X1	12
			53				
3723	1	60, 55.5, 51.2, 62, 62.5		58.2	none	11X4	15
	2	45.7, 47, 50.7		47.7	none	2.6X2.4	7
	3	52, 55.5, 57.5		55	none	5X1.5	5
	4	49.5, 52, 58.2		53.2	none	2.5X2.5	4
	5	55, 64.5, 54.2, 57.5, 61.2, 68.5		60.2	none	12X6	15
			56				

TABLE 10 -Continued

Sample		2Vx	Avg. 2Vx	Avg. per grain	Grid twinning	Grain size (mm)	% p-plag.
3724	1	59, 48.5, 46, 49, 47, 57		51	none	7X5	25
	2	50.5, 51.5, 45.5		49	none	2X1	3
	3	48.7, 50.5		49.5	none	NR	3
	4	58.2, 51.2, 54, 49.7, 59 51.2, 48, 47.7, 56.7 46.5, 55.7		52.5	none	7X9	15
	5	63.5, 52.2, 52, 69.5, 53.5		58.2	none	7X4	20
			52.5				
3725	1	41, 49		45	none	2.5X2	NR
	2	57, 56.5, 47.5		53.5	none	8X6	0
	3	54.5, 53.7, 48, 53.5		52.5	none	2X4	0
	4	47.5, 46		46.7	NR	NR	NR
	5	48.2, 51, 51, 50, 56.5		51.2	none	7X6	1
	6	55, 61.2, 50, 51		54.2	none	8X3	3
			51.5				
3726	1	53.5, 51.5, 57.7, 57.7, 52.7		54.5	none	7X3	0
	2	49.5, 46, 48.7, 45.2		47.5	none	5X3	0
	3	49, 50.5, 51.5		50.2	none	2.5X1.5	0
	4	55.5, 61, ≈58, 60		58.5	none	7X4	1
	5	61.5, 60, 62		61	NR	NR	NR
			54.2				
3727	1	60.7, 61, 61.5		61	mod.	3X3	1
	2	81.2, 81, 81.5		81.2	weak	8X4.5	17
	3	82, 77, 66.7, 61.5, 61.7		69.7	?	.5X3	1
	4	58.5, 57.5, 57, 53		56.5	mod.	3X4	7
	5	77.5, 78.7, 66.7, 75, 78.7		75.5	weak	5.5X2	1
			69				

TABLE 10 -Continued

Sample		2Vx	Avg. 2Vx	Avg. per grain	Grid twinning	Grain size (mm)	% p-plag.
3728	1	76.7, 74.5, 79.2, 75.5		76.5	none	5X7	15
	2	80, 75.2, 75.2		77	weak	1X1.5	2
	3	70.2, 80, 82.5, 64, 74.5, 80.5		75.2	weak?	6X2.5	7
	4	55, 58.7, 56.5		56.7	none	2.5X2.2	2
	5	78.5, 70, 81.2, 63.2		73	weak	8X8	12
			72.5				
3729	1	61.5, 56.5, 62.7, 60.2, 58.2 58.5, 59.5		59.5	NR	NR	NR
	2	65, 64.5, 66		65	none	2X3	5
	3	67.2, 60.5, 65		64.2	none	4X4	17
	4	58.5, 69.7, 57.5, 52		59.5	none	3X3	7
	5	62.5, 62, 61.7		62	none	1.5X.5	5
			61.5				
3730	1	59.2, 59.5, 63.7		60.7	weak	2X2	7
	2	63.2, 58, 63		61.5	none	1X1.5	5
	3	67.5, 66.5, 70.2		68	weak	4X3	15
	4	60.2, 55.5, 67.5		61	none	2X2	5
	5	64.2, 66.2, 69.2		66.5	none	2X3	10
			63.5				
3731	1	65.5		65.5	none	1X1	5
	2	59.5		59.4	none	1.2X1.2	8
	3	57.5		57.5	none	1X1	8
	4	67, 69, 67.7		68	none	1X.5	5
	5	74, 59.5, 61.2, 62		64.2	weak	4X5	25
	6	71, 80		75.5	none	4X2.5	20
	7	61.2, 59.5		60.2	none	2.2X2.5	12
	8	64.5, 82.7, 68.2, 90.7		76.5	none	1.5X1.2	0
			67.7				

1 – p-plag. is the plagioclase phase of the alkali feldspar and the percent given was obtained by visual estimate. 2Vx was measured on the Or phase when p-plagioclase was visible. ¼, ½, and 3/4 are represented by .2, .5, and .7 for ease of typing. Grid twinning development refers to Or phase. NR means not recorded.

TABLE 11 -Modal proportions of plagioclase, alkali feldspar and quartz and proportions of albite, orthoclase and quartz in rocks from the Mineral Range. All in weight percent.

	Plagioclase	Alkali feldspar	Quartz	Albite	Orthoclase	Quartz
3700	52.0	8.8	39.2	47.0	11.2	41.9
3701	65.0	3.0	32.1	51.8	8.9	39.3
3702	27.1	20.8	52.2	25.7	19.3	55.0
3703	28.1	38.3	33.6	30.7	33.8	35.4
3704	57.1	23.6	19.3	50.0	28.5	21.6
3705	80.5	13.6	5.9	68.1	24.7	7.2
3706	26.9	31.7	41.3	27.1	29.5	43.5
3707	74.3	1.7	24.0			
3708	42.6	12.7	44.7	37.8	13.8	48.4
3709	30.0	38.3	31.7	34.7	32.5	32.8
3710	87.2	10.3	2.6	75.5	21.1	3.5
3711	33.7	42.1	24.2	36.9	37.2	25.9
3712	59.0	28.1	12.9	56.7	28.6	14.7
3713	35.8	35.7	28.4	39.3	30.7	30.0
3714	34.0	39.5	26.4	39.3	32.9	27.9
3715	31.3	25.9	42.7	31.7	23.0	45.4
3716	35.8	24.4	39.7	35.3	22.1	42.6
3717	42.2	26.1	31.7	41.5	24.3	34.2
3718	29.4	33.9	36.7	35.3	26.5	38.2
3719	41.6	33.7	24.7	46.1	28.7	25.3
3720	23.4	31.8	44.8	30.6	23.2	46.2
3721	27.8	32.2	40.1	33.1	26.0	40.9
3722	26.7	31.2	42.0	32.7	24.6	42.7
3723	29.4	21.0	49.6	32.3	16.5	51.2
3724	29.8	29.5	40.8	35.5	22.6	41.9
3725	53.4	20.2	26.3	49.5	21.4	29.1
3726	67.9	16.8	15.3	60.5	22.0	17.5
3727	37.7	23.7	38.6	38.1	20.9	41.0
3728	37.2	31.2	31.6	37.4	29.0	33.6
3729	39.1	26.8	34.2	39.5	24.3	36.3
3730	32.6	36.2	31.2	36.3	30.9	32.8
3731	31.6	33.4	35.0	35.0	28.7	36.3

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APPENDIX A - CHEMICAL ANALYSES

General

Weight percents of Al, Si, K, Ca, Fe, Rb, Sr, and Ba in the alkali and plagioclase feldspars were obtained by using the direct pelletizing X-ray Emission Spectrographic technique described by Volborth (1962a, 1962b). Weight percents of Na and Mg were obtained by Flame Emission and Flame Absorption Spectrophotometry respectively, because the soft X-ray apparatus had not yet become operational at the time of this study. Chemical data is listed in Tables A4, A5, and A6.

I was unable to obtain a sufficient number of analysed feldspars at the beginning of this study for use as natural standards and so prepared synthetic standards to establish the calibration curves. While performing the chemical analyses I obtained two analysed feldspars from R. C. Emmons and some chemical analyses on the feldspars being studied. The analysed natural feldspars provide the basis for the calibration curves and are referred to as natural standards. None of my natural standards are prime standards because in most cases an analysis based on a single determination is the best that could be obtained. Even those analyses based on duplicate or triplicate determinations are not prime standards because I analysed only one pellet per sample by X-ray spectroscopy. Despite the lack of demonstrable precision, the natural standards tend to group or disperse somewhat symmetrically along or around a straight or slightly curved line when plots of X-ray intensity versus composition are made. Such lines are the calibration curves and are the foundation of the chemical analyses reported.

Plots of X-ray intensity versus composition on the synthetic standards (a mixture of reagent grade inorganic compounds corresponding closely to natural feldspars in composition) are generally parallel or subparallel to the standard calibration curves but not coincident with them. The synthetic standards are therefore used to shape and extend the range of the standard calibration curves where necessary.

Synthetic standards were prepared by mixing different compounds in proportions such that a desired feldspar composition was achieved. All the compounds used were of Reagent-grade purity except the potassium silicofluoride which was at least 99 percent pure. In addition the reagents used are practically insoluble in water at room temperature. This eliminates a possible deposition of salts on the pellet surface due to evaporation of the water binder. Reagents used for the synthetic standards are given below.

Silicon dioxide ---- SiO
Aluminum oxide ---- Al_2O_3
Calcium carbonate ---- $CaCO_3$
Magnesium oxide ---- MgO
Sodium silicofluoride ---- Na_2SiF_6
Ferric oxide ---- Fe_2O_3
Barium carbonate ---- $BaCO_3$
Strontium carbonate ---- $SrCO_3$
Potassium silicofluoride ---- K_2SiF_6

It was necessary to make three groups of synthetic plagioclase standards and three groups of synthetic alkali feldspar standards to accommodate the expected and observed ranges of feldspar compositions. The group labeled A, B, C, D, E, F, corresponds approximately to An_9, An_{26}, An_{42}, An_{80}, and An_{99} respectively and was made for normal plagioclase. The group aA, bA, cA, dA, was prepared by adding SiO_2 to standard A and allows for plagioclase contaminated with quartz. The group aC and bC was prepared by adding potassium silicofluoride to standard C to allow for high potassium content in plagioclase.

The group kA, kB, kC, kD, kE, kF, is selected at approximately Or_{20}, Or_{35}, Or_{50}, Or_{65}, Or_{80}, Or_{90}, to include normal alkali feldspar except for sodium rich anorthoclase. Two additional groups were necessary to establish useful calibration curves for Al and Si because of the small variation of these two elements in the kA-kF group. The group akA and bkA was prepared by adding SiO_2 to kA, and the group akC and bkC was prepared by adding Al_2O_3 to kC.

In order to approach ideal standard conditions, it is necessary that the synthetic standards contain elements like those in the feldspars and in feldspar proportions. The first condition is not met completely because of the necessity of using silicofluorides for Na and K, and carbonates for Ca, Sr, and Ba. The second condition was met for the major elements in plagioclase by plotting the theoretical oxide percents of Na, Al, Si, Ca versus An content. The proportions of the major elements in the alkali feldspar were approximated by striking an average through a plot of the oxides of Na, Al, Si, and K versus Or content for all microlines, orthoclases, sanidines, and adularias listed in Deer, Howie, and Zussman, v. 4 (1963). Anorthoclasses were excluded because I did not expect to include them in my study. The minor trace element proportions and amounts were determined partly again by plotting available analyses from Deer, Howie, and Zussman, v. 4 (1963) against Or content. The amounts used depended in part also on my estimate of what would constitute an intensity change between samples large enough to be useful in constructing a calibration curve.

Preparation of synthetic standard and blank pellets

The two major groups of synthetic standards; A, B, C, D, E, F, and kA, kB, kC, kD, kE, kF, were prepared in lots of approximately 115 grams to provide stock material and to reduce the effect of small errors in weighing. Weighings were done by difference without removing the vial from the pan on a single beam Mettler balance reproducible to two milligrams. The powders were stored in the same plastic vials that they were weighed in. After weighing, the mixtures were manually shaken for a few minutes in the tightly capped vial and then homogenized in two large V- shaped plastic containers for periods ranging from 24 to 92 hours. The capacity of the V-shaped containers used were about 350 and 1000 grams. Homogenization times were varied because I had no previous experience with 10 component mixtures. Triplicate analyses obtained from the pellets of these powders indicate that 24 hours is ample time for homogenization. Brent Fabbi, research assistant at the Nevada Mining Mining Analytical laboratory, found that 16 hours was ample time for two to five component mixtures (personal communication, 1965).

While recovering the first two samples from the homogenization chambers, I noticed small red balls of iron oxide and small white flakes seemingly of magnesium oxide in the homogenized powders. Examination of the ten samples not yet homogenized showed similar material in each. Therefore all twelve powders were sieved through a 115 mesh brass screen and the red balls and white flakes remaining on the screen were brushed through before further homogenization. After this no balls or flakes were observed in the homogenized powders.

The remaining synthetic standards and blanks were prepared in lots of about 25 grams. They were homogenized without being removed from their plastic containers.

After homogenization three consecutive pellets were made from each sample according to the following procedure. Enough sample was added to a small prebalanced crucible so that sample plus crucible would overbalance a 1.000 gram weight but not the 1.000 gram plus a 0.0010 gram weight. Initial sample weights are then quite uniform but not exact because the weighings were performed on a table supporting an operating vacuum pump and an automatic grinder. In addition, sample weight in the pellet does not equal initial sample weight because of small losses associated with grinding, mixing with distilled water, and pressing the pellet. After weighing, the sample was ground automatically for 30 (± 1) minutes using a mullite mortar and pestle. The sample was manually raked toward the center of the mortar every five minutes with a plastic spatula because the pestle invariably would thrust some of the powder outside the grinding radius. Sieve tests were made on the fourth, eleventh, and twenty-first grind of the synthetic plagioclase powders and on the first, twelfth, and twenty-first grind of the synthetic alkali feldspar powders. In all cases 99 percent or more passed through the 400 mesh nylon screen. Three drops of distilled water was thoroughly mixed into each ground powder with a heavy glass stirring rod before pressing the powder into a pellet. The water apparently acts as a binder and prevents surface popping of the pellet after pressing. After mixing with distilled water the powder is placed in the die on a glass disk and a layer of bakelite (3 to 4 grams) is placed over the sample. The sample is then pressed to 30,000 psi, held under that pressure for 30 seconds and the pressure allowed to relax spontaneously to about 3,000 psi. The pressure is released manually to zero, the pellet is retrieved from the die, labeled, and placed for at least one half hour in a désiccator undergoing continuous vacuum pumping. The pellet is then placed face down on thin concave plastic strips securred to a small one by two inch cardboard box and stored in a larger covered box or cabinet.

Blanks consisting of those reagents whose weight percents are in excess of one percent in synthetic standards A, B, C, D, E, F, and kA, kB, kC, kD, kE, kF were prepared in order to refine the calibration curves of the synthetic standards. They were prepared by taking twenty percent of the amounts of the reagents used in preparation of the synthetic standards and thus the proportions of the major elements in the blanks are for practical purposes like those in the corresponding synthetic standards mentioned above. The blank pellets were prepared like the synthetic standard pellets with the following exceptions. They were weighed and homogenized in the same vial using an improvised vial holder since the capacity of the vial is about four times the volume of the sample contained. Homogenization times varied from 16 hours for BL-A, BL-B, BL-C, BL-D, BL-E, BL-kB, to 24 hours for BL-F, BL-kA, BL-kC, BL-kD, BL-kE, and BL-kF. Screen tests were made only after the thirteenth and thirty-sixth grind with at least 98.5 percent passing through the 400 mesh nylon screen. Eight instead of three drops of distilled water were used as the binder. The blanks are labeled to correspond with the synthetic standard of similar composition.

Thus BL-A and BL-kF correspond in composition to plagioclase synthetic standard A and alkali feldspar synthetic standard kF respectively.

Sources of error in preparation of synthetic standards

Two possible sources of error were recognized while preparing the synthetic powders for pelletizing. Both are concerned with actual versus weighed amounts of reagent. The reagents concerned are Fe_2O_3 and Al_2O_3.

After completing all weighings except for Al_2O_3 for the two synthetic standard groups A to F and kA to kF, the Al_2O_3 weighings were begun by adding the necessary amount of Al_2O_3 to the vials containing the other reagents. But no stable endpoint on the balance could be obtained after adding Al_2O_3 to the first vial. Instead the vial plus reagents, plus the added Al_2O_3 became heavier with time. The weight gain suggested that the Al_2O_3 used is hygroscopic. I attempted to systematize any weight gains by weighing the Al_2O_3 for the remaining samples within ten minutes after removing it from the tightly capped storage bottle. I also attempted to assess the significance of the weight gains and found:

1. The total increase in weight for synthetic powder E is about .15 percent of the Al_2O_3 added. The time interval allowed was 90 minutes and the plot of weight versus time is almost a straight line.

2. A 28 gram sample of pure Al_2O_3 from the stock used in the synthetic standards gained continuously over a period of seven days .2 percent of its original weight. A 34 gram sample gained about 1.0 percent of its original weight. Both samples reached a maximum at seven days and alternately gained and lost small amounts for three days thereafter. After the tenth day both samples were heated for 23 hours at 42 degrees C and no appreciable weight loss was recorded. Heating for 46 hours at 108 degrees C caused the 28 gram sample to lose about 95 percent of the weight gained and the 34 gram sample 60 percent. Continued heating at 108 degrees C for seven days caused no further significant weight changes in either sample.

These small experiments on the weight changes apparently associated with hygroscopic Al_2O_3 suggest that the Al_2O_3 content of the synthetic standards may be in error up to one percent of the amount present and the error may not be systematic. The absorption of water prior to weighing would lead to lower values than those calculated from the amount of weighed Al_2O_3. Perhaps this is why the Al intensity in the sythetic standards is lower than that of the Al intensity in a natural standard of the same composition.

A second possible source of error may have resulted from the extra handling required to crush the small iron oxide balls and white MgO flakes prior to homogenization. I cannot assess the significance of the possible errors resulting from this manipulation but thus far I have not detected any ill effects that might be related.

Preparation of feldspar pellets

The pelletizing procedure for the feldspars is like that of the synthetic standards with a few exceptions. Twenty-one samples; 3700P1-3710P1, 3712P1-3716P1, and 3718P1-3722P1 were pressed without the water binder and many pellets flaked or popped upon removal from the press. A. Volborth and B. Fabbi of the Nevada Mining Analytical laboratory suggested therefore that I mix a few drops of distilled water with the powder after grinding. I did this and lost no pellets thereafter. The feldspar powders (generally less than 25 grams) were homogenized manually with a rubberized cloth and not automatically like the synthetic powders. The feldspar powders are somewhat coarser than the synthetic powders before grinding. Each feldspar powder passed through the 115 mesh but not the 250 mesh screen before grinding with the Fisher automatic whereas the synthetic powders were ground as received, probably about 300 mesh or more. Screen tests on feldspar powders 3700P1, 3710P1, 3721P1, 3730P1, 3713Ks, and 3724Ks showed at least 98 percent of all material passed the 400 mesh nylon screen.

After the main sequence of feldspar pellets had been prepared, three additional pellets were pressed from powders 3700Pl 3718Pl, 3724Pl, 3706Ks, 3718Ks, and 3731Ks in that order. Those six samples were analysed in quadruplicate and are designated as 3700Pl, 3700Pl-A, 3700Pl-B, 3700Pl-C. Most of the feldspar pellets were pressed from one gram of powder but the C pellets for each of the quadruplicates and pellets 3700Ks, 3701Ks, 3710Ks, and 3726Ks were pressed from one half gram of powder. This difference in weight of the powder can be correlated with significant intensity changes for the heavier elements; Fe, Rb, Sr, and Ba according to measurements made on the six samples prepared in quadruplicate.

Determination of chemical composition of the feldspars

I determined atomic weight percent composition in the unknown samples by comparing their intensities with the intensities of prepared standards using both synthetic standards and natural feldspar standards. To avoid as much as possible errors associated with electronic drift each element was completed as rapidly as possible before going on to a different one. Ordinarily the synthetic standards were run first in triplicate followed by single determinations of the feldspar pellets except those six run in quadruplicate. The blanks when applicable followed the unknowns and were run in triplicate.

An eight hole sample holder was used in the analyses. Each pellet was counted four times in the following sequences:

1,2,3,4,5,6,7,8; 8,7,6,5,4,3,2,1; 1,2,3,4,5,6,7,8; 8,7,6,5,4,3,2,1. A minimum of two standards in positions 1 and 5 or 1 and 6 in the sequence above were run simultaneously with the natural feldspars and with the synthetic feldspar standards. Two standards were run instead of one to test the reliability of the important assumption that the intensity ratio does not vary. In two cases involving short periods of counting, K in synthetic plagioclase blanks and Ca in synthetic alkali feldspar blanks, only one standard was used. The percent range in composition resulting from the observed variations in intensity or number of counts per second from the same standard or pair of standards is given in column A below. The range in composition for quadruplicate analyses of three plagioclase and three alkali feldspar samples is given in column B for comparison. All results given are in atomic weight percent.

	Plagioclase		Alkali feldspars		
	A	B	A	B	
Al	.25	.73	.23	.47	Al
Si	.30	.78	.95	.69	Si
K	.0095	.063	.06	.15	K
Ca	.02	.040	.005	.010	Ca
Fe	.0010	.009	.0015	.002	Fe
Rb	.0005	.0025	.0020	.003	Rb
Sr	.0015	.0020	.0025	.001	Sr
Ba	.0095	.0030	.0075	.005	Ba

The observed range in composition for Fe, Rb, Sr, and Ba is taken only from the three one gram pellets in the quadruplicate determinations as the fourth pellet, weighing one-half gram, systematically showed higher intensities and therefore was not used. Columns A show that a significant part of the observed range in composition is apparently due to instrumental variations. But except for Ba in plagioclase and alkali feldspar, and Al and Sr in alkali feldspar the observed range in composition is greater than expected from instrumental variation. Thus the observed range in composition rising from the quadruplicate analyses (triplicate analyses for Fe, Rb, Sr, and Ba) serve as approximate limits of precision for the chemical analyses which are based almost completely on single determinations. Finally I should note that except for Ba, the observed range in composition for the plagioclase is taken from replicate determinations of sample 3700Pl. Thus the observed range determined from sample 3700Pl is greater than the range among the samples 3700Pl, 3718Pl, and 3724Pl.

Calibration curves

Instrumental settings and conditions used during X-ray spectroscopic analyses are given in Table A1. Representations of the calibration curves used are shown in Figures A1 to A13. With reference to the calibration curves, samples in the 3700 series are part of the suite studied in this report; 042B and FD156 are analyses feldspars obtained from R. C. Emmons and the lettered samples are the synthetic standards. Chemical data pertinent to the natural standards is given in Table A2. G-1, W-1, and Syenite Rock 1^a are standard rocks of the U. S. Geol. Survey and the

Canadian Geol. Survey plotted on some of the graphs, but not used in defining any of the calibration curves. Solid circles represent synthetic standards analysed in triplicate and the vertical line through the circle gives the intensity range. Plusses and crosses represent natural plagioclase and alkali feldspar standards respectively. The intensity for the standards in the 3700 series is taken from one X-ray measurement from one pellet while that for FD156 and 042B represents an average of six to eight measurements on a single pellet.

The calibration curves based on the synthetic standards were refined for those elements comprising less than one percent oxide composition with blanks. The resulting calibration curves are called corrected calibration curves and are determined by subtracting the intensity obtained on the blank from that obtained on the corresponding synthetic standard. In general the corrected calibration curves are closer to the calibration curves of the natural feldspar standards than the calibration curves of the synthetic standards.

Because of the variation in number and quality of the standards, the calibration curves are not mathematical lines but are based partly on judgment after visual inspection of the dispersion of points on the composition--intensity plots. The following section therefore describes the construction of the calibration curves for each element.

The aluminum calibration curves (Figs. A1, A2) are based on two natural standards and are extended according to the shape of the synthetic calibration curve. The curves indicate that for a given composition the intensity of the synthetic standard is less than that of the natural feldspars. The intensity difference may result from an actual low aluminum content because of the hygroscopic Al_2O_3 used in the synthetic standards.

The silica calibration curves (Figs. A3, A4) are based also on only two standards and are shaped according to the synthetic standard calibration curve. The silica standards are much less consistent than those for aluminum and thus are not as easily related to the synthetic standard curves. Therefore the apparent differences in intensity between natural and synthetic standards may be fictitious.

For the elements K, Ca, Fe, Sr, and Ba the intensity of the synthetic standards is higher than the intensity of the natural feldspar standards of the same composition; synthetic standards of Na, Mg, and Rb were not used in this study. In order to explain the relative high intensity of the synthetic standards, two other related observations shall be brought out. (1) The intensity of the C samples of the specimens run in quadruplicates are higher than the average of the other three in 23 out of 24 observations for the heavy elements; Fe, Ba, Sr, and Rb. The C samples differ from the others only in weight; they weigh one-half gram instead of one gram like the other samples. (2) Off analytical line background intensity for two C samples, 3700Pl-C and 3731Ks-C is about 50 percent higher than that of other one gram samples which remains about constant. I suggest that the high intensities observed for the synthetic standards and those observed on the one-half gram samples result from scattering of X-rays from elements of low atomic weight where scattering is pronounced. The synthetic standards have a larger proportion of elements with low atomic weights than the natural feldspars in the form of carbon and fluorine. The one-half gram samples allow a larger proportion of X-rays through to the bakelite jacket than the one gram samples and thus scattering becomes more pronounced. Sample thickness and grain size as well as scattering may contribute to this problem. I did not pursue the problem further.

The potassium calibration curves (Figs.A5,A6) for plagioclase and alkali feldspar are based on similar standard arrays. Two standards analyses in triplicate, two in duplicate and two single determinations define the plagioclase calibration curves. For the alkali feldspar curve there is one additional standard based on a single determination. I must note here that prior to receiving the duplicate analyses of 3711Ks and 3715Ks from Tokyo and the triplicate analyses of 3714Ks from Harold Vincent, I had drawn the potassium calibration curves for the alkali feldspar through points defined by 3710Ks, 3729Ks, and 3706Ks, all single determinations. The position of the curve was changed after obtaining the duplicate and triplicate analyses to correspond to points defined by 042B, 3711Ks, 3715Ks, and 3714-Ks with little regard for the standards based on single determinations. It is to be expected that the single determinations are more susceptibile to error than the duplicate and triplicate determinations obtained from three different laboratories because the single determinations were run at the same time by the same operator using the same equipment.

The calcium calibration curves are shown in Figs. A7, A8. Three standards based on double determinations and three based on single determinations form the curves for calcium in plagioclase. One triplicate determination, 3725Pl, was not used in construction of the curves because it falls so far from the other analyses. The alkali feldspar standard array is like that of plagioclase except that only two standards based on single determinations were used. One triplicate determination, 3714Ks, was not used because like 3725Pl it falls far short of the curve based on the other analysed. Both 3714Ks and 3725Ks were run about the same time with the same instrument. An extension of the corrected curve for calcium in alkali feldspar gives an approximately symmetrical dispersion of natural standard points and so is used as the calibration curve. The calibration curve for iron in plagioclase (Fig. A9) is defined by two standards based on triplicate determinations and two based on single determinations. One standard analysed in triplicate and three analysed singly define the iron calibration curve for alkali feldspar (Fig. A10). One triplicate determination, 042B, falls off the curve and was not used. The corrected curve for plagioclase and alkali feldspar is practically coincident with the natural feldspar calibration curves. All the non-X-ray values used in constructing the calibration curves except for FD156 were obtained colorimetrically by Harold Vincent of the Nevada Mining Analytical Laboratory.

The rubidium calibration curves are given in Fig. A11. I prepared no synthetic rubidium standards because suitable compounds were not readily available and at the time was uncertain of the X-ray method of analyses for rubidium in minor or trace amounts. While performing the chemical analyses I obtained a few rubidium analyses on the feldspars studied and used the analysed material as standards. Two standards based on duplicate analyses and three based on single analyses were used to define the upper part of the calibration curve for the alkali feldspars. The zero point of the curve is fixed at the off-analytical line background level taken about one-half degree 2-theta off the analytical line for rubidium. Sample 3711Ks was not used in constructing the curve. The value given for standard 3710Ks is corrected to allow for the one-half gram weight of the powder in the pellet. One standard based on a double determination and one based on a single determination determine to a large extent the rubidium calibration curve for the plagioclase. Other standards with trace amounts serve to anchor the lower part of the curve in an indefinite manner. The rubidium values for plagioclase are probably less reliable than those for the alkali feldspars because of the low concentrations resulting in a relatively high background level, and because of an insufficient number of standards.

The calibration curves for strontium are shown in Figure A12. Strontium determinations reported in this study are not demonstrably reliable because of the uncertainty in locating the calibration curves. The corrected curve was used for strontium in plagioclase because two of the three standards based on single determinations made by atomic absorption, the value for FD156, and the value obtained by flame emission spectrophotometry after separation of strontium from the matrix tend to fall near that curve. No synthetic alkali feldspar standards for strontium were prepared. The alkali feldspar calibration curve is drawn through three standards based on single determinations performed by atomic absorption and agrees well with the value O42B. The strontium values obtained by flame emission spectrophotometry tend to group apart from those values obtained by atomic absorption. The latter values were for the calibration curves mainly because of their close approach to the corrected curve and their close agreement with O42B, and FD156. The data in Fig. A12 also shows a marked change in strontium percent resulting from separation of strontium from the matrix prior to analysis by flame emission spectrophotometry.

The barium calibration curves are shown in Fig. A13. The barium values like the strontium values give a large scatter and therefore may not be reliable. One standard based on double determination and on based on a single determination are used to define the barium calibration curve for alkali feldspar. This curve corresponds closely to corrected curve. Barium analyses in standards 3704Ks and 3717Ks may be unreliable according to the analyst, fall above the corrected curve, and therefore were not used in constructing the calibration curve. The plagioclase curve used is the lower end of the alkali feldspar calibration curve. It falls about midway between the values obtained by flame emission and atomic absorption and includes FD156. The barium values obtained on alkali feldspar and plagioclase by flame emission prior to separation from the matrix were reported as "not detected" or in amounts less than .0069 percent and are not indicated on Fig. A13.

Sodium and magnesium

All sodium values used in this study were obtained by flame emission spectrophotometry. All magnesium values listed in this report were obtained with atomic absorption with the exceptions noted in Table A3.

I prepared sodium and magnesium solutions for analysis with one-half gram portions of plagioclase material and one-quarter gram portions of alkali feldspar material with the following exceptions:

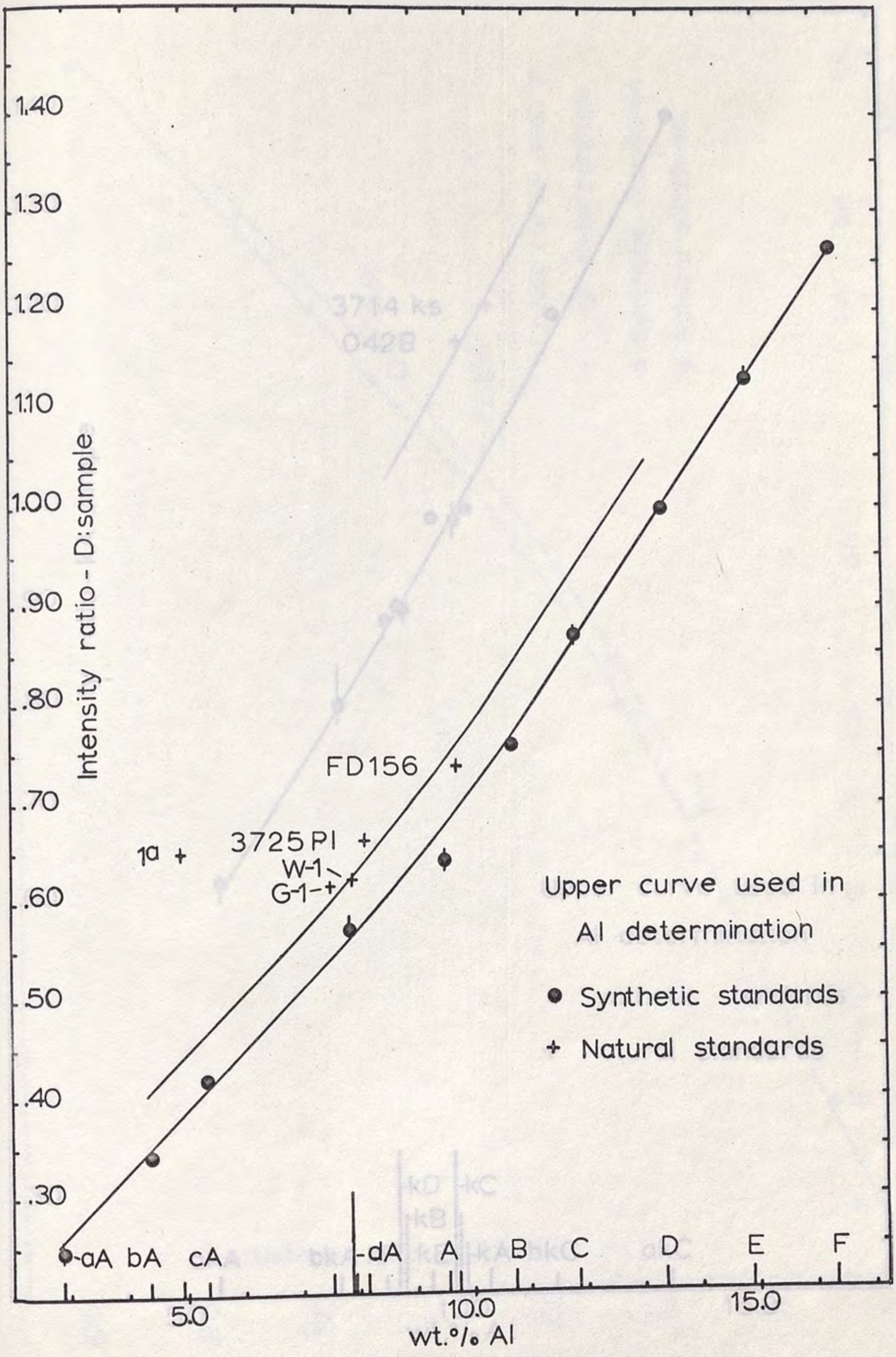
3701Ks	.1g	3702Ks	.5g	3704Pl & 3704Ks	1g
3707Ks	.01g	3703Ks	.5g	3717Pl & 3717Ks	1g
		3706Ks	.5g	3721Pl & 3721Ks	1g

The six one gram samples were taken into solution at the U.S. Bureau of Mines at Reno, and the solutions bottled for several months before being analysed in the Nevada Mining Analytical Laboratory. The results from these six may not be reliable but the solutions were nevertheless used because the feldspar samples were lost in the process. All the oxide totals of these six samples exceed 100 percent, are significantly higher than the average oxide total, but are unusually deficient in Al_2O_3 (see appropriate samples in Tables A4 and A5). Hence I recalculated the Na_2O percent to correspond with feldspar compositions with zero percent deficient Al_2O_3 because I think the aluminum analyses obtained by X-ray emission spectroscopy are more reliable. Several other sodium analyses were either revised or discarded before using the feldspar An content in geologic interpretation. This is discussed on page 1 .

The reproducibility of magnesium analyses among different laboratories and even among analyses from the same laboratory is so poor that no geologic interpretation of magnesium is attempted. In addition the magnesium values probably could not be used for geologic interpretation because of a close correlation between high magnesium content and percent dark impurities in the feldspar material analysed. Magnesium analyses were obtained and included in the oxide totals of all samples with the following exceptions. No results were obtained from samples 3717Ks and 3727Ks because of too little sample solution and samples 3718Ks to 3731Ks inclusive were not included in the oxide totals because they arrived after the tables of oxide totals were typed. I would not have included any of the magnesium analyses in the oxide totals had the inter-laboratory results been obtained prior to typing the tables of the chemical analysis.

Reliability of chemical analysis

Fifty-five of the sixty-one analyses presented are based on single determinations. Therefore I cannot demonstrate precision for these analyses. An estimate of exceptable precision is given by the maximum range of composition taken from the replicate analyses of samples 3700Pl, 3718Pl, 3724Pl, 3706Ks, 3718Ks, and 3731Ks as listed on page A12 columns B. I cannot demonstrate a high accuracy either because of a lack of prime standards. However I believe the analyses are useful because of the fair agreement between X-ray and non X-ray methods (Table A3) and because of the approach toward 100 percent of most of the oxide totals (Fig. A14). It is tempting to suggest that the bias toward low oxide totals is due to water and other elements not looked for. However this bias may also be due to misplacement of one or more of the major element calibration curves, especially those of aluminum and silica.



Upper curve used in Al determination

Fig. A1 Al Calibration curve - Plagioclase

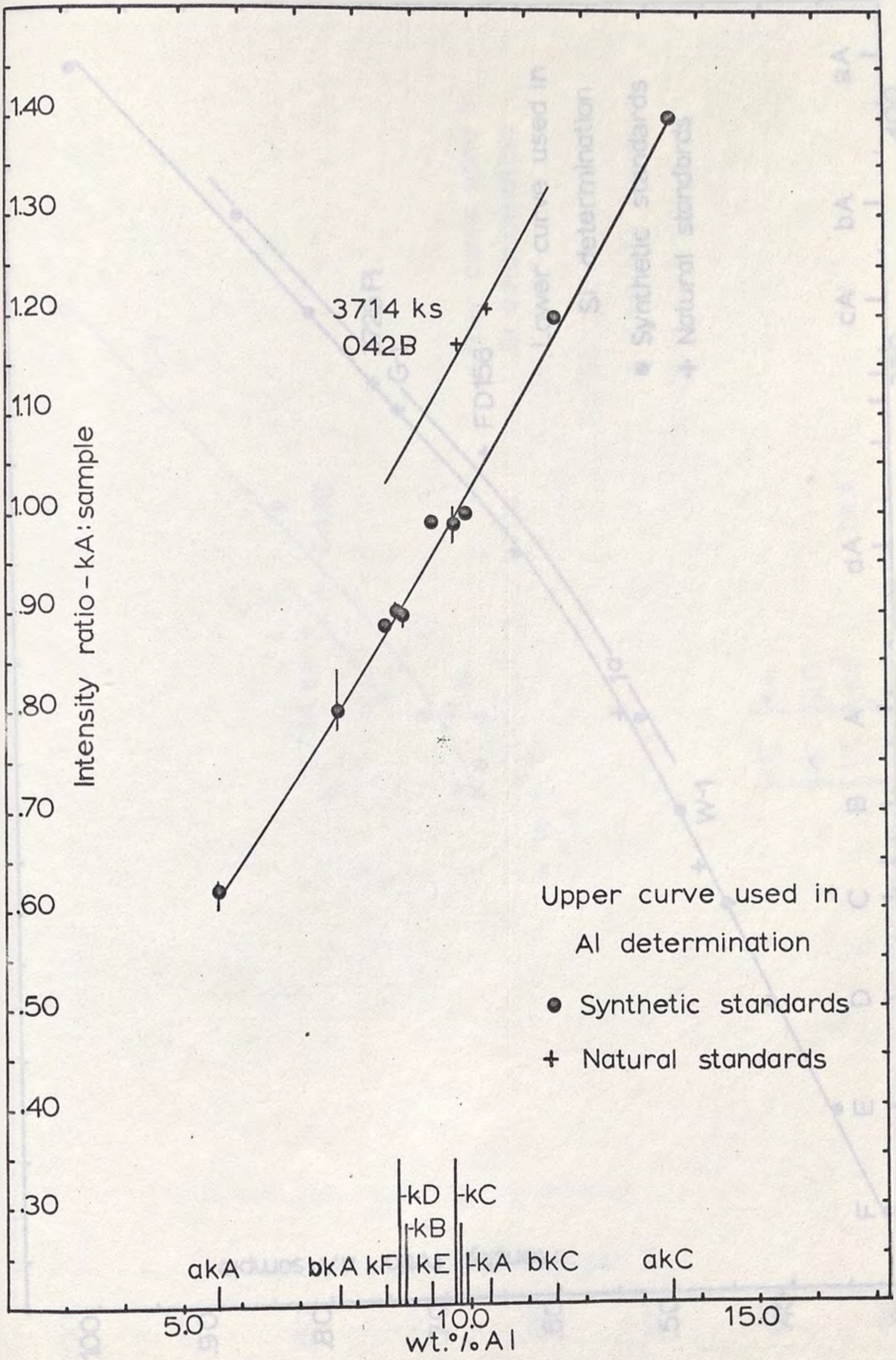


Fig. A2 Al Calibration curve - Alkali feldspar

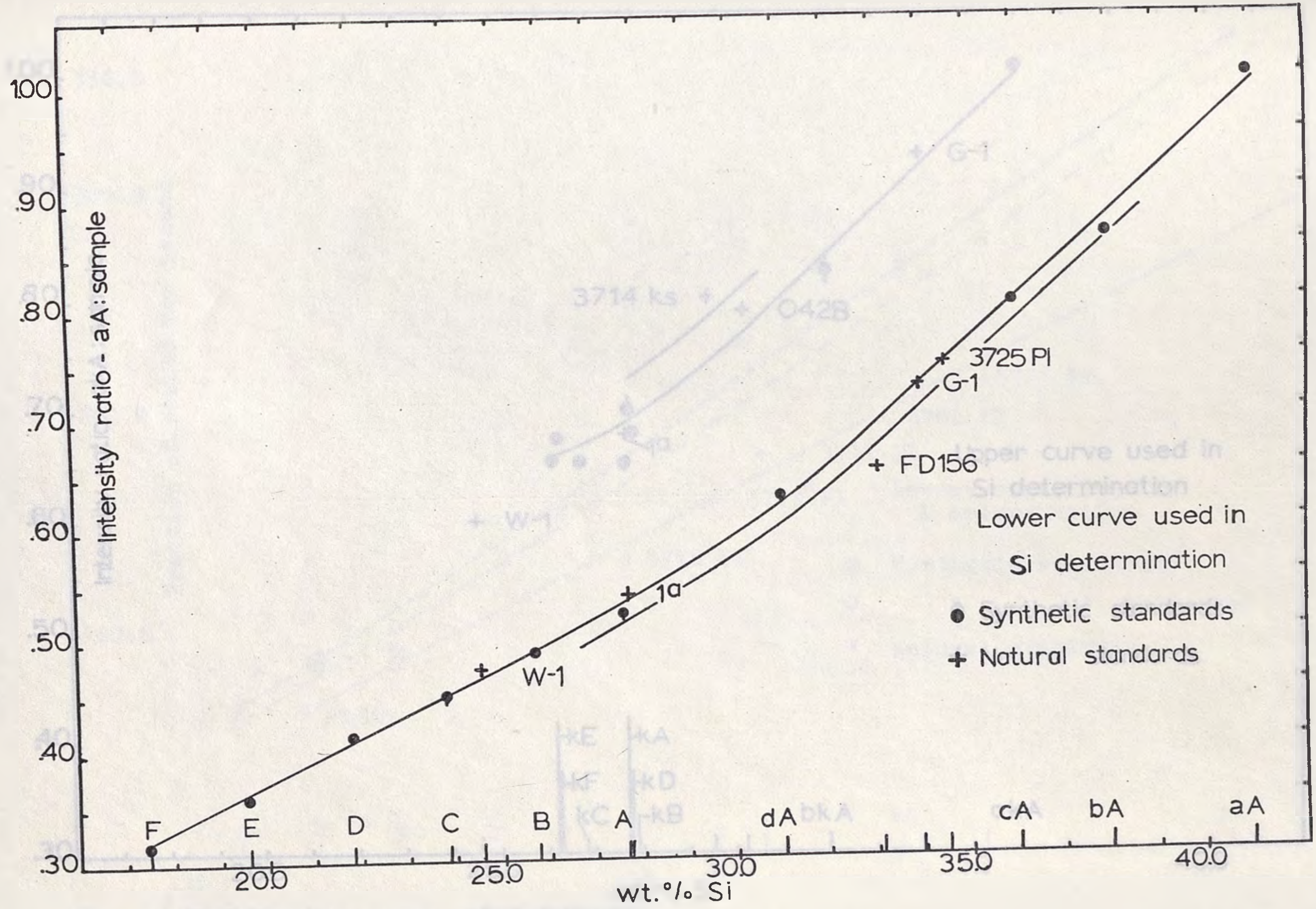


Fig. A3 Si Calibration curve - Plagioclase

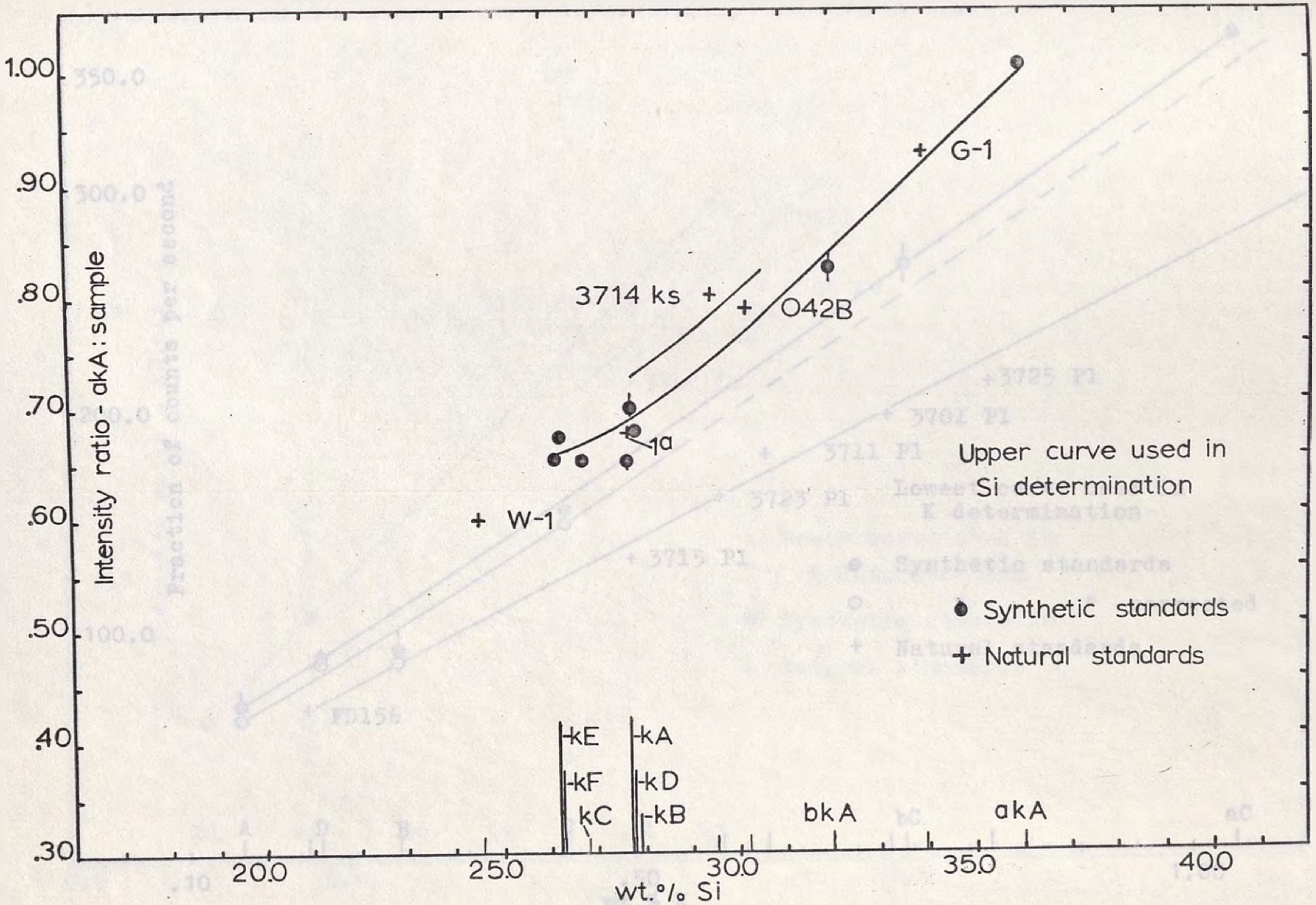


Fig. A4 Si Calibration curve - Alkali feldspars

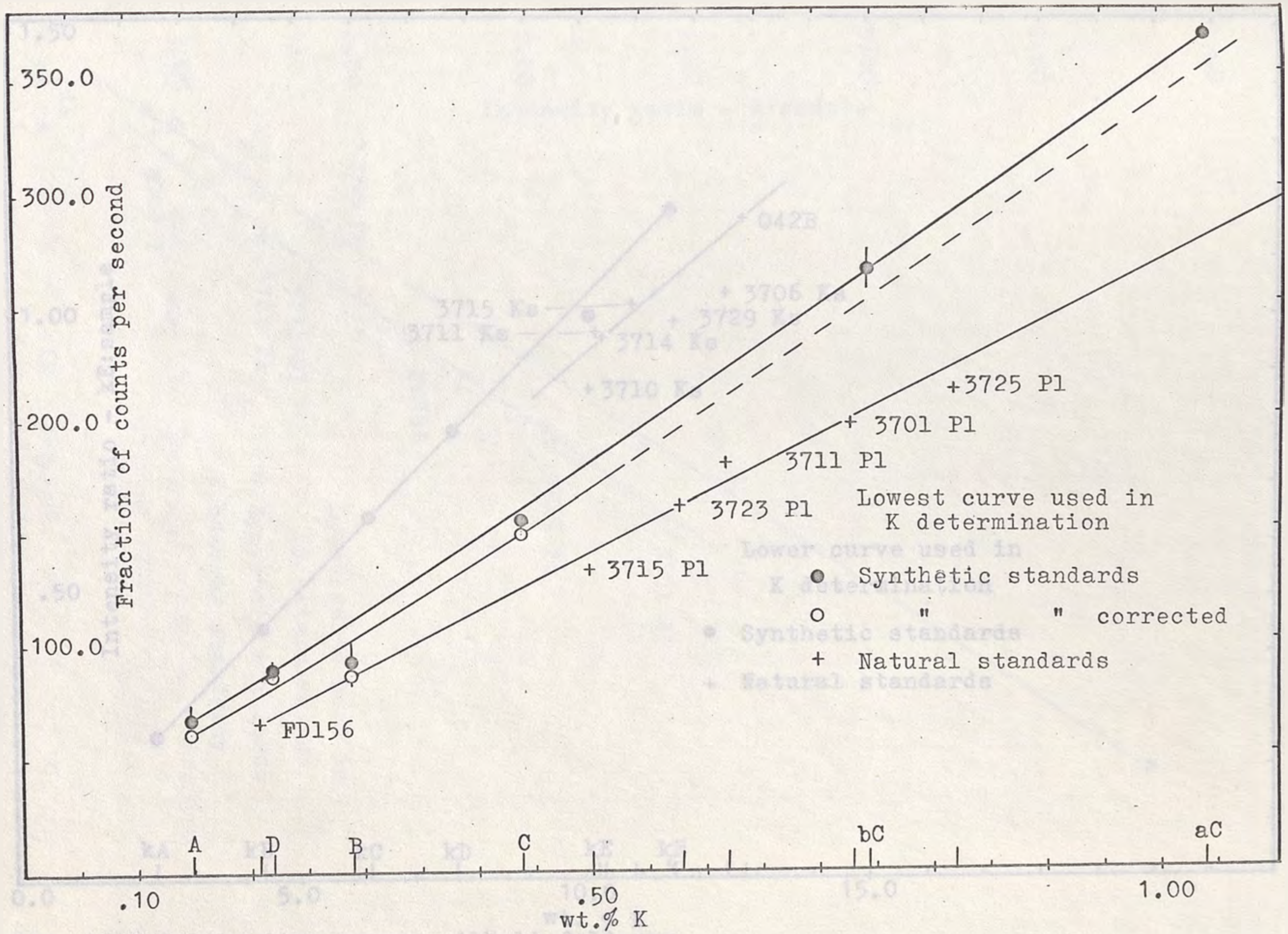


Fig. A5 K Calibration curve - Plagioclase

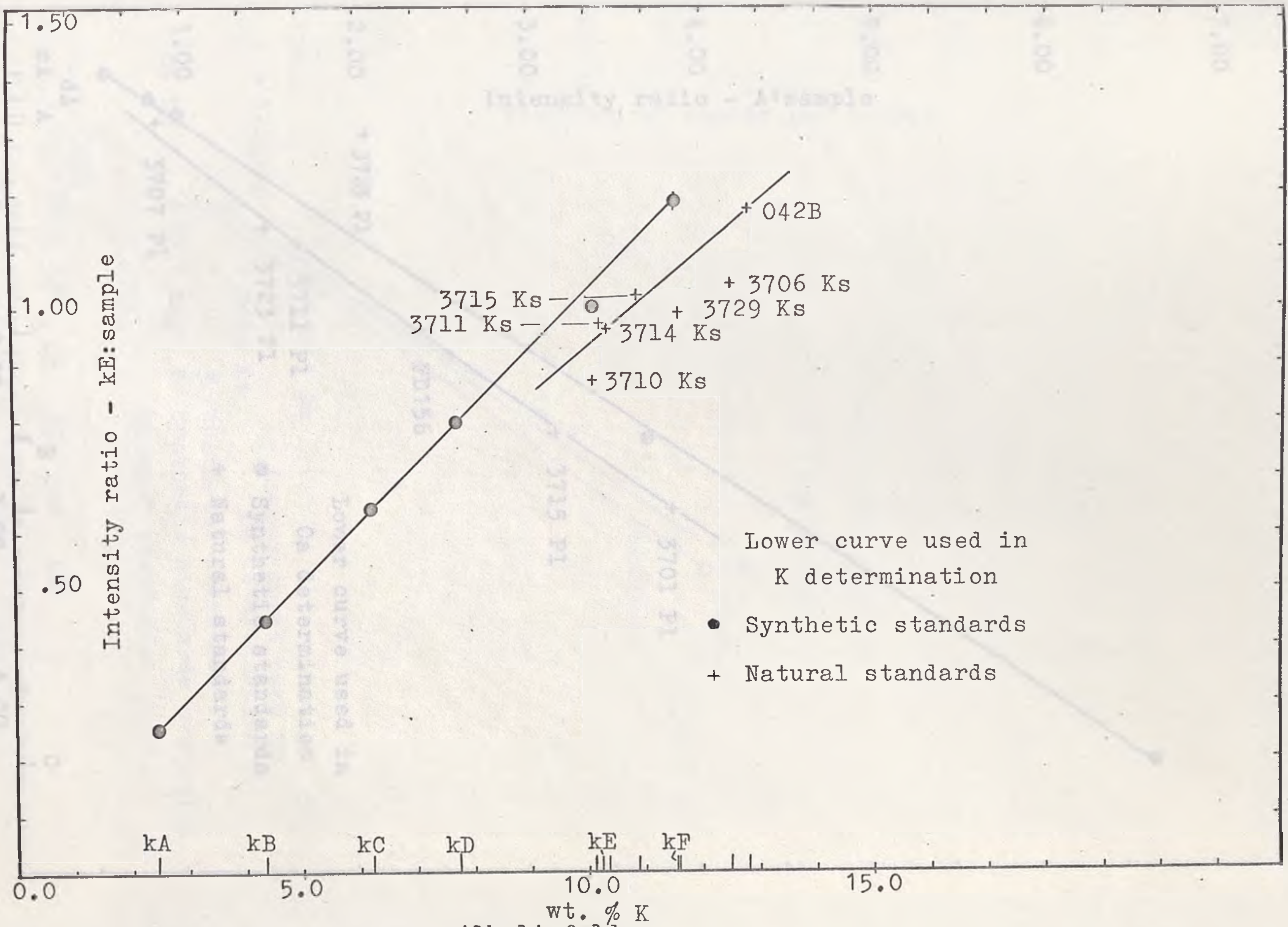


Fig. A6 K Calibration curve - Alkali feldspar

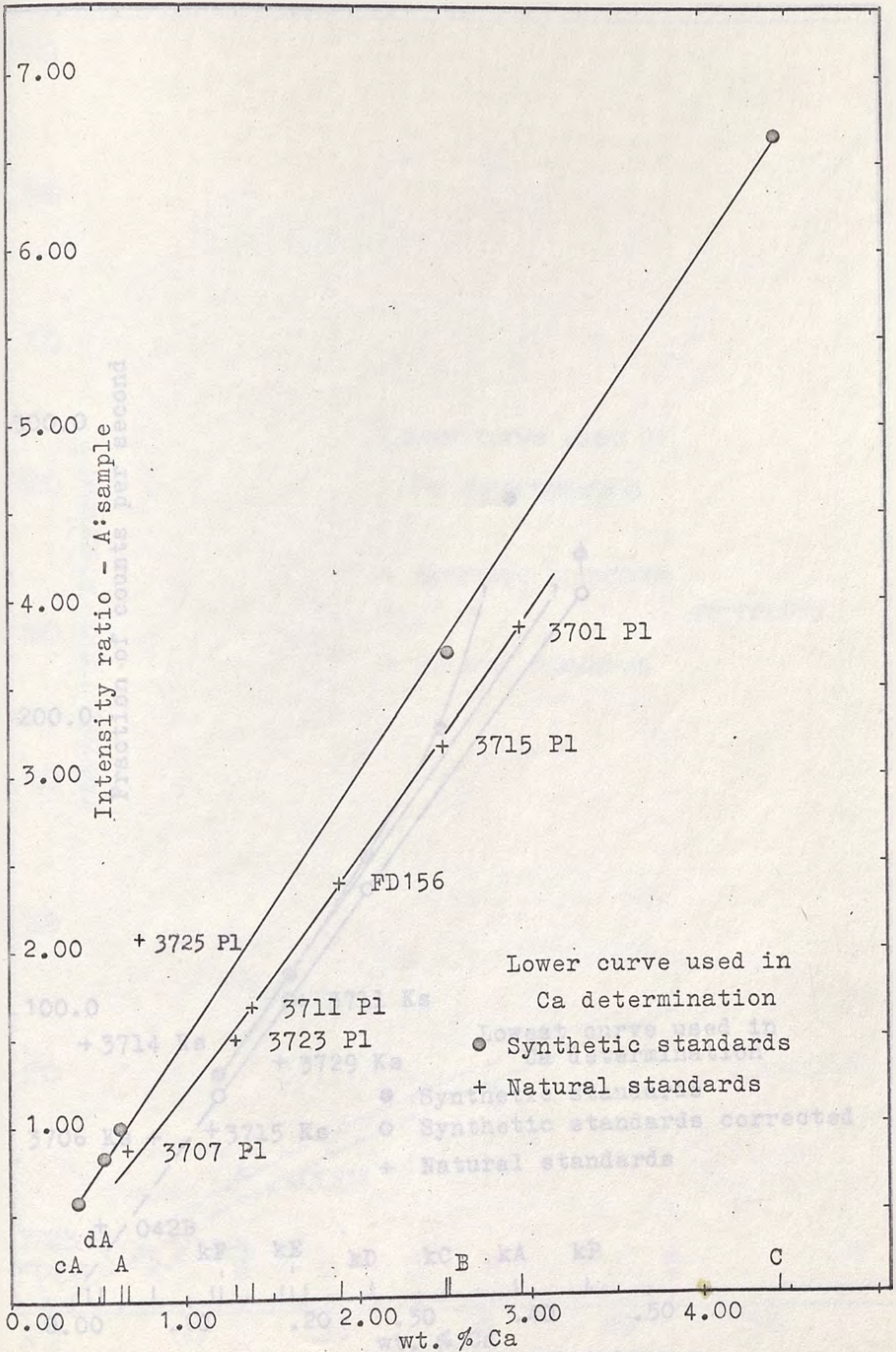


Fig. A7 Ca Calibration curve - Plagioclase

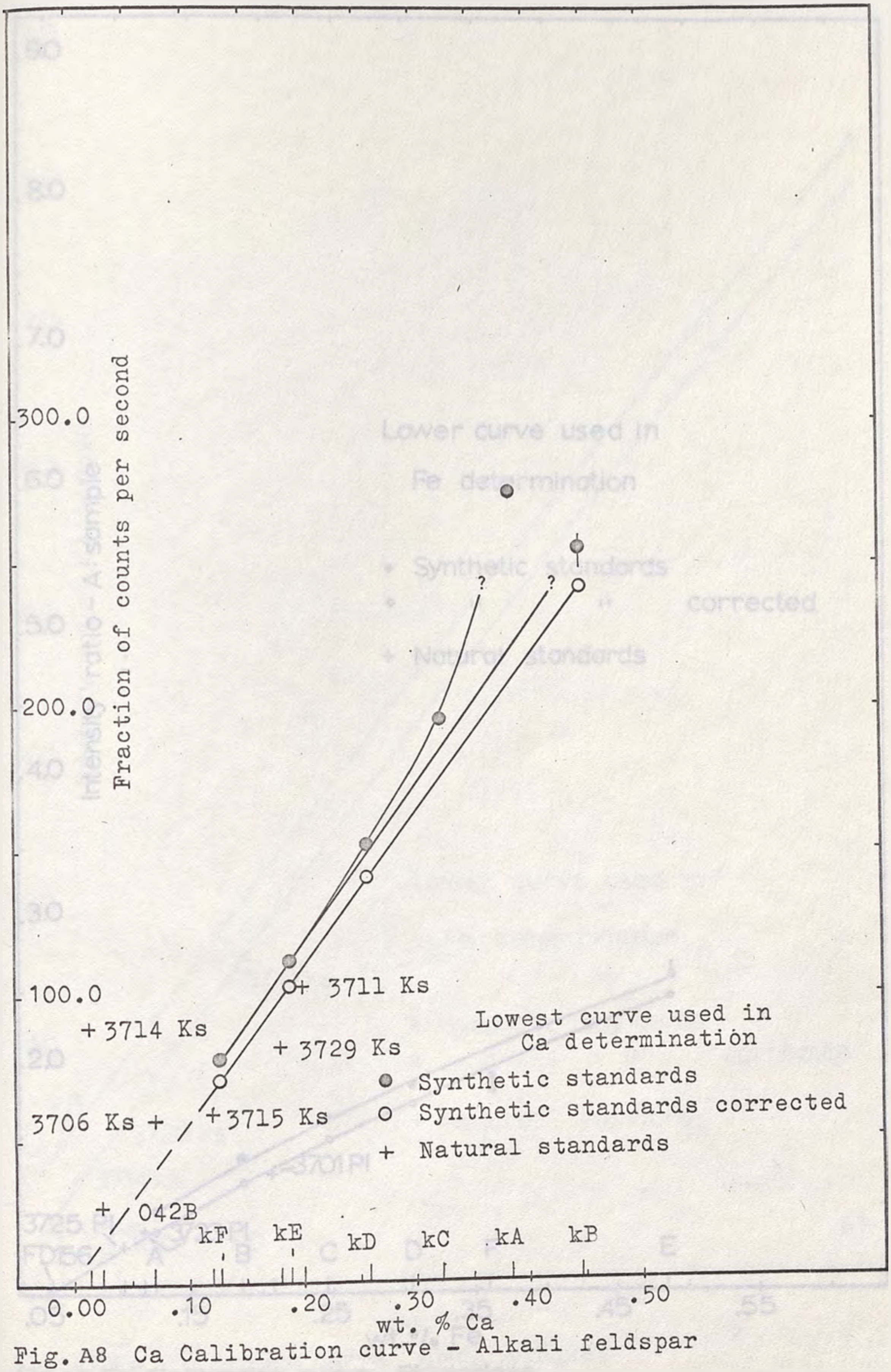


Fig. A8 Ca Calibration curve - Alkali feldspar

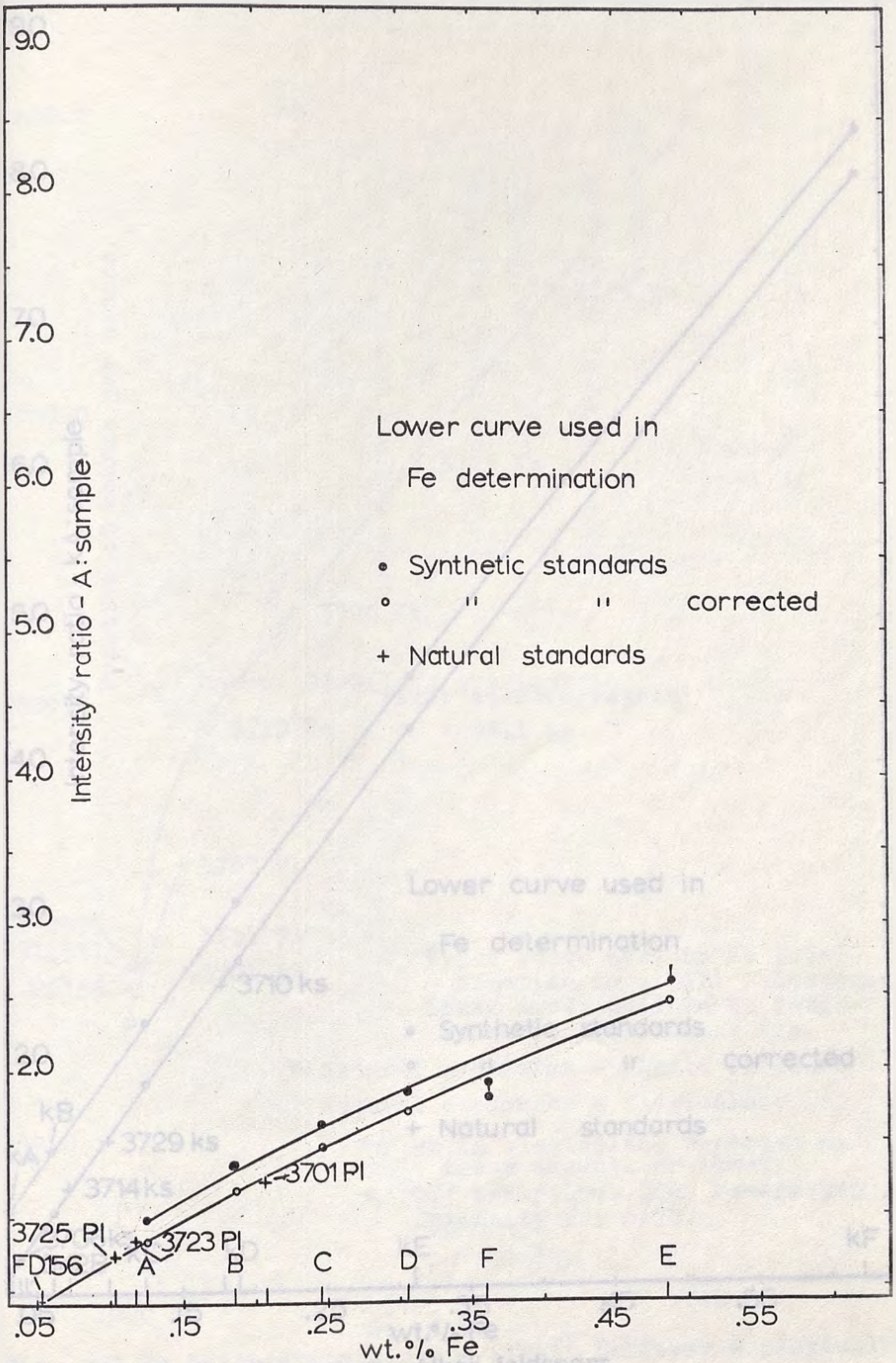


Fig. A9 Fe Calibration curve - Plagioclase

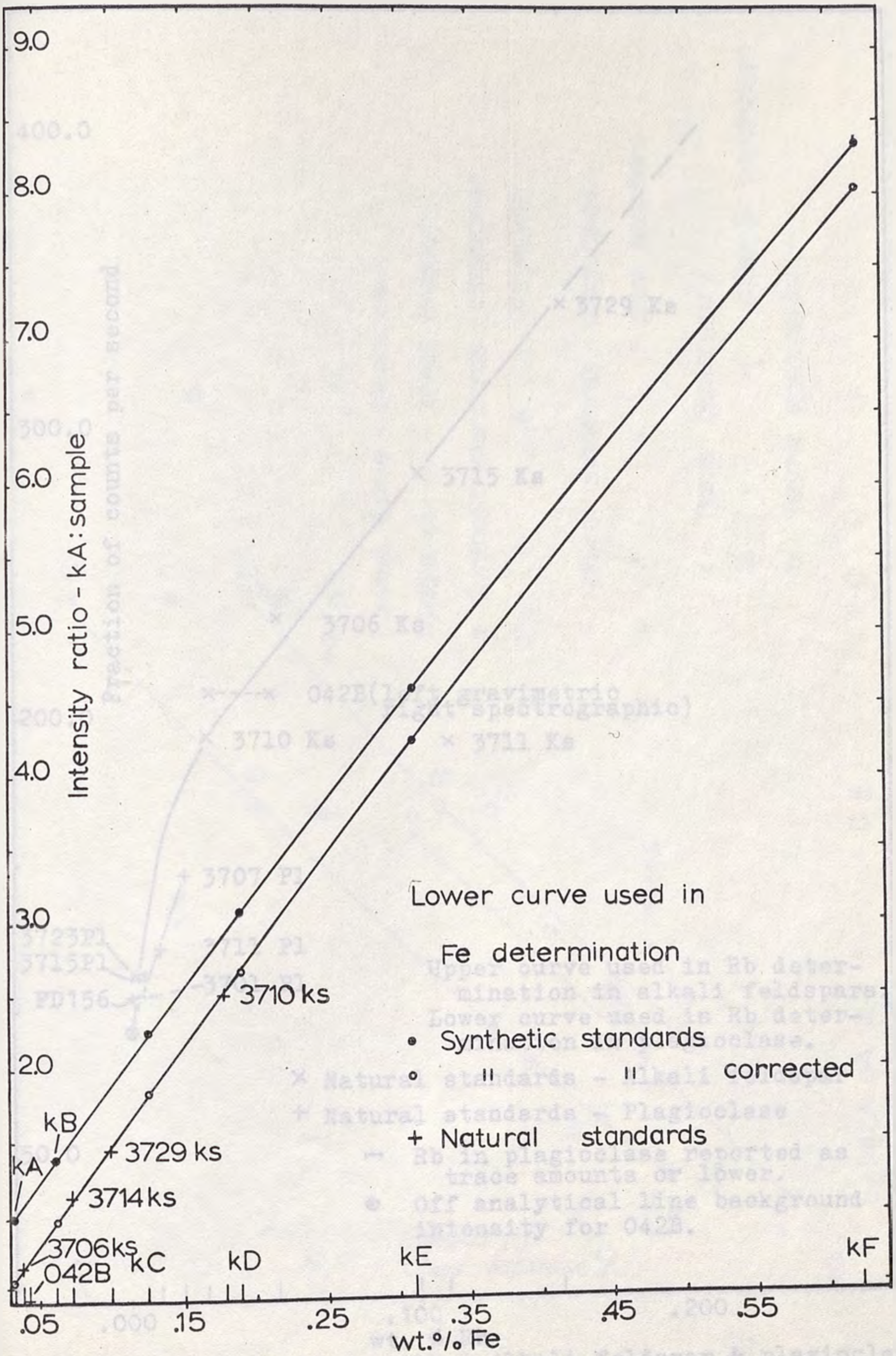


Fig. A10 Fe Calibration curve - Alkali feldspars

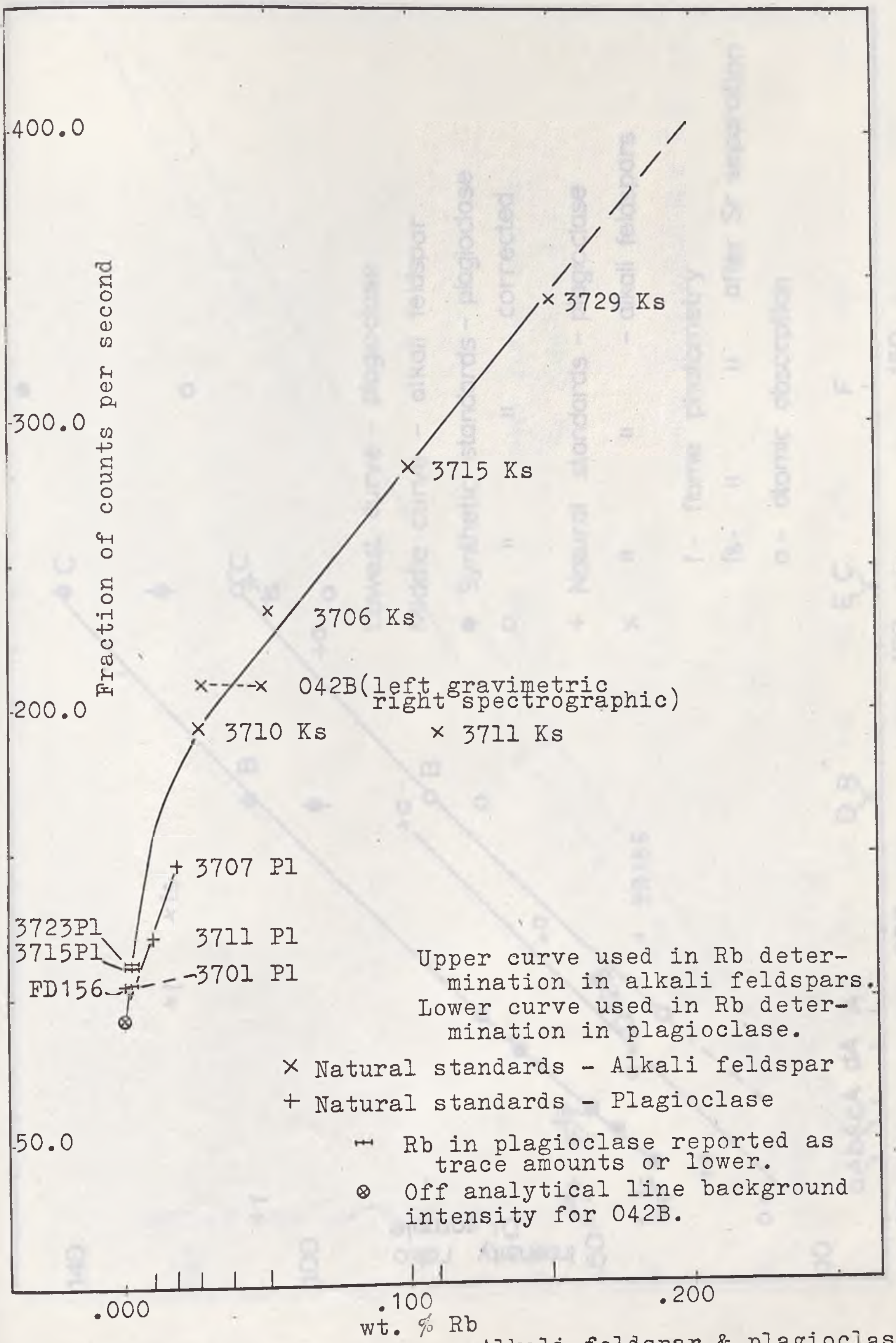


Fig. A11 Rb Calibration curve - Alkali feldspar & plagioclase

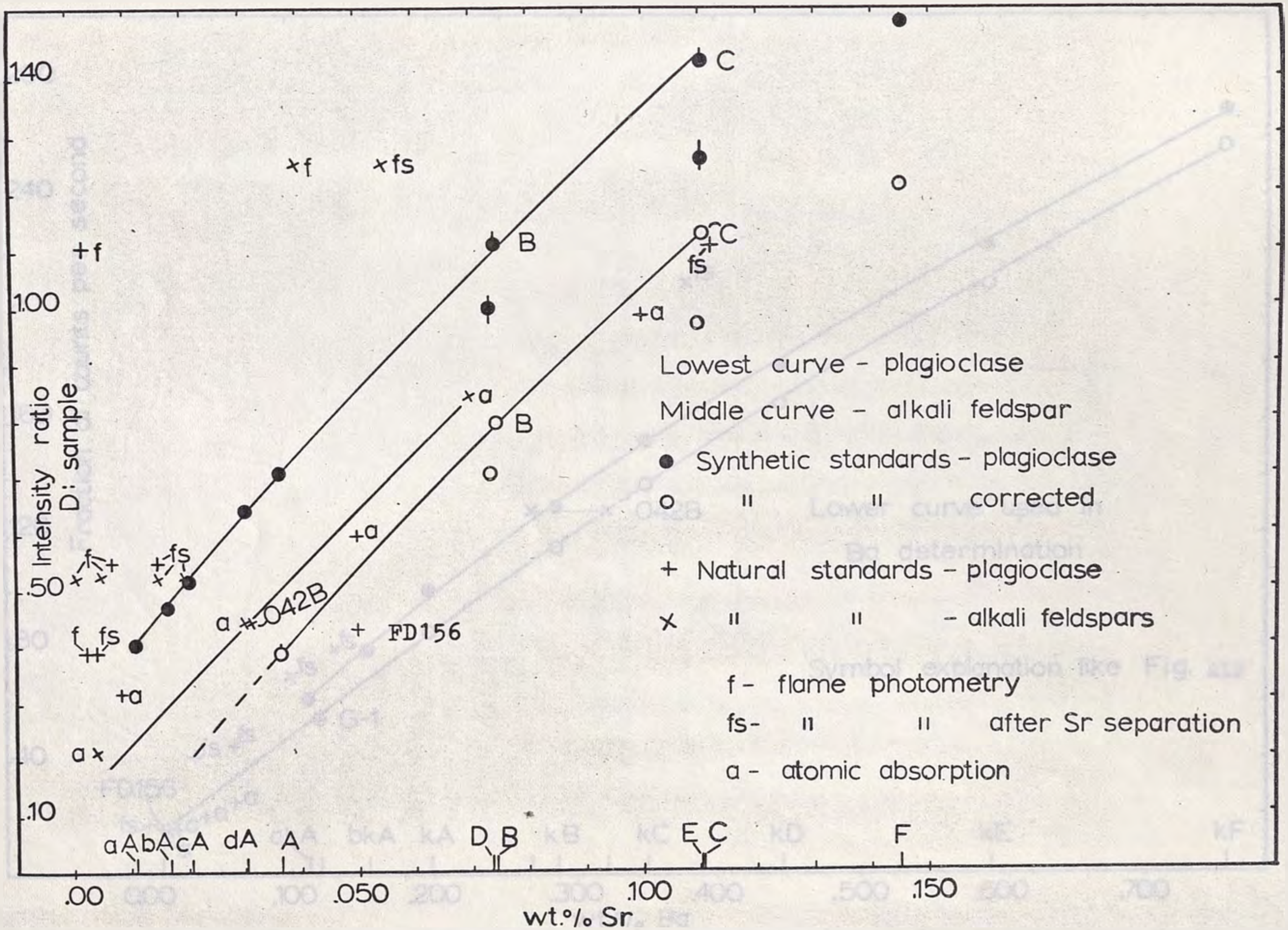


Fig. A12 Sr Calibration curve - Plagioclase and Alkali feldspar

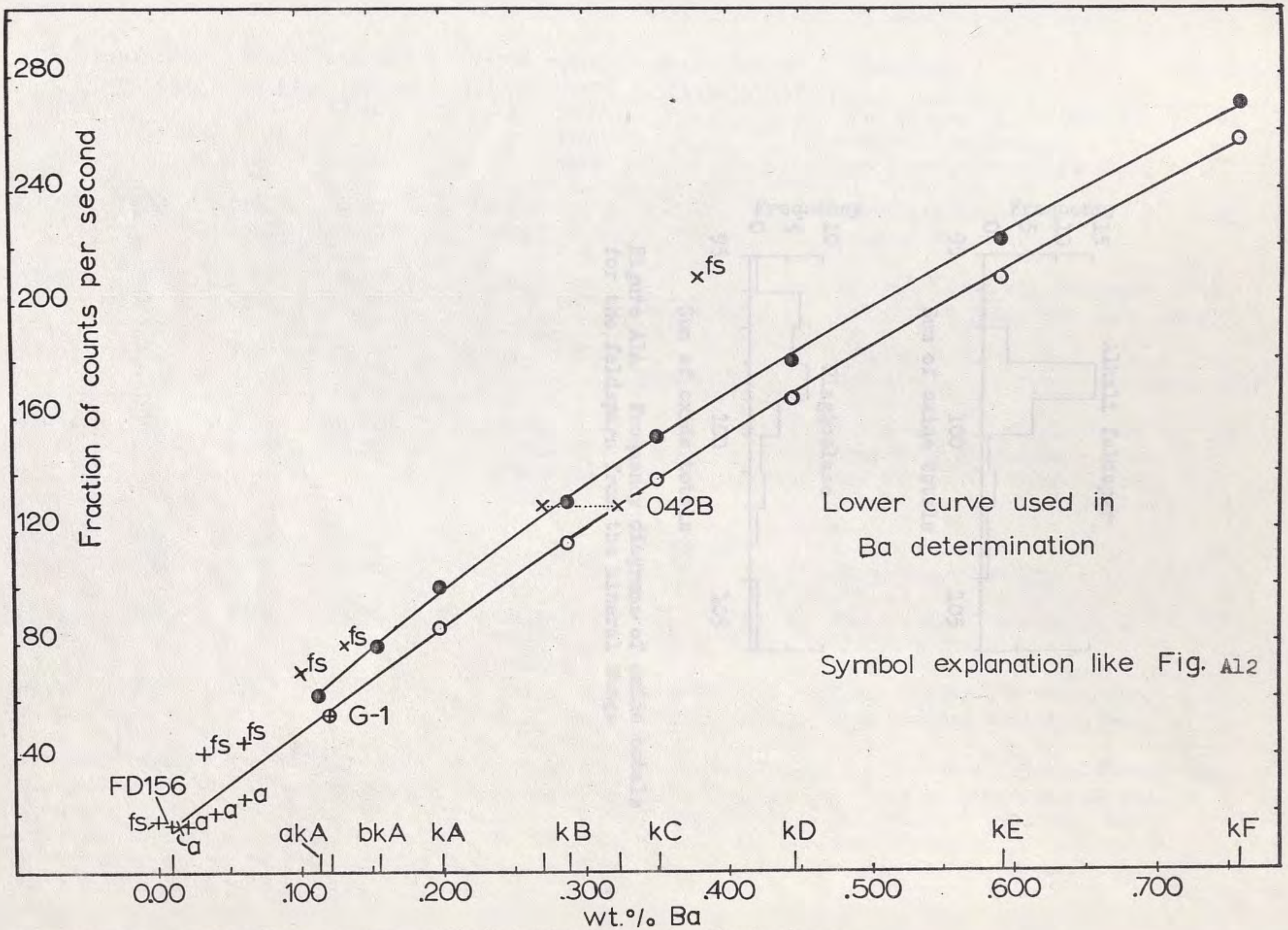


Fig. A13Ba Calibration curve - Alkali feldspar and Plagioclase

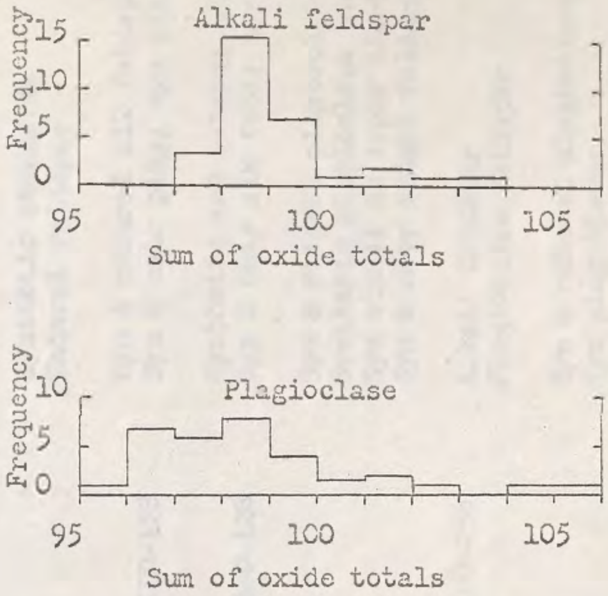


Figure A14 Frequency diagrams of oxide totals for the feldspars from the Mineral Range

Table A1 Instrumental settings and conditions for chemical analyses by X-ray Spectroscopy

2θ	Amplifier voltage	Base volts	Window volts	Total counts (fixed count)	Scale factor (fixed time)	Remarks	Element
142.99	1580	1.20	17.40	51200 to 25600		Synthetic plag. standards	Al
				25600		Natural plagioclase	
		1.80	16.20	25600		Syn & natural alk feldspar	
107.99	1570	1.20	18.90	204800		Synthetic standards	Si
		1.50	19.80	102400		Natural feldspar	
49.92	1625	3.60	19.20	256000		Syn & natural alk feldspar	K
	1575	4.20	22.80		1-100-128	Syn & natr plag; syn plag blanks	
44.47	1555	3.90	20.70	204800 to 102400		Synthetic and natural plag	Ca
					1-100-128	Syn & natr alk feld; syn alk blanks	
57.11	810	2.10	18.90	204800		Syn & natural plagioclase	Fe
		2.40	19.80	51200		Synthetic plagioclase blanks	
				25600		Syn alkali feldspar blanks	
				204800		Syn & natr alkali feldspars	
26.55	715	2.10	11.10		1-100-256	Alkali feldspar	Rb
	785	6.00	18.60			Plagioclase feldspar	
24.54	700	2.10	10.80	204800		Syn & natural plagioclase	Sr
				51200		Syn plag blanks	
				103400		Natural alkali feldspar	
36.63	1475	3.90	11.10		1-100-32	Syn and natr alk feld, alk feld blanks, and natr plag	Ba

Tungsten radiation used throughout with power held at 50 Kv and 35mA. Characteristic radiation is K-alpha except for Ba where L-alpha is used. EDDT analysing crystal and Flow proportional counter with gas flow of .5 SCFH/air P-10 (90% Ar - 10% CH_4) used for Al,Si,K, and Ca. LiFl analysing crystal and Scintillation counter used for Fe,Rb, and Sr. All analyses performed in vacuum and collimation for Al,Si,K,Ca and for Rb in plagioclase is 20 mils. Collimation for Fe,Sr,Ba and Rb in alkali feldspar is 5 mils,

TABLE A2-Data on chemical analyses of materials used as standards for X-ray Spectroscopy[1]

Methods used in analyses

SiO_2 and Al_2O_3 - Gravimetric
Fe_2O_3 - Colorimetric
CaO and MgO - 3725Pl and 3714Ks analyzed by Flame Emission Spectrophotometry; 3711Pl, 3715Pl, 3711Ks, and 3715Ks analyzed by Gravimetric or Volumetric methods; the remaining samples analyzed by Atomic Absorption
Na_2O - Flame Emission Spectrophotometry
K_2O - Flame Emission Spectrophotometry
Rb_2O, BaO, SrO - H. A. Vincent[2] analyzed by Flame Emission Spectrophotometry; Keith Stever analyzed by Atomic Absorption

Number of determinations per reported analysis

3725Pl and 3714Ks - Triplicate determinations except for P_2O_5, MnO, and loss on ignition at 1000°C which are single determinations
3711Pl, 3715Pl, 3711Ks, and 3715Ks - Duplicate determinations
3701Pl, 3704Pl, 3707Pl, 3717Pl, 3721Pl, 3723Pl, 3704Ks, 3706Ks, 3710Ks, 3717Ks, 3721Ks, and 3729Ks - Single determinations

Keith Stever suggested that all his BaO determinations may be low, and that BaO for 3704Ks and 3717Ks may be unreliable.
Lanthanum was added to the solutions of samples 3700Pl to 3710Pl inclusive, 3716Pl, 3706Ks, and 3711Ks prior to the MgO determinations. Lanthanum was not added to the rest of the samples.

1-Data for Na_2O and MgO is listed only for future reference. No X-ray Emission Spectrographic determinations for Na_2O and Mgo were made.

2-Hiroshi Asari analyzed Rb_2O by Flame Emission Spectrophotometry.

TABLE A3 - Comparison of chemical analyses obtained by X-ray Emission Spectroscopy with those obtained by other methods

Sample 3725Pl

	A	B	C	Average of triplicate	X-ray Spectroscopy
SiO_2	73.78	73.60	74.17	73.85	75.13
Al_2O_3				15.39	16.02
Fe_2O_3	.148	.151	.143	.147	.149
CaO	.84	.84	[1]1.01	.84	2.32
Na_2O	5.73	5.70	5.73	5.72	6.19*
K_2O	1.01	.96	[1]1.26	.99	.95
BaO					.065
SrO					.129
Rb_2O					.011
MgO	.052	.055	.055	.054	.131*
P_2O_5				ND	
MnO				.008	
loss on ignition @ 1000°C				.22	
TiO_2	.15	[1].052	.17	.16	
				97.38	101.09

Sample 3714Ks

	A	B	C	Average of triplicate	X-ray Spectroscopy
SiO_2	63.20	63.36	62.89	63.15	64.26
Al_2O_3				19.55	19.27
Fe_2O_3	.101	.105	.110	.105	.106
CaO	.027	.015	.015	.019	.225
Na_2O	2.67	2.78	2.97	2.81	3.03*
K_2O	12.43	12.48	12.56	12.49	12.49
BaO					.187
SrO					.053
Rb_2O					.063
MgO	.014	.011	.012	.012	.007*
P_2O_5				.008	
MnO				.002	
loss on ignition @ 1000°C				.12	
TiO_2				.041	
				98.31	99.69

Columns A, B, C, are individual determinations of triplicate silicate analyses performed by Harold A. Vincent, Chemist, Nevada Mining Analytical Laboratory.

*-Na_2O was obtained by Flame Emission Photometry and MgO was obtained by Atomic Absorption.

1-Not used in average.

TABLE A3 -Continued

	Na_2O			MgO			Rb_2O			
			PPW			WB				
	HAV	HA	LJH	HAV	HA	LJH	HAV	HA	RCE	X-ray
3701Pl	5.38		5.61	.16		.145	tr			.008
3704Pl										
3707Pl	5.05		5.30	.087		.136	.020			.019
3711Pl		4.65	4.77		.008	.025		.01		.010
3715Pl		9.34	9.19		.008	.020		.00		.007
3723Pl	10.25		9.80	.038		.066	tr			.011
3725Pl	5.72		6.19	.054		.131				
FD156									ND	.005
3706Ks	2.18		2.80	.003		.275	.055			.060
3710Ks	3.38		2.36	.56		.071	.028			.034
3711Ks		2.45	3.55		.008	.280		.12		.026
3714Ks	2.81		3.03	.012		.007				
3715Ks		2.13	2.80		.008	.007		.11		.108
3729Ks	2.33		2.64	.007		.012	.164			.162
042B									.03	.042

HA -Hiroshi Asari, Analyst, Japan Analytical Chemistry Research Institute, Tokyo.
WB -Woody Barry, Junior Chemist, Nevada Mining Analytical Laboratory, Reno.
LJH-Lawrence J. Herber, Mackay School of Mines, Reno.
KS -Keith Stever, Analyst, United States Bureau of Mines, Reno.
HAV-Harold A. Vincent, Ph.D., Chemist, Nevada Mining Analytical Laboratory, Reno.
PPW-Paul P. Weyler, Chemist, Nevada Mining Analytical Laboratory, Reno.

FD156 furnished by R. C. Emmons. For details, see Emmons (1953).
042B furnished by R. C. Emmons. For details, see Hewlett (1959).

ND-Looked for but not detected.
tr-Trace.

TABLE A3 -Continued

	Fe_2O_3			CaO				K_2O			
	HAV	RCE	X-ray	HAV	HA	RCE	X-ray	HAV	HA	RCE	X-ray
3701Pl	.296		.287	4.10			4.11	.87			.871
3707Pl	1.12		1.258	.92			.97	4.13			3.66
3711Pl					1.94		1.92		.75		.789
3715Pl					3.50		3.44		.60		.569
3723Pl	.169		.176	1.79			1.80	.70			.699
3725Pl	.147		.149	.84			2.32	.99			.947
FD156		.08	.077			2.66	2.66			.25	.25
3706Ks	.056		.058	.097			.137	15.0			13.61
3710Ks	.259		.254	1.19			1.12	12.2			11.21
3711Ks					.28		.260		12.34		12.64
3714Ks	.105		.106	.019			.225	12.49			12.49
3715Ks					.17		.146		13.11		13.27
3729Ks	.143		.136	.25			.206	14.0			12.87
042B		.06	.00			.02	.062			15.44	15.44

	SiO_2		Al_2O_3	
	RCE	X-ray	RCE	X-ray
FD156	70.79	69.31	18.40	18.03
042B	64.60	63.53	18.55	18.78

TABLE A3 -Continued

	BaO					SrO				
	HAV[1]	HAV[2]	KS	RCE	X-ray	HAV[1]	HAV[2]	KS	RCE	X-ray
3701Pl	.003	.071*			.099	.003	.132*			.127
3704Pl			.067		.042			.118		.111
3707Pl	.003	.029			.089	.008	.018			.060
3711Pl										
3715Pl										
3717Pl			.045		.028			.059		.065
3721Pl			.022		.017			.011		.035
3723Pl	ND	ND			.018	.003	.006			.043
FD156				.011	.013				.06	.047
3704Ks			.112		.348			.083		.083
3706Ks	ND	.112			.176	tr	.018			.045
3710Ks	ND	.424			.630	.047	.065			.131
3711Ks										
3715Ks										
3717Ks			.067		.151			.035		.035
3721Ks			.017		.013			.005		.011
3729Ks	ND	.145			.207	.006	.024			.046
042B				.36	.366				.04	.036

1-Analyses without separation from matrix.
2-Analyses after separation from matrix by ion exchange.
*-Uncertain dilution factor; value may be inaccurate.

TABLE A4 -Chemical analyses of plagioclase feldspars from the Mineral Range, Utah, in weight percent

Sample	3700P1				3700P1-A			
	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.
Si-SiO_2	36.67	78.44	1305	61.99	37.45	80.11	1333	63.98
Al-Al_2O_3	7.36	13.91	136.4	24.52	6.92	13.08	128.3	23.69
Fe-Fe_2O_3	.125	.179	1.1	.316	.118	.169	1.1	.306
Ca-CaO	.92	1.29	23.0	2.27	.90	1.26	22.5	2.28
Na-Na_2O	3.81	5.13	82.8	9.04	3.81	5.13	82.8	9.29
K -K_2O	.528	.636	6.8	1.12	.580	.699	7.4	1.27
Ba-BaO	.030	.033	.2	.058	.029	.032	.2	.058
Sr-SrO	.036	.043	.4	.076	.037	.044	.4	.080
Rb-Rb_2O	.010	.011	.06	.019	.012	.013	.07	.024
Mg-MgO	.060	.099	2.5	.175	.060	.099	2.5	.179
		99.77		99.58		100.64		101.16

Sample	3700P1-B				3700P1-C			
	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.
Si-SiO_2	37.24	79.66	1326	63.29	36.98	79.11	1317	62.62
Al-Al_2O_3	6.66	12.53	122.9	22.61	7.12	13.45	131.9	24.06
Fe-Fe_2O_3	.116	.166	1.0	.300	.121	.173	1.1	.310
Ca-CaO	.91	1.27	22.6	2.29	.88	1.23	21.9	2.20
Na-Na_2O	3.81	5.13	82.8	9.26	3.81	5.13	82.8	9.18
K -K_2O	.521	.628	6.7	1.13	.517	.623	6.6	1.11
Ba-BaO	.028	.031	.2	.056	.034	.038	.2	.068
Sr-SrO	.035	.041	.4	.074	.045	.053	.5	.095
Rb-Rb_2O	.009	.010	.05	.018	.033	.036	.19	.064
Mg-MgO	.060	.099	2.5	.179	.060	.099	2.5	.177
		99.57		99.21		99.94		99.88

TABLE A4-Chemical analyses of plagioclase feldspars from the Mineral Range, Utah, in weight percent

Sample	3701Pl Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.	3702Pl Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.
Si-SiO_2	32.45	69.42	1155	59.54	28.70	61.40	1022	
Al-Al_2O_3	10.09	19.07	187.0	25.24	11.37	21.48	210.7	
Fe-Fe_2O_3	.201	.287	1.8	.380	.091	.130	.8	
Ca-CaO	2.94	4.11	73.3	5.44	2.50	3.50	62.4	
Na-Na_2O	4.16	5.61	90.5	7.42	6.93	9.34	150.7	
K -K_2O	.723	.871	9.2	1.15	.658	.793	8.4	
Ba-BaO	.089	.099	.6	.131	.020	.022	.1	
Sr-SrO	.107	.129	1.2	.171	.044	.052	.5	
Rb-Rb_2O	.007	.008	.04	.011	.007	.008	.04	
Mg-MgO	.088	.145	3.6	.192	.039	.065	1.6	
		99.75		99.68		96.79		

Sample	3703Pl Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.	3704Pl Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.
Si-SiO_2	29.15	62.36	1038		33.14	70.89	1180	69.68
Al-Al_2O_3	11.27	21.29	208.8		9.98	18.86	185.0	19.64
Fe-Fe_2O_3	.106	.152	1.0		.128	.183	1.1	.191
Ca-CaO	2.16	3.02	53.9		2.15	3.01	53.7	3.13
Na-Na_2O	6.94	9.35	150.9		6.86	9.25	149.2	9.63
K -K_2O	.814	.981	10.4		1.41	1.70	18.0	1.77
Ba-BaO	.023	.026	.2		.038	.042	.3	.044
Sr-SrO	.069	.082	.8		.094	.111	1.1	.116
Rb-Rb_2O	.011	.012	.06		.012	.013	.07	.014
Mg-MgO	.025	.041	1.0		.084	.139	3.4	.145
		97.31				104.20		104.36

TABLE A4-Chemical analyses of plagioclase feldspars from the Mineral Range, Utah, in weight percent

Sample	3705Pl				3706Pl			
	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.
Si-SiO$_2$	30.03	64.24	1069	61.60	30.95	66.21	1102	62.57
Al-Al$_2$O$_3$	11.03	20.84	204.4	22.38	10.59	20.01	196.3	22.17
Fe-Fe$_2$O$_3$	.332	.475	3.0	.510	.098	.140	.9	.155
Ca-CaO	2.71	3.79	67.6	4.07	2.13	2.98	53.1	3.30
Na-Na$_2$O	5.25	7.07	114.1	7.59	5.76	7.76	125.2	8.60
K -K$_2$O	1.70	2.05	21.8	2.20	1.05	1.26	13.4	1.40
Ba-BaO	.041	.046	.3	.049	.023	.026	.2	.029
Sr-SrO	.125	.148	1.4	.159	.061	.072	.7	.080
Rb-Rb$_2$O	.018	.020	.11	.021	.011	.012	.06	.013
Mg-MgO	.124	.205	5.1	.220	.020	.033	.8	.037
		98.88		98.80		98.50		98.35

Sample	3707Pl				3708Pl			
	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.
Si-SiO$_2$	32.42	69.35	1154	60.59	28.73	61.46	1023	
Al-Al$_2$O$_3$	9.96	18.82	184.6	24.20	11.53	21.79	213.7	
Fe-Fe$_2$O$_3$	.876	1.26	7.9	1.62	.278	.397	2.5	
Ca-CaO	.69	.97	17.3	1.25	2.53	3.54	63.1	
Na-Na$_2$O	3.93	5.30	85.5	6.81	6.66	8.97	144.7	
K -K$_2$O	3.04	3.66	38.9	4.71	.888	1.07	11.4	
Ba-BaO	.080	.089	.6	.114	.031	.035	.2	
Sr-SrO	.051	.060	.6	.077	.065	.077	.7	
Rb-Rb$_2$O	.018	.019	.10	.024	.008	.009	.05	
Mg-MgO	.082	.136	3.4	.175	.021	.035	.9	
		99.66		99.57		97.38		

TABLE A4 -Chemical analyses of plagioclase feldspars from the Mineral Range, Utah, in weight percent

Sample	3709Pl				3710Pl			
	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.
Si-SiO_2	38.54	82.44	1372	65.79	28.57	61.12	1017	60.03
Al-Al_2O_3	6.05	11.43	112.1	22.27	11.95	22.58	221.5	23.22
Fe-Fe_2O_3	.132	.189	1.2	.368	.327	.468	2.9	.481
Ca-CaO	.70	.98	17.5	1.91	3.72	5.21	92.9	5.36
Na-Na_2O	3.51	4.74	76.5	9.23	5.19	7.00	112.9	7.20
K -K_2O	.866	1.04	11.0	2.03	1.33	1.60	17.0	1.65
Ba-BaO	.028	.031	.2	.060	.076	.085	.6	.087
Sr-SrO	.049	.058	.6	.113	.201	.238	2.3	.245
Rb-Rb_2O	.011	.012	.06	.023	.009	.010	.05	.010
Mg-MgO	.042	.069	1.7	.134	.100	.166	4.1	.171
		100.99		101.93		98.48		98.45

Sample	3711Pl				3712Pl			
	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.
Si-SiO_2	36.57	78.23	1302	61.67	28.66	61.31	1020	61.80
Al-Al_2O_3	7.56	14.28	140.1	25.14	11.38	21.50	210.9	22.46
Fe-Fe_2O_3	.111	.159	1.0	.280	.203	.290	1.8	.249
Ca-CaO	1.37	1.92	34.2	3.38	2.80	3.92	69.9	3.42
Na-Na_2O	3.54	4.77	77.0	8.40	6.46	8.71	140.5	8.93
K -K_2O	.655	.789	8.4	1.39	.795	.958	10.2	.629
Ba-BaO	.031	.035	.2	.062	.039	.044	.3	.037
Sr-SrO	.070	.083	.8	.146	.108	.128	1.2	.120
Rb-Rb_2O	.009	.010	.05	.018	.006	.007	.04	.010
Mg-MgO	.015	.025	.6	.044	.032	.053	1.3	.026
		100.30		100.53		96.92		[illegible]

TABLE A4-Chemical analyses of plagioclase feldspars from the Mineral Range, Utah, in weight percent

Sample	3713Pl				3714Pl			
	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.
Si-SiO_2	28.80	61.61	1025		28.53	61.03	1016	
Al-Al_2O_3	11.22	21.20	207.9		11.16	21.09	206.8	
Fe-Fe_2O_3	.132	.189	1.2		.124	.177	1.1	
Ca-CaO	2.11	2.95	52.6		2.18	3.05	54.4	
Na-Na_2O	6.76	9.11	147.0		7.02	9.47	152.8	
K -K_2O	.765	.922	9.8		.704	.848	9.0	
Ba-BaO	.023	.026	.2		.027	.030	.2	
Sr-SrO	.074	.088	.8		.081	.096	.9	
Rb-Rb_2O	.009	.010	.05		.007	.008	.04	
Mg-MgO	.011	.018	.4		.014	.023	.5	
		96.13				95.82		

Sample	3715Pl				3716Pl			
	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.
Si-SiO_2	28.77	61.54	1024		32.73	70.02	1165	61.88
Al-Al_2O_3	11.30	21.35	209.4		9.43	17.82	174.8	22.66
Fe-Fe_2O_3	.146	.209	1.3		.136	.194	1.2	.247
Ca-CaO	2.46	3.44	61.3		1.92	2.69	47.9	3.42
Na-Na_2O	6.82	9.19	148.3		5.21	7.02	113.3	8.93
K -K_2O	.472	.569	6.0		.411	.495	5.3	.629
Ba-BaO	.032	.036	.2		.026	.029	.2	.037
Sr-SrO	.080	.095	.9		.067	.079	.8	.100
Rb-Rb_2O	.006	.007	.04		.007	.008	.04	.010
Mg-MgO	.012	.020	.4		.098	.162	4.0	.206
		96.64				98.52		98.12

TABLE A4-Chemical analyses of plagioclase feldspars from the Mineral Range, Utah, in weight percent

Sample	3717P1				3718P1			
	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.
Si-SiO_2	36.36	77.78	1294	69.36	29.53	63.17	1051	
Al-Al_2O_3	7.36	13.91	136.4	19.18	11.13	21.03	206.3	
Fe-Fe_2O_3	.114	.163	1.0	.225	.145	.207	1.3	
Ca-CaO	1.50	2.10	37.4	2.90	1.93	2.70	48.1	
Na-Na_2O	5.62	7.58	122.3	10.45	7.06	9.52	153.6	
K -K_2O	.346	.417	4.4	.575	.852	1.03	10.9	
Ba-BaO	.025	.028	.2	.039	.033	.037	.2	
Sr-SrO	.055	.065	.6	.090	.058	.069	.7	
Rb-Rb_2O	.008	.009	.05	.012	.008	.009	.05	
Mg-MgO	.006	.010	.2	.014	.008	.013	.3	
		102.06		102.85		97.78		

Sample	3718P1-A				3718P1-B			
	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.
Si-SiO_2	29.55	63.21	1052		29.52	63.15	1051	
Al-Al_2O_3	10.95	20.69	202.9		10.97	20.73	203.3	
Fe-Fe_2O_3	.145	.207	1.3		.144	.206	1.3	
Ca-CaO	1.93	2.70	48.1		1.95	2.73	48.7	
Na-Na_2O	7.06	9.52	153.6		7.06	9.52	153.6	
K -K_2O	.874	1.05	11.1		.842	1.01	10.7	
Ba-BaO	.031	.035	.2		.031	.035	.2	
Sr-SrO	.058	.069	.7		.058	.069	.7	
Rb-Rb_2O	.008	.009	.05		.009	.010	.05	
Mg-MgO	.008	.013	.3		.008	.013	.3	
		97.50				97.47		

TABLE A4 -Chemical analyses of plagioclase feldspars from the Mineral Range, Utah, in weight percent

Sample	3718P1-C				3719P1			
	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.
Si-SiO_2	29.60	63.32	1054		36.66	78.42	1305	65.39
Al-Al_2O_3	11.08	20.94	205.4		6.94	13.11	128.6	21.02
Fe-Fe_2O_3	.149	.213	1.3		.089	.127	.8	.204
Ca-CaO	1.94	2.71	48.3		.42	.59	10.5	.946
Na-Na_2O	7.06	9.52	153.6		4.72	6.36	102.6	10.20
K -K_2O	.861	1.04	11.0		.535	.644	6.8	1.03
Ba-BaO	.040	.045	.3		.013	.015	.1	.024
Sr-SrO	.062	.073	.7		.027	.032	.3	.051
Rb-Rb_2O	.033	.036	.19		.011	.012	.06	.019
Mg-MgO	.008	.013	.3		.011	.018	.4	.029
		97.91				99.33		98.91

Sample	3720P1				3721P1			
	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.
Si-SiO_2	29.87	63.90	1063	63.69	39.47	84.43	1405	78.81
Al-Al_2O_3	10.70	20.22	198.3	20.34	4.85	9.16	89.8	12.46
Fe-Fe_2O_3	.178	.254	1.6	.255	.064	.092	.6	.125
Ca-CaO	1.55	2.17	38.7	2.18	.43	.60	10.7	.82
Na-Na_2O	7.07	9.52	153.6	9.57	7.00	9.44	152.3	12.84
K -K_2O	.685	.825	8.8	.830	.360	.434	4.6	.590
Ba-BaO	.024	.027	.2	.027	.015	.017	.1	.023
Sr-SrO	.045	.053	.5	.053	.030	.035	.3	.048
Rb-Rb_2O	.008	.009	.05	.009	.010	.011	.06	.015
Mg-MgO	.012	.020	.5	.020	.012	.020	.5	.027
		97.00		96.97		104.24		105.76

TABLE A4-Chemical analyses of plagioclase feldspars from the Mineral Range, Utah, in weight percent

Sample	3722Pl				3723Pl			
	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.
Si-SiO_2	30.05	64.28	1070	63.62	30.76	65.80	1095	65.04
Al-Al_2O_3	10.41	19.67	192.9	20.03	10.11	19.10	187.3	19.53
Fe-Fe_2O_3	.155	.222	1.4	.226	.123	.176	1.1	.180
Ca-CaO	1.14	1.60	28.5	1.63	1.29	1.80	32.1	1.84
Na-Na_2O	7.06	9.52	153.6	9.69	7.27	9.80	158.1	10.02
K -K_2O	.780	.940	10.0	.957	.580	.699	7.4	.715
Ba-BaO	.019	.021	.1	.021	.016	.018	.1	.018
Sr-SrO	.038	.045	.4	.046	.036	.043	.4	.044
Rb-Rb_2O	.010	.011	.06	.011	.010	.011	.06	.011
Mg-MgO	.009	.015	.4	.015	.004	.066	1.6	.067
		96.32		96.25		97.52		97.47

Sample	3724Pl				3724Pl-A			
	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.
Si-SiO_2	30.17	64.54	1074		30.02	64.22	1069	
Al-Al_2O_3	10.43	19.71	193.3		10.37	19.59	192.1	
Fe-Fe_2O_3	.122	.174	1.1		.122	.174	1.1	
Ca-CaO	1.10	1.54	27.5		1.12	1.57	28.0	
Na-Na_2O	7.73	10.42	168.1		7.73	10.42	168.1	
K -K_2O	.599	.722	7.7		.608	.732	7.8	
Ba-BaO	.019	.021	.1		.018	.020	.1	
Sr-SrO	.036	.043	.4		.036	.043	.4	
Rb-Rb_2O	.012	.013	.07		.012	.013	.07	
Mg-MgO	.008	.013	.3		.008	.013	.3	
		97.19				96.79		

TABLE A4 -Chemical analyses of plagioclase feldspars from the Mineral Range, Utah, in weight percent

Sample	3724Pl-B				3724Pl-C			
	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.
Si-SiO_2	29.77	63.68	1060		29.65	63.43	1056	
Al-Al_2O_3	10.39	19.63	192.5		10.62	20.07	196.8	
Fe-Fe_2O_3	.123	.176	1.1		.131	.187	1.2	
Ca-CaO	1.11	1.55	27.6		1.11	1.55	27.6	
Na-Na_2O	7.73	10.42	168.1		7.73	10.42	168.1	
K -K_2O	.603	.726	7.7		.596	.718	7.6	
Ba-BaO	.016	.018	.1		.023	.026	.2	
Sr-SrO	.036	.043	.4		.045	.053	.5	
Rb-Rb_2O	.011	.012	.06		.037	.041	.22	
Mg-MgO	.008	.013	.3		.008	.013	.3	
		96.27				96.51		

Sample	3725Pl				3726Pl			
	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.
Si-SiO_2	35.12	75.13	1250	64.33	32.07	68.60	1142	63.05
Al-Al_2O_3	8.48	16.02	157.1	22.97	10.06	19.01	186.4	22.37
Fe-Fe_2O_3	.104	.149	.9	.214	.161	.230	1.4	.271
Ca-CaO	1.66	2.32	41.4	3.33	2.09	2.92	52.1	3.44
Na-Na_2O	4.59	6.19	99.9	8.88	5.36	7.22	116.5	8.50
K -K_2O	.786	.947	10.1	1.36	1.09	1.31	13.9	1.54
Ba-BaO	.058	.065	.4	.093	.100	.112	.7	.132
Sr-SrO	.109	.129	1.2	.185	.149	.176	1.7	.207
Rb-Rb_2O	.010	.011	.06	.016	.015	.016	.09	.019
Mg-MgO	.079	.131	3.2	.188	.027	.045	1.1	.053
		101.09		101.57		99.64		99.58

TABLE A4-Chemical analyses of plagioclase feldspars from the Mineral Range, Utah, in weight percent

Sample	3727Pl				3728Pl			
	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.
Si-SiO_2	29.18	62.42	1039		37.27	79.73	1327	63.61
Al-Al_2O_3	10.93	20.65	202.5		6.37	12.04	118.1	21.61
Fe-Fe_2O_3	.142	.203	1.3		.106	.152	1.0	.273
Ca-CaO	2.11	2.95	52.6		1.15	1.61	28.7	2.89
Na-Na_2O	7.37	9.93	160.2		3.79	5.10	82.3	9.15
K -K_2O	.603	.726	7.7		.479	.577	6.1	1.04
Ba-BaO	.025	.028	.2		.024	.027	.2	.048
Sr-SrO	.074	.088	.8		.053	.063	.6	.113
Rb-Rb_2O	.011	.012	.06		.013	.014	.07	.025
Mg-MgO	.037	.061	1.5		.025	.041	1.0	.074
		97.07				99.35		98.83

Sample	3729Pl				3730Pl			
	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.
Si-SiO_2	29.63	63.38	1055		37.83	80.93	1347	62.71
Al-Al_2O_3	10.96	20.71	203.1		6.38	12.08	118.5	23.62
Fe-Fe_2O_3	.153	.219	1.4		.102	.146	.9	.285
Ca-CaO	2.05	2.87	51.2		.92	1.29	23.0	2.52
Na-Na_2O	7.08	9.54	153.9		3.47	4.67	75.3	9.13
K -K_2O	.792	.954	10.1		.444	.535	5.7	1.05
Ba-BaO	.035	.039	.3		.025	.028	.2	.055
Sr-SrO	.072	.085	.8		.045	.053	.5	.104
Rb-Rb_2O	.016	.017	.09		.011	.012	.06	.023
Mg-MgO	.022	.036	.9		.012	.020	.5	.039
		97.85				99.74		99.54

TABLE A4 -Chemical analyses of plagioclase feldspars from the Mineral Range, Utah, in weight percent

Sample	3731P1			
	Atomic %	Oxide %	Mol. propns.	Oxide % recalcd.
Si-SiO_2	29.91	63.98	1065	
Al-Al_2O_3	10.70	20.22	198.3	
Fe-Fe_2O_3	.142	.203	1.3	
Ca-CaO	1.59	2.22	39.6	
Na-Na_2O	7.96	10.73	173.1	
K -K_2O	.944	1.14	12.1	
Ba-BaO	.031	.035	.2	
Sr-SrO	.055	.065	.6	
Rb-Rb_2O	.020	.021	.11	
Mg-MgO	.136	.225	5.6	
		98.84		

TABLE A5–Chemical analyses of alkali feldspars from the Mineral Range, Utah, in weight percent

Sample	3700Ks			3701Ks			3702Ks		
	Atomic %	Oxide %	Mol. propns.	Atomic %	Oxide %	Mol. propns.	Atomic %	Oxide %	Mol. propns.
Si-SiO_2	30.08	64.35	1071	29.03	62.10	1033	29.82	63.79	1062
Al-Al_2O_3	10.06	19.01	186.4	10.28	19.42	190.5	10.02	18.93	185.7
Fe-Fe_2O_3	.065	.093	.6	.063	.090	.6	.052	.074	.5
Ca-CaO	.162	.227	4.0	.199	.278	5.0	.150	.210	3.7
Na-Na_2O	1.63	2.19	35.3	.673	.91	14.7	1.36	1.83	29.5
K -K_2O	10.49	12.64	134.1	11.29	13.60	144.3	11.41	13.74	145.8
Ba-BaO	.189	.211	1.4	1.43	1.60	10.4	.183	.204	1.3
Sr-SrO	.031	.037	.36	.058	.069	.67	.031	.037	.36
Rb-Rb_2O	.075	.082	.4	.021	.023	.1	.027	.030	.2
Mg-MgO	.019	.031		.014	.023		.010	.017	
		98.87			98.11			98.86	

Sample	3703Ks			3704Ks			3705Ks		
	Atomic %	Oxide %	Mol. propns.	Atomic %	Oxide %	Mol. propns.	Atomic %	Oxide %	Mol. propns.
Si-SiO_2	30.07	64.33	1071	29.82	63.79	1062	29.15	62.36	1038
Al-Al_2O_3	10.02	18.93	185.7	10.05	18.99	186.2	10.14	19.16	187.9
Fe-Fe_2O_3	.061	.087	.5	.083	.119	.7	.116	.166	1.0
Ca-CaO	.117	.164	2.9	.186	.260	4.6	.261	.365	6.5
Na-Na_2O	1.59	2.15	34.7	3.74	5.04	81.3	2.23	3.00	48.4
K -K_2O	11.06	13.32	141.4	10.89	13.12	139.2	9.74	11.73	124.5
Ba-BaO	.171	.191	1.3	.312	.348	2.3	.392	.438	2.9
Sr-SrO	.040	.047	.45	.070	.083	.80	.069	.082	.79
Rb-Rb_2O	.055	.060	.3	.048	.052	.3	.051	.056	.3
Mg-MgO	.004	.007		.025	.041		.111	.184	
		99.29			101.84			97.54	

TABLE A5-Chemical analyses of alkali feldspars from the Mineral Range, Utah, in weight percent

Sample	3706Ks			3706Ks-A			3706Ks-B		
	Atomic %	Oxide %	Mol. propns.	Atomic %	Oxide %	Mol. propns.	Atomic %	Oxide %	Mol. propns.
Si-SiO_2	29.69	63.51	1057	29.51	63.13	1051	29.64	63.41	1055
Al-Al_2O_3	10.08	19.05	186.8	10.14	19.16	187.9	10.13	19.14	187.7
Fe-Fe_2O_3	.040	.057	.4	.041	.059	.4	.040	.057	.4
Ca-CaO	.100	.140	2.5	.099	.139	2.5	.095	.133	2.4
Na-Na_2O	2.08	2.80	45.2	2.08	2.80	45.2	2.08	2.80	45.2
K -K_2O	11.32	13.64	144.7	11.29	13.60	144.3	11.29	13.60	144.3
Ba-BaO	.160	.179	1.2	.155	.173	1.1	.158	.176	1.2
Sr-SrO	.038	.045	.43	.038	.045	.43	.038	.045	.43
Rb-Rb_2O	.056	.061	.3	.053	.058	.3	.056	.061	.3
Mg-MgO	.166	.275		.166	.275		.166	.275	
		99.76			99.44			99.70	

Sample	3706Ks-C			3708Ks (No 3707Ks)			3709Ks		
	Atomic %	Oxide %	Mol. propns.	Atomic %	Oxide %	Mol. propns.	Atomic %	Oxide %	Mol. propns.
Si-SiO_2	29.45	63.00	1048	29.62	63.36	1054	29.67	63.47	1056
Al-Al_2O_3	10.19	19.25	188.8	10.14	19.16	187.9	10.07	19.03	186.6
Fe-Fe_2O_3	.043	.061	.4	.082	.117	.7	.080	.114	.7
Ca-CaO	.099	.139	2.5	.119	.167	3.0	.164	.229	4.0
Na-Na_2O	2.08	2.80	45.2	1.23	1.66	26.8	1.79	2.42	39.0
K -K_2O	11.17	13.46	142.8	10.95	13.19	140.0	10.08	12.14	128.8
Ba-BaO	.164	.183	1.2	.213	.238	1.6	.152	.170	1.1
Sr-SrO	.042	.050	.48	.042	.050	.48	.045	.053	.51
Rb-Rb_2O	.068	.074	.4	.042	.046	.3	.048	.052	.3
Mg-MgO	.166	.275		.004	.007		.008	.013	
		99.29			98.00			97.69	

TABLE A5--Chemical analyses of alkali feldspars from the Mineral Range, Utah, in weight percent

Sample	3710Ks			3711Ks			3712Ks		
	Atomic %	Oxide %	Mol. propns.	Atomic %	Oxide %	Mol. propns.	Atomic %	Oxide %	Mol. propns.
Si-SiO_2	28.95	61.93	1031	29.84	63.83	1062	29.68	63.49	1057
Al-Al_2O_3	10.40	19.65	192.7	9.95	18.80	184.4	10.08	19.05	186.8
Fe-Fe_2O_3	.178	.254	1.6	.087	.124	.8	.095	.136	.9
Ca-CaO	.800	1.12	20.0	.186	.260	4.6	.255	.357	6.4
Na-Na_2O	1.75	2.36	38.1	2.64	3.55	57.3	1.28	1.72	27.8
K -K_2O	9.31	11.21	119.0	10.49	12.64	134.1	10.66	12.84	136.3
Ba-BaO	.564	.630	4.1	.222	.248	1.6	.343	.383	2.5
Sr-SrO	.111	.131	1.26	.063	.075	.72	.062	.073	.70
Rb-Rb_2O	.031	.034	.2	.024	.026	.1	.026	.028	.1
Mg-MgO	.043	.071		.169	.280		.013	.022	
		97.39			99.83			98.10	

Sample	3713Ks			3714Ks			3715Ks		
	Atomic %	Oxide %	Mol. propns.	Atomic %	Oxide %	Mol. propns.	Atomic %	Oxide %	Mol. propns.
Si--SiO_2	30.23	64.67	1076	30.04	64.26	1069	29.98	64.13	1067
Al-Al_2O_3	10.15	19.18	188.1	10.20	19.27	189.0	9.98	18.86	185.0
Fe-Fe_2O_3	.081	.116	.7	.074	.106	.7	.090	.129	.8
Ca-CaO	.138	.193	3.4	.161	.225	4.0	.104	.146	2.6
Na-Na_2O	2.21	2.98	48.1	2.25	3.03	48.9	2.08	2.80	45.2
K -K_2O	10.55	12.71	134.9	10.37	12.49	132.5	11.02	13.27	140.8
Ba--BaO	.152	.170	1.1	.169	.189	1.2	.156	.174	1.1
Sr--SrO	.044	.052	.50	.045	.053	.51	.033	.039	.38
Rb-Rb_2O	.059	.065	.3	.058	.063	.3	.099	.108	.6
Mg-MgO	.004	.007		.004	.007		.004	.007	
		100.14			99.69			99.66	

TABLE **A5**--Chemical analyses of alkali feldspars from the Mineral Range, Utah, in weight percent

Sample	3716Ks			3717Ks			3718Ks		
	Atomic %	Oxide %	Mol. propns.	Atomic %	Oxide %	Mol. propns.	Atomic %	Oxide %	Mol. propns.
Si-SiO_2	30.02	64.22	1069	30.17	64.54	1074	29.81	63.77	1061
Al-Al_2O_3	9.97	18.84	184.8	9.95	18.80	184.4	9.89	18.69	183.3
Fe-Fe_2O_3	.096	.137	.9	.099	.142	.9	.103	.147	.9
Ca-CaO	.104	.146	2.6	.137	.192	3.4	.141	.197	3.5
Na-Na_2O	2.05	2.77	44.7	4.34	5.85	94.4	2.68	3.61	58.2
K -K_2O	10.95	13.19	140.0	11.07	13.33	141.5	9.72	11.71	124.3
Ba-BaO	.157	.175	1.1	.135	.151	1.0	.130	.145	1.0
Sr-SrO	.032	.038	.37	.030	.035	.34	.029	.034	.33
Rb-Rb_2O	.107	.117	.6	.107	.117	.6	.058	.063	.3
Mg-MgO	.004	.007							
		99.64			103.16			98.37	

Sample	3718Ks-A			3718Ks-B			3718Ks-C		
	Atomic %	Oxide %	Mol. propns.	Atomic %	Oxide %	Mol. propns.	Atomic %	Oxide %	Mol. propns.
Si-SiO_2	29.69	63.51	1057	29.59	63.30	1053	29.59	63.30	1053
Al-Al_2O_3	10.14	19.16	187.9	10.06	19.01	186.4	10.09	19.07	187.0
Fe-Fe_2O_3	.105	.150	.9	.103	.147	.9	.107	.153	1.0
Ca-CaO	.145	.203	3.6	.145	.203	3.6	.149	.208	3.7
Na-Na_2O	2.68	3.61	58.2	2.68	3.61	58.2	2.68	3.61	58.2
K -K_2O	9.70	11.68	123.9	9.66	11.64	123.5	9.60	11.56	122.7
Ba-BaO	.130	.145	1.0	.132	.147	1.0	.141	.157	1.0
Sr-SrO	.028	.033	.32	.029	.034	.33	.034	.040	.39
Rb-Rb_2O	.055	.060	.3	.057	.062	.3	.069	.075	.4
Mg-MgO									
		98.55			98.15			98.17	

TABLE A5 -Chemical analyses of alkali feldspars from the Mineral Range, Utah, in weight percent

Sample	3719Ks			3720Ks			3721Ks		
	Atomic %	Oxide %	Mol. propns.	Atomic %	Oxide %	Mol. propns.	Atomic %	Oxide %	Mol. propns.
Si-SiO_2	30.02	64.22	1069	29.75	63.64	1059	30.20	64.60	1075
Al-Al_2O_3	9.94	18.78	184.2	9.97	18.84	184.8	9.94	18.78	184.2
Fe-Fe_2O_3	.090	.129	.8	.108	.154	1.0	.090	.129	.8
Ca-CaO	.080	.112	2.0	.164	.229	4.1	.068	.095	1.7
Na-Na_2O	3.94	5.31	85.7	3.16	4.26	68.7	4.44	5.98	96.5
K -K_2O	10.47	12.61	133.8	9.33	11.24	119.3	10.28	12.38	131.4
Ba-BaO	.007	.008	.1	.086	.096	.6	.012	.013	.1
Sr-SrO	.008	.009	.09	.023	.027	.26	.009	.011	.11
Rb-Rb_2O	.196	.214	1.1	.071	.078	.4	.195	.213	1.1
Mg-MgO									
		101.39			98.56			102.20	

Sample	3722Ks			3723Ks			3724Ks		
	Atomic %	Oxide %	Mol. propns.	Atomic %	Oxide %	Mol. propns.	Atomic %	Oxide %	Mol. propns.
Si-SiO_2	29.82	63.79	1062	29.86	63.88	1063	29.87	63.90	1063
Al-Al_2O_3	9.87	18.65	182.9	9.90	18.71	183.5	9.97	18.84	184.8
Fe-Fe_2O_3	.104	.149	.9	.103	.147	.9	.096	.137	.9
Ca-CaO	.110	.154	2.7	.096	.134	2.4	.109	.153	2.7
Na-Na_2O	2.62	3.54	57.1	2.50	3.37	54.4	2.48	3.34	53.9
K -K_2O	9.82	11.83	125.5	9.74	11.73	124.5	9.74	11.73	124.5
Ba-BaO	.056	.063	.4	.040	.045	.3	.039	.044	.3
Sr-SrO	.015	.018	.17	.014	.017	.16	.013	.015	.14
Rb-Rb_2O	.159	.174	.9	.166	.182	1.0	.196	.214	1.1
Mg-MgO									
		98.37			98.22			98.37	

TABLE A5-Chemical analyses of alkali feldspars from the Mineral Range, Utah, in weight percent

Sample	3725Ks			3726Ks			3727Ks		
	Atomic %	Oxide %	Mol. propns.	Atomic %	Oxide %	Mol. propns.	Atomic %	Oxide %	Mol. propns.
Si-SiO_2	29.64	63.41	1055	29.43	62.96	1048	29.63	63.38	1055
Al-Al_2O_3	10.06	19.01	186.4	10.32	19.50	191.3	10.09	19.07	187.0
Fe-Fe_2O_3	.081	.116	.7	.092	.132	.8	.100	.143	.9
Ca-CaO	.213	.298	5.3	.208	.291	5.2	.194	.271	4.8
Na-Na_2O	2.09	2.81	45.3	1.95	2.62	42.3	1.92	2.59	41.8
K -K_2O	10.21	12.30	130.5	10.45	12.59	133.6	10.58	12.74	135.2
Ba-BaO	.422	.471	3.1	.421	.470	3.1	.185	.207	1.4
Sr-SrO	.083	.098	.95	.079	.093	.90	.040	.047	.45
Rb-Rb_2O	.056	.061	.3	.080	.087	.5	.164	.179	1.0
Mg-MgO									
		98.57			98.74			98.63	

Sample	3728Ks			3729Ks			3730Ks		
	Atomic %	Oxide %	Mol. propns.	Atomic %	Oxide %	Mol. propns.	Atomic %	Oxide %	Mol. propns.
Si-SiO_2	29.83	63.81	1062	29.67	63.47	1056	29.84	63.83	1062
Al-Al_2O_3	10.03	18.95	185.9	10.08	19.05	186.8	10.12	19.12	187.5
Fe-Fe_2O_3				.095	.136	.9	.102	.146	.9
Ca-CaO	.132	.185	3.3	.147	.206	3.7	.147	.206	3.7
Na-Na_2O	1.66	2.24	36.1	1.96	2.64	42.6	2.05	2.77	44.7
K -K_2O	11.06	13.32	141.4	10.68	12.87	136.6	10.49	12.64	134.1
Ba-BaO	.199	.222	1.4	.185	.207	1.4	.138	.154	1.0
Sr-SrO	.041	.048	.46	.039	.046	.44	.030	.035	.34
Rb-Rb_2O	.158	.173	.9	.148	.162	.9	.085	.093	.5
Mg-MgO									
		98.95			98.79			98.99	

TABLE A5--Chemical analyses of alkali feldspars from the Mineral Range, Utah, in weight percent

Sample	3731Ks			3731Ks-A			3731Ks-B		
	Atomic %	Oxide %	Mol. propns.	Atomic %	Oxide %	Mol. propns.	Atomic %	Oxide %	Mol. propns.
Si-SiO_2	30.00	64.18	1068	29.68	63.49	1057	29.77	63.68	1060
Al-Al_2O_3	10.14	19.16	187.9	10.02	18.93	185.7	10.03	18.95	185.9
Fe-Fe_2O_3	.095	.136	.9	.096	.137	.9	.095	.136	.9
Ca-CaO	.125	.175	3.1	.135	.189	3.4	.129	.180	3.2
Na-Na_2O	2.07	2.79	45.0	2.07	2.79	45.0	2.07	2.79	45.0
K -K_2O	10.60	12.77	135.5	10.58	12.74	135.2	10.53	12.68	134.6
Ba-BaO	.125	.140	.9	.122	.136	.9	.125	.140	.9
Sr-SrO	.026	.031	.30	.026	.031	.30	.026	.031	.30
Rb-Rb_2O	.190	.208	1.1	.188	.206	1.1	.190	.208	1.1
Mg-MgO									
		99.59			98.65			98.80	

Sample	3731Ks-C		
	Atomic %	Oxide %	Mol. propns.
Si-SiO_2	29.73	63.60	1058
Al-Al_2O_3	10.18	19.24	188.7
Fe-Fe_2O_3	.098	.140	.9
Ca-CaO	.133	.186	3.3
Na-Na_2O	2.07	2.79	45.0
K -K_2O	10.49	12.64	134.1
Ba-BaO	.128	.143	.9
Sr-SrO	.033	.039	.38
Rb-Rb_2O	.181	.198	1.1
Mg-MgO			
		98.98	

TABLE A6-Samples corrected for Na_2O

Sample	3704Pl Corr. Oxide %	3704Pl Corr. Mol. propns.	3704Pl Oxide % Recalcd.	3717Pl Corr. Oxide %	3717Pl Corr. Mol. propns.	3717Pl Oxide % Recalcd.	3721Pl Corr. Oxide %	3721Pl Corr. Mol. propns.	3721Pl Oxide % Recalcd.
SiO_2			64.90			64.48			65.73
Al_2O_3			22.74			22.24			20.16
Fe_2O_3			.221			.261			.203
CaO			3.63			3.36			1.32
Na_2O	7.00	112.9	8.44	5.87	94.7	9.38	4.62	74.5	10.17
K_2O			2.05			.667			.955
BaO			.051			.045			.037
SrO			.134			.104			.077
Rb_2O			.016			.014			.024
MgO			.168			.016			.044
			102.35			100.57			98.72
Wt. % An÷(An+Ab)			20.1			17.3			7.1
Mol. % An			17.3			16.1			6.5
Mol. % Ab			71.2			80.1			88.0
Mol. % Or			11.5			3.9			5.6
+ or - SiO_2			+24.07			+48.15			+64.63
% quartz in sample as calcd. from anal.			+17.06			+37.45			+54.57

	Corr. Na_2O %	Corr. Mol. propns.	Corr. oxide total	Mol. % An	Mol. % Ab	Mol. % Or	+ or - SiO_2	% quartz in sample as calcd. from anal.
3704Ks	2.46	39.7	99.26	1.5	21.7	76.8	-2.73	-1.74
3717Ks	2.39	38.6	99.70	1.0	21.1	77.9	-1.86	-1.20
3721Ks	3.14	50.7	99.36	.5	27.5	72.0	-2.60	-1.68

Wt. % feldspar

	Or	Ab	An	(Ba)	(Sr)	(Rb)	Total
3704Ks	77.54	20.82	1.29	.85	.26	.18	100.94
3717Ks	78.78	20.22	.95	.37	.11	.41	100.84
3721Ks	73.16	26.57	.47	.03	.04	.74	101.01

APPENDIX B - PETROGRAPHY OF SAMPLES FROM THE MINERAL RANGE

3700

F- Biotite schist; a few thin pegmatites cut the foliation.

Pl- 1/2 to 2, equant to elongate, sub- to anhedral, weakly or unzoned grains with fine polysynthetic twinning. Some crystals are fractured and many have bent twin lamellae.

Af- 1/2 to 1 1/2, equant, anhedral grains with weak development of p-plag and grid-twinning. Some grains show good patchy grid development and some show well developed p-plag. Mortar structure is common around the feldspar.

Qz- 1/4 to 1, equant, anhedral grains commonly showing undulatory extinction and sutured boundaries.

Bi- 8%. 1/8 to 1 1/2, ragged, interstitial biotite interpenetrating with muscovite (8%) of similar size, shape, and occurrence. Both micas commonly bent and may also occur as discrete grains or within fractures in the feldspars. X = pale brown; Y = Z = dark brown.

Name-Quartz-feldspar-mica schist.

F-Field description; Pl-Plagioclase; Af-Alkali feldspar; Qz-Quartz; Bi-Biotite; Hn-Hornblende; Acc-Accessories; P-plag is the Ab phase of the alkali feldspars.

The fractions or whole numbers introducing grain descriptions refer to grain size and are in millimeters. Underlining indicates relative dominance. All zoning is normal unless otherwise specified. Mineral percentages given are obtained by visual estimate. The rock name is derived from consideration of percent total dark minerals, An content of plagioclase, ratio of modal plagioclase to alkali feldspar, and microscopic texture according to Williams, Turner, and Gilbert (1955) and Peterson (1965).

Petrography-Continued

3701
F- Schistose gneiss layer which grades into 3700 and 3702.

Pl- 1/2 to 3, equant to elongate, sub- to anhedral, weakly or unzoned distinctly fractured grains with polysynthetic twinning. Wedge, discontinuous twinning common and may be most frequent along grain edges. Subrounded grains common.

Af- Minor. 1 to 10, equant to elongate, anhedral grains with splotchy extinction, minor p-plag, and indistinct or no grid twinning.

Qz- 1/10 to 2, irregularly shaped interstitial grains with highly undulatory extinction and sutured boundaries.

Bi- 8%. Interstitial ragged shreds, flakes, or clusters. X = brown, reddish brown, or greenish brown. Y = Z = dark green.

Acc- Ragged interstitial grains of hornblende; may occur intimately mixed with biotite. X = pale brown, Y = brownish green, Z = dark bluish green. Interstitial and included sphene, epidote, iron ore, apatite, and zircon.

Remarks-Well developed foliation results from segregation of light from dark minerals. Mortar texture common.

Name-Quartz diorite.

3702
F- Schistose gneiss somewhat finer-grained and lighter in color than 3701.

Pl- 1/2 to 2, equant to slightly elongate, anhedral, unzoned or weakly zoned grains. Twinning is polysynthetic but may or may not be developed. Many grains include a few, subrounded quartz grains and biotite shreds.

Af- 1/2 to 2, equant to slightly elongate, anhedral, untwinned grains with slightly undulatory to splotchy extinction. Weakly or non perthitic. Grid twinning is uncommon and poorly developed but some grains show differential grid development. Many grains contain a few subrounded, small quartz inclusions.

Qz- 1 or less, irregularly shaped, elongate, anhedral interstitial grains commonly showing undulatory extinction and sutured boundaries.

Bi- 5% or less. 1/4, interstitial shreds. X = pale greenish brown; Y = Z = dark brownish green.

Acc- Green chlorite associated with biotite; interstitial and included sphene and zircon.

Remarks-Foliation results from subparallel, elongate feldspars and quartz and subparalled zones of unaligned biotite grains. Mortar structure parallel to the foliation is commonly developed along the long dimension of the feldspar grains.

Name-Quartz-feldspar-biotite gneiss.

3703

F- Weakly foliated gneiss. A few thin pegmatites cut the foliation.

Pl- 1 to 3 and 4 to 8, equant to elongate, eu- to anhedral, weakly to strongly zoned grains with spongy, irregular boundaries. The cores of the strongly zoned grains are more highly altered than the weakly zoned grains. Many grains are partly enclosed with alkali feldspar and most contacts between plagioclase and alkali feldspar are irregular and protruding. Polysynthetic twinning is common and twins are commonly bent. Antiperthitic.

Petrography-Continued

3703-Continued

Af- 2 to 6, equant to elongate, anhedral grains with very irregular and protruding boundaries. Grid twinning common but not dominant. Many grains include plagioclase and minor small, subrounded or irregular quartz grains. Grain contacts between plagioclase (included or otherwise) are frequently myrmekitic, vermiculitic, or interpenetrating. Perthite generally not strongly developed.

Qz- 1 or less, irregularly shaped to equant, interstitial grains with undulatory extinction and sutured boundaries. Large mosaic grains or grain clusters occur.

Bi- 5%. 1 or less, interstitial or included plates and shreds. X = pale brown; Y = Z = dark greenish brown.

Acc- Chlorite associated with biotite; interstitial and included sphene, iron ore, and zircon.

Name-Porphyritic adamellite or alaskite.

3704

F- Schistose gneiss.

Pl- 1 to 2 1/2, elongate, sub- to euhedral, zoned, highly altered (epidote, dust, sericite), twinned (polysynthetic and Carlsbad) grains. Twin lamellae and some grains are bent or more rarely broken.

Af- 1 to 2, equant to elongate, anhedral grains with little or no p-plag. Grid in many grains preferentially developed at boundaries or near cracks, but generally absent. Many grains have undulatory extinction. Grains are clean and clear relative to plagioclase. Vermiculitic and myrmekitic texture commonly developed between alkali feldspars and between alkali feldspars and plagioclase.

Petrography-Continued

3704-Continued
Qz- 1 or less, equant to irregular, anhedral grains with weak undulatory extinction. Locally large clusters with internal sutured boundaries occur.

Mafics-5 to 10%. Hornblende-1/2 to 2, subhedral, ragged grains. May be weakly aligned. X = Y=pale brown; Z = dark green. Biotite-1/4 to 1, ragged shreds and plates. Amount biotite slightly lower than hornblende. X = very light brown; Y = Z = very dark brown.

Acc- Green chlorite interpenetrating with biotite and commonly associating with or enclosing sphene, epidote granules, and iron ore. Accessories generally interstitial but locally included in feldspars. The dark minerals provide a very weak foliation.

Name-Trondhjemite.

3705
F- Amphibolite layer with abrupt or gradational contact with 3704. Locally, nonfoliated granide protrudes from the gneiss into the amphibolite.

Pl- 1/4 to 1, equant to elongate, sub- to anhedral, weakly to unzoned, well twinned, commonly angular grains with long axis subparallel to foliation. Twinning is fine polysynthetic and simple consisting of only a few individuals. Many grains show two and three types of twinning.

Af- Minor - 2, equant to elongate, anhedral grains with little or no p-plag and generally no grid development. A few grains may have vaguely developed grid twinning. Nearly all the alkali feldspar found is in a discontinuous segregation layer with few mafic minerals. A few small pieces occur in spongy contact with plagioclase.

3705-Continued

Qz- 1/2, irregular to elongate shape, generally interstitial grains. Long axis commonly subparallel to foliation. Plagioclase and quartz host many transparent acicular inclusions.

Hn- 30%. 1/8 to 3/4, elongate, subhedral, aligned grains producing a good foliation. Inclusions of small subrounded quartz and plagioclase grains common but not abundant in any given hornblende grain. X = pale brown; Y = dark green; Z = dark bluish green.

Acc- Biotite-shreds nearly always interpenetrating with green chlorite which is more abundant. X = pale brown; Y = Z = dark brown. Calcite, sphene, iron ore, and epidote. A few transverse fractures cross foliation and contain "vein alkali feldspar", and the named accessories.

Name--Amphibolite.

3706

F- Massive granide[1] between schists 3705 and 3707. Sample taken at contact with 3707. Contact with 3707 is abrupt where observed.

Pl- 1 to 2, equant to elongate, eu- to anhedral, weakly to well zoned, polysynthetically twinned grains. Contacts with alkali feldspar grains are very spongy and irregular, myrmekitic, or vermiculitic. A few large (6mm) grains occur. Some antiperthitic.

Af- 2 to 5, equant to elongate, anhedral, weakly perthitic (stringlet) grains with no or indistinct grid development. Many grains contain small, locally aligned, zoned plagioclase. Plagioclase-alkali feldspar contacts are notably spongy.

Qz- 1, irregular to equant, anhedral, interstitial grains with undulatory extinction. Clusters of grains with sutured boundaries are common.

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[1] 1-Terminology of Johannsen (1939, p. 56).

3706-Continued

Bi- 5%. Interstitial shreds, some bent, up to 2mm long. Some are wholly or partly included in the feldspars. X = pale brown; Y = Z = dark orange brown or dark brown.

Acc- Muscovite occurs along cracks in feldspars and interpenetrating with biotite. Zircon included in biotite.

Name-Porphyritic alaskite.

3707

F- Well foliated mica schist in abrupt contact with 3706 gneiss to the west and in irregular contact with gneiss to the east. The gneiss to the east contains many broken inclusions of the mica schist.

Pl- 1/4 to 1/2, irregularly shaped, anhedral grains with interpenetrating boundaries. Zoning is well- to undeveloped. Twinning is polysynthetic when present. Grains generally broken; vermiculitic quartz inclusions are common, and splotchy extinction common. Layers of plagioclase and quartz segregated from muscovite-biotite-sillimanite layers.

Af- Similar in size and shape to plagioclase. No grid development but string perthite is not uncommon. Many alkali feldspar-like grains not positively identified interpenetrating with muscovite.

Qz- 1/8 to 1/2, irregularly shaped, anhedral grains with undulatory extinction. Some large clusters (1mm) of grains with sutured contacts occur. Quartz is generally segregated with plagioclase and alkali feldspar.

Bi- 5 to 10%. Shreds and ragged plates up to 1mm. Most commonly interpenetrating with muscovite. X = pale brown; Y = Z = orange brown.

Petrography-Continued

3707-Continued

Ms- 50%. 1 or less, subhedral plates and books, commonly including quartz, feldspar, or iron ore. Muscovite and biotite plates are commonly in plane of foliation but may also be transverse.

Sillimanite-5% or less, gray fibrolite-like sheaves subparallel to foliation. Sheaves occur only intermixed with muscovite or biotite. A few distinct grains occur also but are most commonly associated with muscovite.

Iron ore-1%. Very small, anhedral and euhedral disseminated grains and trails subparallel to foliation.

Note-All the minerals commonly have mutually interpenetrating contacts.

Name-Sillimanite-mica-feldspar schist.

3708

F- Sample taken about 20 feet east of 3707. The outcrop contains many broken pieces of mica schist 3707.

Pl- 1/2 to 1 1/2, rarely 3, equant to elongate, an- to sub- to euhedral, weakly or non-zoned grains, many with low frequency twinning, polysynthetic or simple. Many grains highly altered (mica and dust) and have interpenetrating contacts with other grains, but others are clear and have sharp contacts. Some grains are antiperthitic.

Af- 1 to 2, equant to elongate, subhedral grains. Grid twinning very uncommon but distinct when developed; perthite very weakly developed. Grains may occur in sharp contact with plagioclase and quartz, with quartz only, or enclosing or protruding into plagioclase grains. Inclusions of zircons, iron ore, and small plagioclase grains, and myrmekitic borders are common.

Petrography-Continued

3708-Continued

Qz- 1, irregularly shaped, interstitial grains. Clusters of sutured quartz grains up to 5mm in diameter comprise much of the quartz present.

Bi- 10 to 15%. Some occur as disseminated interstitial plates or shreds. Most occur in layers in schistose parts of the rock associated with anhedral, locally altered, interpenetrating feldspars. The schistose parts in outcrop appear to be broken inclusions of 3707 but little muscovite or sillimanite is present in thin section. X = pale brown; Y = Z = orange brown.

Acc- Iron ore occurs mainly in schistose part of rock; needles of sillimanite (?) in plagioclase in schistose part of rock. Muscovite interpenetrating with biotite or less commonly in fractures in feldspars.

Name-Granodioritic rock mixed with biotite schist.

3709

F- Massive granide.

Pl- 1 to 2, a few up to 4, equant, sub- to euhedral, weakly zoned, commonly altered grains (brown dust and sericite) with fine polysynthetic twinning. Commonly spongy or myrmekitic contacts with alkali feldspar. Twins are bent in many grains.

Af- 1 to 5, a few up to 8, equant to elongate, subhedral grains. P-plag ranges from 0 to about 10% of grain area and may be fine (stringlet) or coarse (up to .1mm beads or distinct grains). P-plag granules are common between and at grain boundaries or twin boundaries. One grain is partly jacketed by unzoned plagioclase. Spongy contacts between plagioclase and alkali feldspar are common. Some alkali feldspars show zonal extinction and lower percent of p-plag near stringers than within grain. Grid twins generally not well developed but are distinct, though patchy, in some grains. Splotchy extinction is common. Small inclusions of zoned, rimmed, and unzoned plagioclase grains are common. Mortar structure is developed around many of the feldspar grains.

Petrography-Continued

3709-Continued

Qz- 1/4 to 1/2, irregularly shaped, anhedral, interstitial grains with undulatory extinction. Locally, large interstitial clusters of irregularly shaped grains occur.

Acc- Less than 5%. Interstitial biotite and interpenetrating green chlorite shreds in association with sphene euhedra, iron ore, zircon and epatite. Locally an accessory may be included within feldspar.

Name-Porphyritic alaskite.

3710

F- Dark rock layer about 200 feet thick outcropping within granide.

Pl- 1 to 2, elongate, subhedral, highly embayed, strongly zoned grains with polysynthetic twinning. Many grains fractured and broken. Alteration (preferentially of cores) to sericite is common.

Af- Minor. 1/2 to 1, a few grains up to 3mm, irregularly shaped, anhedral, non perthitic grains. Grid twinning present indistinctly in a few grains, otherwise not developed. Grains occur commonly partly enclosing plagioclase grains. Equant, interstitial grains are uncommon.

Qz- Minor. Irregularly shaped, anhedral, interstitial grains less than 1/4mm.

Hn- 40%. 1/2 to 1, elongate, sub- to anhedral grains commonly associated with or including sphene and magnetite euhedra; less commonly including subrounded quartz and plagioclase. X = pale brown; Y = Z = dark green. Some grains have Y = Z = bluish green along edges.

Acc- Brown biotite interpenetrating with green chlorite; sphene, iron ore, zircon, and apatite are most commonly associated with biotite.

Petrography-Continued

3710-Continued
A few fractures containing fine grained anhedra of feldspar and acicular hornblende parallel to fracture are present.

Name-Diorite.

3711
F- Granide in contact with eastern side of 3710. Several thin aplitic dikes cut across the outcrop.

Pl- 1 to 3, equant to elongate, sub- to anhedral, moderately well, or unzoned finely polysynthetically twinned grains. Grains are commonly fractured, have splotchy extinction, and generally are in spongy contact with alkali feldspar. Weakly or unzoned plagioclase partly jackets alkali feldspar and has same extinction as the included p-plag. Some grains are antiperthitic. A few grains are highly altered to sercite-like material in the central part.

Af- 2 to 4, rarely 6 to 8, equant to elongate, anhedral, perthitic (string, braid or grain p-plag) grains commonly with weak grid development. Carlsbad twins common. Splotchy extinction is common. Spongy contacts with plagioclase are common. Many grains include small, equant and elongate, zoned or unzoned plagioclase grains. Many of the plagioclase inclusions contain beads of quartz and are thinly rimmed with albite. Most of the feldspars contain many dusty inclusions.

Qz- Most of the quartz occurs in clusters between the feldspars. The clusters are about 5mm in diameter and include 1mm grains commonly with sutured boundaries, undulatory extinction, and mosaic structure. Quartz less commonly occurs intergrown with alkali feldspar.

Bi- 5% or less. 1 or less, ragged plates, occurring most commonly in clusters between the feldspars. Rarely biotite occurs in alkali feldspar fractures. X = pale brown or yellow-brown; Y = Z = dark green or orange green.

3711-Continued

Acc- Sphene euhedra, zircon, apatite and anhedral iron ore most commonly associated with the biotite clusters. Rarely do the accessories occur as inclusions. Green chlorite is minor but occurs interpenetrating with biotite.

Name-Porphyritic alaskite.

3712

F- Schist within granide containing subhedral feldspars which subparallel the schistosity.

Pl- 1/4 to 2, rarely larger, most commonly anhedral, irregularly shaped, highly embayed, fractured grains. The larger grains are commonly elongate, subhedral. Polysynthetic twinning and strong zoning are common. Spongy, interlocking grain contacts are common. Acicular, transparent inclusions are plentiful and small biotite plates are included in many grains. Many grains show splotchy extinction and core boundaries are commonly highly irregular. Euhedral oscillatory zoning and preferentially altered cores are developed in some grains. Many grains antiperthitic.

Af- Minor. Most commonly less than 1mm. In outcrop up to 20mm. Interstitial, or interlocking anhedral grains with very weak perthite development. Grid twinning is rare and where distinct is of local development in a given grain. Many grains show undulatory extinction.

Qz- Minor. 1/4 to 1/2, irregularly shaped, anhedral, interstitial and interlocking grains commonly with undulatory extinction and mosaic structure. Streaks of connected quartz grains also occur.

Bi- 15%. Sub-oriented, ragged, commonly bent, interstitial or interlocking plates up to 1 1/2mm. Concentrated in subparallel zones associated with fine grained angular feldspar and quartz. X = pale brown or pale yellow brown; Y = Z = dark green or orange green.

Petrography-Continued

3712-Continued

Acc- Green hornblende, zircon, sphene, apatite, tourmaline, and acicular, transparent needles occur most commonly as inclusions in the feldspars or biotite. A few hornblende and sphene grains are interstitial.

Name-Adamellite.

3713

F- Massive granide; large feldspar grains are locally aligned.

Pl- 1 to 2 1/2, elongate to equant, subhedral, moderately well zoned, polysynthetically twinned grains. Irregular contacts with alkali feldspar common. Preferential alteration of core to sericite-like material common.

Af- 2 to 6, some up to 10, equant to elongate, sub- to anhedral, moderately perthitic (string, patch, vein, grain) grains commonly with weak grid twinning. Fine grained inclusions of zoned or rimmed and unzoned equant plagioclase are common, especially in the grain boundaries. Larger elongate, commonly embayed, weakly zoned or unzoned, twinned plagioclase grains are partly or wholly included and may parallel the grain boundary. Percent p-plag in some grains is lower near the boundaries than within. Weak grid twinning is preferentially developed near boundaries of a few grains. Mortar-like structure developed around some grains. Several Baveno twins present.

Qz- 1/4 to 1, anhedral, interstitial grains commonly showing undulatory extinction. May occur in clusters.

Bi- Less than 5%. 1/4 to 1, subhedral, interstitial flakes. Most commonly occurs in interstitial clusters of several grains. X = pale brown or pale yellowish brown; Y = Z = dark green or orange green.

3713-Continued

Acc- Sphene, iron ore, apatite and zircon commonly occur with biotite but some is included in feldspars. Apatite most commonly occurs included in biotite.

Note-Visual estimates suggest that plagioclase (exclusive of albite phase of alkali feldspar) comprises less than 1/3 of the total feldspar. Modal analyses suggests 1/2.

Name-Porphyritic alaskite.

3714

F- Granide

Pl- 1/2 to 2, rarely 4 or more, equant to elongate, subhedral, moderately well zoned, polysynthetically twinned grains. Many are altered somewhat to sericite, may be antiperthitic, and have undulatory or splotchy extinction.

Af- 3 to 8, some up to 15, elongate, sub- to anhedral, weakly to distinctly grid-twinned, commonly highly perthitic (stringlet, string, vein, patch, grain) grains. Grid locally preferentially developed along grain boundaries. A few grains with coarse grain p-plag are partly enclosed with unzoned plagioclase with same extinction as p-plag. Grain p-plag in coarse perthite (p-plag .1 to .2mm) is associated with or more commonly includes small irregular or beadlike grains of quartz with even extinction. Weakly zoned or unzoned, elongate, spongy or embayed plagioclase grains are not uncommonly included near grain boundary; some are aligned parallel to grain boundary.

Qz- 1 to 3, equant, anhedral, interstitial grains with undulatory extinction. Much of the quartz occurs in clusters of several grains with sutured boundaries. Some grains have mosaic structure and show a very weak grid pattern similar to but much finer than microcline grid.

Petrography-Continued

3714-Continued

Bi- 5% or less. Shreds or subhedral plates up to 1mm commonly occurring as interstitial clusters. Some is partly included in alkali feldspars. Apatite inclusions not uncommon. X = pale brown or pale yellow brown; Y = Z = dark green or orange green.

Acc- Sphene euhedra, iron ore, apatite, and zircon commonly associated with biotite but may occur as discrete interstitial grains or inclusions in alkali feldspars.

Name-Porphyritic alaskite.

3715

F- Massive granide.

Pl- 1 to 2, rarely 4 to 6, equant to elongate, subhedral, strongly zoned, polysynthetically twinned grains. Zoning and twinning uneven and discontinuous in many grains but euhedral oscillatory zoning occurs in many grains. Alteration (sericite, dust, minor biotite) is noticeable and commonly preferentially developed in cores. Antiperthitic.

Af- 1/2 to 1 1/2, equant to elongate, anhedral, interstitial and commonly interlocking grains. Grid twinning is commonly weakly and unevenly developed. String and vein (less common) perthite well developed. Very large grains up to 15mm are not uncommon in hand specimen. Microscopically these grains may be partly zoned, include highly embayed, zonally arranged, weakly or unzoned plagioclase. Stringers of small subrounded quartz grains occur near to and parallel the borders. Plumose p-plag with indefinite polysynthetic twinning up to 1/4mm thick is common at grain contacts of small alkali feldspars.

Qz- 1/2 to 2, equant, anhedral, interstitial grains. Undulatory extinction and well developed mosaic structure is common. Arms of the uniaxial interference figure are commonly offset. A few small bipyramidal subhedra occur.

Petrography-Continued

3715-Continued

Bi- 5 to 10%. Interstitial shreds and subhedral plates. May occur in clusters. Commonly includes sphene. X = pale orange brown; Y = Z = orange brown.

Acc- Green hornblende granules, sphene (commonly euhedral), apatite (commonly included in biotite), and zircon.

Name-Porphyritic alaskite or adamellite.

3716

F- Massive granide.

Pl- 1/2 to 2, rarely 3 or more, equant to elongate, sub- to anhedral, strongly zoned grains with altered cores and polysynthetic twinning. Zoning is commonly euhedral and oscillatory. Cores commonly have uneven extinction, and include iron ore and transparent acicular grains. A few "grains" contain cores which are isolated by more sodic material and have similar extinction positions, or connecting cores with different extinction positions. Rarely, jackets of euhedrally zoned plagioclase partly enclose large alkali feldspar. Extinction of the jackets seldom coincides with p-plag of the alkali feldspar. Euhedral oscillatory zoning is not uncommon in the jackets.

Af- Less than 2, irregularly shaped interlocking, or equant interstitial, anhedral grains with weak to well developed perthite (stringlet, string, vein). Grid twinning is weakly or not developed. Plumose p-plag with indefinite, discontinuous polysynthetic twinning is common at grain or large twin boundaries. The host grain may have weak or well developed perthite texture. Large grains up to 8mm are not uncommon. These grains have strongly developed perthite, are commonly zoned, contain embayed, elongate, zoned and unzoned plagioclase paralleling the boundary and have distinct grid twinning. Percent p-plag is relatively lower at rim but grid twinning is commonly better developed at the rim of these large grains.

Petrography-Continued

3716-Continued

Qz- 1/2 to 2 1/2, rarely 5 or more, irregularly shaped to equant anhedral, interstitial and interlocking grains. Many grains have well developed mosaic structure and all have undulatory extinction. Some are surrounded by thin wisps of alkali feldspar. Very fine grid developed in many grains.

Bi- 5% or less. 1 or less, disseminated, interstitial or partly included shreds. Some subhedral plates. X = pale orange brown or pale brown; Y = Z = orange brown to dark green.

Acc- Sphene, apatite, and iron ore associated with biotite and included preferentially in plagioclase. Iron ore most commonly magnetite euhedra.

Name-Porphyritic alaskite.

3717

F- Sample from zone gradational with, but finer grained than massive granide.

Pl- 1/2 to 2, rarely 3 or more, elongate, sub- to euhedral, strongly zoned, polysynthetically twinned grains commonly showing preferential alteration of cores. Euhedral oscillatory zoning is common. Some relatively highly altered zones (sericite and dust), contain transparent acicular inclusions and iron ore, and may have uneven extinction.

Af- 2 or less, rarely 10 or more, irregularly shaped to equant, interstitial interlocking grains with weak to well developed perthite. Weakly developed grid is common but some grains have distinctly well developed, though uneven grid twinning. P-plag grains and plumose, continuous stringers with indistinct polysynthetic twinning are developed along some grain contacts.

Qz- 1/4 to 2, equant to irregularly shaped, anhedral, interstitial or interlocking grains with undulatory extinction and commonly weak mosaic structure.

Petrography-Continued

3717-Continued

Bi- 2%. Shreds or subhedral plates up to 2mm most commonly partly included in feldspars. Apatite inclusions (euhedra) are common. X = light yellow green to pale brown; Y = Z = dark green black to orange green.

Acc- Sphene euhedra, iron ore, and zircon associated with biotite and commonly included at feldspar boundaries.

Name-Alaskite.

3718

F- Massive granide gradational into 3717.

Pl- 1/2 to 2 but 4 or more not uncommon, elongate, subhedral, well zoned grains with polysynthetic twinning. Most zoning is progressive normal but some grains show a few euhedral oscillations. Grain contacts with alkali feldspar are irregular. Preferential core alteration to sericite and dust is not uncommon. A few cores show uneven extinction associated with discontinuous twinning and many irregularly shaped small quartz inclusions.

Af- Two different sizes:
1/2 to 1 1/2, equant or irregularly shaped, sub- to anhedral grains with weakly or well developed perthite (string), but no grid twinning. P-plag grains and stringers along grain contacts are common. Locally partly jackets larger plagioclase grains.
2 to 10, elongate, subhedral and irregularly shaped grains commonly with simple twinning. Euhedral zoning is common in the larger (5mm or more) grains. Perthite is common (string) but may be weakly or strongly developed. Grid twinning is absent or locally indistinct at best. Plagioclase inclusions are uncommon.

Qz- 1/4 to 2, irregularly shaped to equant, interstitial and interlocking grains with undulatory extinction and commonly developed mosaic structure. Clusters of equant grains with sutured boundaries occur.

Petrography-Continued

3718-Continued

Bi- 2%. Interstitial and partly included shreds and subhedral plates up to 1 1/2mm occur. Commonly include apatite. X = pale brown or pale green brown; Y = Z = orange or dark green.

Acc- Sphene and iron ore (commonly euhedral) occur together partly or wholly included near feldspar boundaries or occur as interstitial grain in the groundmass.

Name-Porphyritic alaskite.

3719

F- Massive, medium grained, quartz rich granide.

Pl- 1/2 to 1 1/2, rarely 2 or more, elongate, sub- to euhedral, weakly zoned, polysynthetically and simply twinned grains. Grain boundaries are very irregular in contact with alkali feldspar. Grains are most commonly surrounded by several alkali feldspar grains but rarely included.

Af- 1 to 2, rarely 3 or more, irregularly shaped, anhedral grains. P-plag may be weakly or strongly developed (string, vein, or grain) with grains but is commonly well developed near grain contacts. Grains of p-plag within alkali feldspars and stringers of p-plag at alkali feldspar boundaries commonly attain a thickness of 1/3 that of the host grain. Polysynthetic twinning may be undeveloped or well developed in the p-plag. Grid twinning is rare, but if present is indistinct.

Qz- 1/2 to 2, anhedral interstitial to interlocking irregularly shaped grains commonly with well developed mosaic structure. Clusters of grains with sutured contacts are common.

Acc- Total dark minerals probably less than 1/2%. Consist mainly of large (up to 4mm) green biotite flakes and relatively very low % of very small sphene, iron ore, and transparent acicular grains.

Petrography-Continued

3719-Continued
Note: Modal plagioclase percent of total feldspar appears to be about 30 or less by visual inspection in contrast to 50 or more obtained on bulk sample.

Name-Granite.

3720
F- Massive granide.

Pl- 1 to 4, elongate, sub- to anhedral, weakly zoned, polysynthetically twinned grains commonly surrounded by several alkali feldspar grains, but rarely included. Grain borders are commonly irregular and spongy in contact with alkali feldspar. A few grains over 10mm occur and have uneven extinction, discontinuous twinning, and irregular inclusion of quartz in their cores.

Af- 2 to 8, rarely up to 15, equant to irregularly shaped interlocking, anhedral, highly perthitic (string, vein, braid) grains. Grid twins are rare and at best indistinct. Grains and rims of p-plag are developed along some grain boundaries. Inclusions of plagioclase are rare.

Qz- 1/2 to 4, equant to irregularly shaped, anhedral (several euhedral grains), interstitial to interlocking grains. Mosaic structure associated with well developed polysynthetic or grid lamellae is common.

Bi- 2% or less. Shreds or subhedral plates up to 1mm. Commonly partly included in rim of feldspars. Apatite inclusions common. X = pale brown or pale yellow brown; Y = Z = dark green or orange.

Acc- Small iron ore euhedra and sphene occur with biotite or less commonly are included in feldspar rims.

Name-Porphyritic granite.

Petrography-Continued

3721

F- Fine to medium grained granide grading into coarser grained 3722 thru an irregular contact zone.

Pl- 1/2 to 1 1/2, elongate, subhedral, weakly zoned, polysynthetically twinned grains commonly with irregular to embayed borders. Grains are generally enclosed though rarely included by surrounding interlocking alkali feldspars. Some are bent.

Af- 1 to 2 1/2, irregularly shaped interlocking, to equant anhedral grains. String, vein, braid, and patch perthite is well developed. P-plag grains and stringers are common along grain contacts and within grains, and may attain a thickness 1/2 that of host grain (1/4mm). No grid twins developed.

Qz- 1/2 to 2, rarely larger, equant, anhedral grains with undulatory extinction. Mosaic structure developed in some grains.

Acc- 1% or less. Shreds and subhedral plates of interstitial and partly included green and brown biotite up to 1 1/2mm. Sphene and iron ore (mostly included in feldspars) is very sparse.

Note:Modal plagioclase percent of feldspar is almost certainly less than 25% by visual inspection in contrast to 46% obtained on bulk sample.

Name-Granite.

3722

F- Massive granide.

Pl- 1/2 to 2, rarely larger, elongate, subhedral, weakly zoned, polysynthetically twinned grains which are most commonly enclosed completely by several alkali feldspar grains. A few grains are included or interstitial. Euhedral oscillatory zoning is rare. Grain contacts with alkali feldspar are irregular. A few of the larger grains include small subhedral or rounded quartz grains near their borders.

3722-Continued

Af- Two grain sizes:
3 to 8, equant to elongate, anhedral, strongly perthitic (interlocking) grains with no grid twinning. Subhedral, rounded, and irregularly shaped quartz grains (1/10 to 1/3mm) are commonly included. Zoned, elongate plagioclase inclusions paralleling the grain boundaries are present but not prevalent in some grains.
1/2 to 1 1/2, equant to elongate, interstitial to interlocking grains forming a matrix along with small quartz grains between the large alkali feldspar grains. No grid development. The small grains are commonly less perthitic than the large grains. P-plag grains and stringers along grain contacts are common to both grain sizes though not strongly developed.

Qz- 2 to 4, equant, anhedral, interstitial grains with undulatory extinction and weak mosaic structure. Small (less than 1/2mm), equant, sub- to anhedral quartz occurs in the groundmass and as inclusions in the feldspars.

Bi- 2% or less. Interstitial to partly included shreds and subhedral plates commonly associated with iron ore. May be green, red, or pale brown.

Acc- Mainly interstitial, included, or partly included grains and irregularly shaped clusters of iron ore. Sphene is rare.

Name-Porphyritic granite.

3723

F- Massive granide; a few thin pegmatites cut the outcrop.

Pl- 1/2 to 2, rarely larger, elongate, subhedral, weakly to well zoned grains with polysynthetic twinning. Cores of well zoned grains preferentially altered to brown dust and sericite. Grain boundaries commonly irregular especially in contact with alkali feldspar.

Qz- 1 to 4, rarely larger, equant, anhedral, interstitial grains with undulatory extinction. Locally, large clusters of quartz grains occur.

Petrography-Continued

3723-Continued

Bi- 2% or less; Interstitial, partly included shreds and subhedral plates; commonly includes apatite granules. X = pale brown or pale green brown; Y = Z = dark green or orange green.

Acc- Interstitial and partly included iron ore, sphene, apatite, zircon and one spinel (?) grain. Accessories are commonly associated together and with biotite.

Name-Porphyritic granite.

3724

F- Massive granide.

Pl- 1/2 to 1 1/2, elongate, subhedral, weakly to well zoned, polysynthetically twinned grains. Cores of more strongly zoned grains show preferential alteration to brown dust and sericite, and rarely show euhedral oscillatory zoning. Grains are commonly partly included or surrounded by several alkali feldspar grains and are embayed.

Af- 2 to 6, equant to elongate, an- to subhedral, commonly highly perthitic (string, vein, interlocking) grains with no grid development. P-plag grains and stringers common between grains and large simple twins. Partial or complete jackets of alkali feldspar around plagioclase is not uncommon. The larger grains are weakly zoned.

Qz- 1 to 4, equant, an- to rarely euhedral, interstitial to partly included grains with undulatory extinction and commonly developed mosaic structure.

Acc- Associated interstitial or partly included brown biotite, muscovite, sphene, and iron ore. Apatite inclusions in biotite are common.

Name-Porphyritic granite.

Petrography-Continued

3725

F- Fine grained with closely spaced (1 in.) sheeting dipping about 15° west.

Pl- 1/2 to 1 1/2, rarely 2 or more, elongate, subhedral, interstitial interlocking to partly included grains showing strong zoning. Grains commonly have embayed borders. Euhedral oscillatory zoning occurs to a minor extent. Grains are commonly simply and polysynthetically twinned.

Af- 2 to 8, irregularly shaped to elongate, interlocking, very weakly perthitic grains with no grid development. The grains include strongly zoned plagioclase laths which are commonly most prevalent near the outer two-thirds of the grain, and may be crudely aligned to the grain boundaries. The plagioclase laths are smaller than the interstitial plagioclase, less strongly zoned, and may show clean, spongy, or myrmekitic contacts with the alkali feldspar. Biotite is also included and may be parallel to grain boundaries.

Qz- 1/4 to 2, equant interstitial to irregularly shaped interlocking grains which may occur in clusters. Undulatory extinction is not pronounced.

Bi- 2 to 5%. Disseminated shreds and subhedral plates commonly included within feldspars and quartz. Inclusions of apatite are common. Minor green chlorite interpenetrating with biotite. X = pale brown; Y = Z = dark brown or brown green.

Acc- Iron ore, sphene, and apatite euhedra commonly included in feldspars.

Name-Strongly porphyritic trondhjemite.

3726

F- Fine grained granide like 3725 but slightly finer grained. 3725 and 3726 grade into coarser grained massive granide on either side.

Petrography-Continued

3726-Continued

Pl- 1/2 to 1 1/2, elongate, sub- to euhedral, well zoned grains with development of simple and polysynthetic twins. Grains are commonly corroded or embayed especially in contact with alkali feldspar. A few of the larger, more strongly zoned grains show uneven extinction and preferential alteration of the cores. Elongate plagioclase grains are abundantly included in larger alkali feldspars. In some grains the plagioclase inclusions are weakly aligned subparallel to the host boundary, unalignment is most common.

Af- 2 to 6, rarely larger, irregularly shaped, anhedral, interlocking, very weakly perthitic grains with no grid twinning. Inclusions of elongate, zoned plagioclase, rarely aligned, are abundant. Subhedral plates and shreds of biotite commonly unaligned are also included. Many of the larger grains are simply twinned.

Qz- 1 or less, irregularly shaped to equant, anhedral, grains commonly with good extinction comprise the groundmass along with plagioclase. Quartz commonly includes laths of zoned plagioclase but locally is interstitial to plagioclase.

Bi- about 5%. Shreds and subhedral plates included in the alkali feldspars and interstitial to partly included in the quartz-plagioclase groundmass. X = pale brown; Y = Z = dark brown or dark greeen brown.

Acc- Euhedra of iron ore (most commonly magnetite) up to 3%, sphene, and apatite are most commonly associated with biotite. Apatite is commonly included in the biotite. Minute transparent acicular inclusions are also common.

Name-Porphyritic trondhjemite.

3727

F- Massive granide.

Petrography-Continued

3727-Continued

Pl- 1/2 to 1 1/2, much less common 2 or more, elongate, subhedral, weakly to well zoned grains. The cores of some of the larger grains are preferentially altered to brown dust and include green biotite shreds. The larger grains also show euhedral oscillatory zoning (rare). Grains occur interstitial to, and partly or wholly included in larger alkali feldspars. Included plagioclase is commonly subparallel to alkali feldspar boundaries. Grains of plagioclase in contact with alkali feldspar are most commonly irregular, embayed, spongy or myrmekitic.

Af- 1 1/2 to 4, rarely larger or smaller, irregularly shaped, elongate, or equant, sub- to anhedral grains with weakly to well developed perthite (string, vein, interlocking) and unevenly, though commonly well developed grid twinning. A few grains are partly or wholly mantled by plagioclase; the plagioclase-alkali feldspar boundary is irregular. Zoned plagioclase inclusions parallel to alkali feldspar grain boundaries are common.

Qz- 2 or less. Equant, anhedral, interstitial or interlocking grains with undulatory extinction and commonly well developed mosaic structure. Plagioclase and biotite inclusions occur. Some grains show a well developed fracture pattern intersecting at about right angles. Quartz and plagioclase comprise most of the groundmass.

Bi- about 2%. Interstitial and included subhedral plates up to 1/2mm. Apatite inclusions are common. X = pale brown, rarely pale red; Y = Z = dark brown, rarely orange.

Acc- Iron ore (magnetite), sphene, apatite euhedra, and rutile. Accessories are commonly associated with biotite and are partly or wholly included in the feldspar.

Name-Porphyritic alaskite.

Petrography-Continued

3728
F-- Massive granide.

Pl- 1/2 to 1, elongate, subhedral, weakly to well zoned grains with polysynthetic twinning. Grains occur in the groundmass with quartz and small alkali feldspar grains; and partly or wholly included in larger alkali feldspar grains. Grain contacts with alkali feldspars are irregular, spongy, and commonly myrmekitic. Some grains show incipient alteration to epidote.

Af- 2 to 8, irregularly shaped, equant, elongate, sub- to anhedral grains with weakly to well developed perthite (string and vein). Small, corroded, zoned plagioclase grains are commonly included and are generally aligned parallel to the alkali feldspar border. Grid twinning is commonly well but unevenly developed in many grains. A few of the larger grains are zoned.

Qz- 1/2 to 2, equant, anhedral grains with undulatory extinction. Mosaic structure is present in a few grains.

Bi- 5% or less. 1 or less, interstitial shreds or subhedral plates occurring mainly in the groundmass, or partly included in the feldspars. Apatite inclusions are common. X = pale brown; Y = Z = dark brown.

Acc- Interstitial, partly or wholly included iron ore, sphene, and apatite commonly associated with biotite.

Name-Porphyritic alaskite.

3729
F- Massive granide.

Petrography-Continued

3729-Continued

Pl- 1/2 to 1 1/2, elongate, sub- to euhedral, well zoned grains with polysynthetic twinning. Grains are commonly embayed and have spongy contacts with alkali feldspar. Small, elongate grains are commonly included in alkali feldspars and may be aligned parallel to alkali feldspar grain boundaries. Cores of many grains are highly altered to sericite. Some grains are antiperthitic.

Af- 1 to 3, elongate to equant, sub- to anhedral grains with weakly to well developed perthite. Grid twinning is not common but is distinct in some grains. Some of the larger grains are zoned. Inclusions of small, elongate, zoned plagioclase grains are common and may be aligned parallel to the alkali feldspar grain boundary. Myrmekite is developed along many contacts between plagioclase and alkali feldspar. Jackets of plagioclase on alkali feldspar kernels and the opposite relationship are rare but occur with about equal frequency.

Qz- 1/4 to 2, rarely 3 or more, equant to irregularly shaped, anhedral, interstitial to interlocking grains with undulatory extinction.

Bi- 5% or less. Interstitial shreds up to 1mm long. Commonly associated with very small apatite-like needles. X = pale brown; Y = Z = dark brown, rare: bluish green.

Acc- Mostly interstitial anhedral irregularly shaped grains of iron ore and some sphene. Muscovite is rare and occurs as alteration of plagioclase, interpenetrating with biotite or as discrete interstitial grains.

Name-Weakly porphyritic alaskite.

3730

F- Inequigranular massive granide taken about 50 feet west of rhyolite dike.

Petrography-Continued

3730-Continued

Pl- 1/2 to 1 1/2, rarely 3 or more, elongate, sub- to euhedral, well zoned grains with polysynthetic twinning. Preferential core alteration to brown dust and sericite is common. Euhedral oscillatory zoning occurs in the more strongly zoned grains. Grains are commonly partly included along alkali feldspar boundaries. Completely included grains are not common but they are commonly parallel to alkali feldspar boundary. Grain contacts between plagioclase and alkali feldspars may be normal, irregular, spongy or myrmekitic.

Af- 1 to 3, less commonly 4 or more, elongate to equant, sub- to anhedral grains with weakly (smaller grains) to well developed perthite (string, vein). Grid twinning is common but not well developed. Some grains include stringers of minute, anhedral, equant or elongate quartz grains which may parallel alkali feldspar boundaries. Inclusions of zoned plagioclase occur but are not common.

Qz- 1/4 to 3, rarely larger, equant to irregularly shaped, interstitial to interlocking. Small quartz grains are commonly partly or wholly included in alkali feldspar. Undulatory extinction is common to nearly all grains but most pronounced in large ones.

Bi- 2 to 5%. Interstitial shreds or plates up to 1/2mm. Many grains are partly included in alkali feldspars. Apatite inclusions are common. X = pale brown; Y = Z = dark brown.

Acc- Largely iron ore and small apatite grains associated with biotite. Sphene is rare.

Name-Porphyritic alaskite.

3731

F- Inequigranular, massive granide taken about 15 feet from rhyolite dike.

Petrography-Continued

3731-Continued

Pl- 1/2 to 1 1/2, elongate, subhedral, weakly to well zoned grains with polysynthetic twinning. Cores are commonly preferentially altered to sericite and brown dust. Grain boundaries are commonly irregular, especially in contact with alkali feldspar. Partial inclusion of plagioclase in alkali feldspar is common but complete inclusion is rare. Some grains appear to be fractured or broken.

Af- 1/2 to 2 1/2, rarely 3 or more, equant to elongate, sub- to anhedral grains with weak to well developed (string, vein) perthite. Grains less than 1/2 are common in the matrix along with quartz and plagioclase. Grid twinning is distinct in many grains but more commonly is weak or undeveloped. Partial or complete jackets of alkali feldspar around plagioclase are not uncommon. Thin (less than .1mm) stringers of p-plag is developed along some of the alkali feldspar grain contacts.

Qz- 1/4 to 1, a few 2 or more, irregularly shaped to equant, anhedral, interstitial to interlocking grains with undulatory extinction. Large grains (2mm or more) are equant, anhedral but with embayed boundaries and commonly are surrounded by fine-grained mosaic of quartz and alkali feldspar. The large grains also have mosaic structure and show a pronounced fine grid.

Bi- 5% or less. Interstititial and partly included shreds and subhedral plates up to 3/4mm. Apatite inclusions are common. X = pale brown; Y = Z = dark brown.

Acc- Largely blotches and euhedra of interstitial to partly included, disseminated iron ore. May be associated with biotite. Apatite, sphene, and rutile very rare.

Name-Weakly porphyritic alaskite.