Tabulation of uranium and thorium data on the Mesozoic-Cenozoic intrusive rocks of known chemical composition in Colorado

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George Phair and Lillie B. Jenkins

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**U. S. Geological Survey
OPEN FILE REPORT** 75-501

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Commentary

Scope of this tabulation.--The purpose of this tabulation is to make available analytical data, for the most part previously unpublished, on some 250 Mesozoic-Cenozoic intrusive rocks in Colorado for use in assessing the "magmatic" uranium potential of areas involved in the search for pitchblende deposits of Classes I and II of Sims ~~Senis~~ and Sheridan (1964, p. 22). Such deposits, unlike those of Class III, appear to share a common magmatic origin with the uranium concentrated in the associated igneous rocks of closely related age. These deposits are, therefore, consanguineous with the intrusives in contrast to deposits of Class III. As will be described in subsequent reports, the uranium in class III deposits is inferred to have been "exogenic" in origin--derived by processes of hydrothermal secretion from much older and otherwise genetically unrelated granitic wall rocks without passing through a magmatic medium

Class I deposits (uranium bearing fluorite deposits) and class II deposits (uranium bearing base metal veins) are found within the Front Range segment of the Colorado Mineral Belt as shoots and pods in veins mined previously for other constituents particularly Ag, Au, Pb, Zn, Cu, and fluorite. Class I and class II uranium deposits are related to concentric zoning patterns centering about centers of "porphyry" intrusion in the Jamestown and Central City Districts, and are mainly localized along relatively small NE-SW faults, the youngest of the two main groups of faults in the region. On the basis of those isotopic Pb/U age determinations on pitchblendes that approach concordancy reasonably closely, it is considered likely that deposits of class II may have post dated those of class III by 13-18 m.y.

In contrast to deposits of classes I and II, those of Class III are found outside of, or on the fringes of, the mineral belt commonly isolated from outcrops of known Mesozoic-Cenozoic intrusives. Sulfide is much less abundant in these deposits than in those of classes I and II, and they have been worked exclusively for their uranium content. Unlike most deposits of class II which apparently formed at considerably higher temperatures (~~Senis~~ Sims and Barton, 1961) many deposits of class III contain coffinite in addition to pitchblende. Deposits of Class III are mainly localized along the NW-SE trending Breccia Reef system, a complex of profound faults that comprise the earliest fractures in the Front Range (Lovering and Goddard, 1950).

The tabulated data coupled with extensive mineralogical studies provide the basis for a detailed companion paper analyzing:

(1) origin and diversification of the early magmas in Colorado

(2) magmatic differentiation in the separate magma series and sub series

(3) the parts played by (a) crystal fractionation, (b) assimilation and (c) aqueous fluids in the fractionation of uranium and thorium

This paper is now in preparation.

Areal, temporal, and chemical/magmatic subdivisions

~~Areal, temporal and chemical magmatic~~ subdivisions.-- The separate areas of intrusion examined in this report are subdivided into major geographic units represented by (1) the Central Front Range east of the Continental Divide (tables 1-11) an area characterized by an abundance of vein-type uranium deposits, (2) the Front range exclusive of the east-central region (Table 12), (3) the Wet Mountains, the southern continuation of the Front Range (Table 13), (4) the individual ranges of the Southern Rocky Mountains lying to the west of the Front Range-Wet Mountains axis (Tables 14-17), and (5) the eastern border of the Colorado Plateaus (Table 18).

The data for subdivisions 3-5 are of a reconnaissance nature, but are adequate to establish that magmatic uranium and thorium enrichment does not occur on any scale comparable to that in the Central Front Range throughout this broad region. Individual intrusives containing more than 2 x the uranium and thorium contents typical of the world wide average for calc alkalic rocks of equivalent composition were not found throught this region, but the possibility cannot be ruled out that isolated enriched rocks may not turn up in the future. In particular, more data on the igneous rocks is needed in the Leadville-St. Kevin ~~Koven~~-Climax region. The data for the Front Range is considerably more detailed and the patterns of uranium and thorium enrichment seem to be solidly based in terms of span, time and geochemistry.

The intrusives of the major geographic units are in turn subdivided; wherever possible, in terms of bulk chemistry, space and time, into petrographic provinces, sub provinces, and separate centers of intrusion. The chemical and normative data for each intrusive suite or separate center of intrusion are listed in the tables in order of increasing SiO_2 content.

The tables show that potential uranium target areas as defined on the basis of higher than normal magmatic uranium are largely confined to the Front Range Province and in particular to that part of the Central Front Range lying east of the Continental Divide. This region includes most of the known vein type uranium deposits in the state.

The classification of the Mesozoic-Cenozoic igneous rocks of the Central Front Range used in the tables listed in order of generally decreasing age is as follows: (1) early mafic magmas, (2) composite phaneritic stocks plutonic in texture and mineralogy, (3A) porphyritic-aphanitic stocks hypabyssal in texture and mineralogy, (3B) dikes and sills related to the porphyritic-aphanitic stocks, and (4) late stage CaO-poor differentiates. The magmatism was notable for the wide variety of chemical types distinguishable by differences in Peacock indices that were intruded in a relatively small region approximately 80 km long by 80 km wide over the short space of 25 m.y. according to K-Ar age determinations compiled by Marvin, Young, Mahnert, and Naeser (1974). Magma series of no less than 7 distinct chemical types are found in the area of the Central Front Range east of the Continental Divide, an area of roughly 50 x 50 km^2. Of these 7 magma types, the sodic alkalic, and the sodic alkali calcic sub series together with the CaO-poor late stage differentiates, the end members of the sodic alkali-calcic line of descent contain markedly more uranium and thorium than do the remaining types including tholeiitic, potassic alkalic, potassic alkali calcic, and alkali calcic transitional into calc alkalic.

Ranked in order of increasing average uranium concentration without regard to relative stage of differentiation, the separate igneous suites fall in the following order:

1) Tholeiitic - tholeiitic andesite subseries represented by the 62 ~~mile~~ Km.-long Iron Dike. Uranium, 0.4-2.6 ppm

2) alkalic potassic series, represented by the nepheline-bearing phaneritic audubon-albion stock. Uranium, 0.8-3.0 ppm.

3) Alkali calcic potassic subseries, a wide spread suite represented by the latite flows of Table Mountain, by a latite dike near Rollinsville, and by the phaneritic Caribou and North Bryan Mountain stocks. Uranium 0.7-7.6 ppm.

4) alkali calcic subseries transitional into calc alkalic represented by a phaneritic hornblende granodiorite stock at Jamestown and presumably by dikes and sills of dellenite and biotite quartz latite along the adjacent mountain front. Uranium 2.1-5.5 ppm.

5) alkali calcic, sodic subseries includes the phaneritic Bryan Mountain granodiorite stock as well as the great majority of the abundant porphyritic-aphanitic stocks and dikes that give the "porphyry belt" its name. Uranium 1.8-19.0 ppm

6) alkalic sodic subseries represented by the phaneritic nepheline bearing Empire stock Uranium 3.8-18.00 ppm.

7) late stage CaO-poor dikes the end product of magmatic differentiation along the alkali calcic sodic line of descent, Uranium 7.0 - 138.6 ppm

The fact that the intrusives enriched in uranium are even more highly enriched in thorium -- a constituent absent from the metal bearing veins in this region -- is only one of several lines of evidence that lead to the conclusion that the uranium is an original constituent of the rocks present prior to final consolidation, and not a later addition brought about by wandering hydrothermal solutions or by weathering solutions genetically unrelated to the crystallizaiton of the intrusives.

Magmatic differentiation as related to the fractionation of uranium and thorium

To take into account the effect of magmatic differentiation upon the fractionation of uranium and thorium when separate subseries are compared, a means must be found to equate the uranium results to the same stage of magmatic evolution. The uranium and thorium contents at the Peacock Index ($U_{P.I.}$, $Th_{P.I.}$) as estimated from variation diagrams provide such a common base for comparison and in addition yield a measure of the magmatic uranium potential of a given early magma that can be compared with those of other magma series or subseries. In the Front Range Province, the Peacock Index tends to lie at or close to the composition points representing the earliest members of any one chemical subprovince. Table 19 makes possible comparison of uranium potentials among the early mafic magmas and the related early members of the phaneritic stocks.

Because uranium and thorium tend to be stored up in the residual magma during fractional crystallization any small "excess" of the constituents present at the early stage represented by the Peacock Index is potentially capable of undergoing multiplication many times over by the time the end member of the particular subseries has differentiated. The precise multiplication factor would depend upon the intensity of the crystal fractionation. Similarly, to the extent that fractional crystallization, per se, was the dominant mechanism throughout the differentiation of any one subseries, a generally progressive build up of uranium and thorium concentration within the limits of scatter of the analytical data, would be expected. The characteristic differences in patterns obtained where uranium and thorium are plotted against SiO_2 for the separate subseries throws light upon the efficacy of fractional crystallization, per se, as a magmatic concentrator of uranium and thorium.

When the U-SiO_2 and Th-SiO_2 curves for the separate subseries are compared, a progressive buildup of uranium and thorium is noted only for those strongly differentiated phaneritic suites that have $U_{P.I.}$ and $Th_{P.I.}$ in a relatively low range. In those phaneritic subseries that show a distinct inital enrichment in uranium and thorium at the Peacock Index, the pattern of uranium and thorium fractionation are more complex, indicating that other agents in addition to fractional crystallization have had an influence on the concentration of uranium and thorium in the magma. Uranium and thorium when plotted against SiO_2 for each enriched series show double maxima separated by a minimum. The first maximum developed very early in the intrusive sequence (50-54 percent SiO_2) apparently by reaction of mafic magma with wall rocks unusually enriched in uranium and/or thorium.

Wall rocks as a source for above normal concentrations of uranium and thorium in the enriched magmas

The evidence for initial enrichment by incorporation of uranium and thorium from the wall rocks is as follows:

1) $U_{P.I.}$ values of the separate phaneritic stocks that intrude metasediments when plotted against the average uranium contents of the metasedimentary wall rocks show a rising trend.

2) $Th_{P.I.}$ values of the four phaneritic stocks that intrude significant sections of thorium-rich Silver Plume granite ~~as~~ are distinctly higher than the $Th_{P.I.}$ values for those that intrude wall rocks of lower thorium content. The one exception to this rule is the relatively thorium-rich Bryan Mountain stock which is not known to intrude thorium-rich country rocks at the present erosion level.

3) $Th_{P.I.}$ values for the four phaneritic stocks that intrude thorium-rich Silver Plume granite when plotted against the average thorium content of the granite fall along a straight line of positive slope with little scatter.

Among the later differentiates, geochemical and spatial relationships that seen to link at least part of the excessive uranium and thorium enrichment shown by the CaO-poor bostonites and quartz bostonites to ~~intrusives~~ intrusions of uraninite-bearing pegmatitic Silver Plume granite in the Central City District will be described in a later section.

While the uranium and thorium contribution of the wall rocks to the fractionation process is clear, it is equally clear that the same wall rocks produced little or no change in the over-all bulk composition of the magma. Assimilation is believed to have been important in shaping the paths of magmatic differentiation of the intrusives in general, but it is inferred to have operated at greater depth. The phaneritic stock showing the highest levels of uranium (3.0 - 18.0 ppm) and thorium enrichment (18.3 - 73.3 ppm) is the Empire stock which intrudes the type Silver Plume batholith, the most thorianiferous (average Th, 79.1 ppm) of the 11 Precambrian granitic batholiths in the Front Range (Phair and Gottfried 1963). Uranium and thorium reached their peaks (18.0 and 73.3 ppm respectively, in the Empire stock ~~with~~ in the earliest members of the intrusive sequence. The same members represent nepheline highs for the intrusive sequence, hence assimilation of Silver Plume granite could not have exercised a major control in the composition of the intruding magma. Plainly, a medium must be found capable of extracting uranium and thorium from the wall rocks and introducing it into the magma without introducing at the same time major quantities of other rock-forming constituents. An aqueous gas phase developed during the emplacement of the enriched intrusives is inferred to provide such a medium.

The role of an aqueous medium in the transfer and reconcentration of uranium and thorium in the magmas

The evidence for an aqueous gas phase as an agent for the reconcentration of uranium and thorium may be summarized as follows:

1) fluorite, a constituent of those rocks most enriched in uranium and as a rough rule, the greater the enrichment the more abundant the fluorite. In all examples, including the sodic alkalic phaneritic stock at Empire, and the CaO-poor late stage differentiates at Central City and Jamestown the fluorite occupies spaces in the texture interstitial to feldspars and is definitely not crosscutting.

2) In the relatively unenriched rocks typical of the potassic alkalic calcic stocks the hydrous mafic minerals hornblende and/or biotite are abundant in the earliest members and increase in abundance at the expense of augite throughout the subsequent course of differentiation. In the alkali calcic phaneritic stock transitional into calc alkalic at Jamestown, hornblende is the dominant mafic mineral in the earliest member and is the exclusive mafic mineral throughout the succeeding sequence. Through~~t~~out the differentiation of these relatively unenriched subseries the different mafic minerals put in their appearances in the order predicted by Bowen's reaction series

augite → hornblende → biotite

The conclusion is that in the unenriched phaneritic series much of the H_2O content of the magmas became locked up in hydrous mafic minerals and relatively little was left over to form a separate gas phase during crystallization.

In contrast to the less enriched phaneritic stocks, the more uraniferous porphyritic-aphanitic stocks are characterized by reversals in Bowens mafic reaction series, the anhydrous phase sodian augite replacing biotite and/or hornblende. Not uncommonly all three minerals are present and ~~remaining~~ rimming relations indicate formation in the paragenetic sequence.

biotite → hornblende → sodian augite

Such a sequence is strong evidence for progressive de-volatilization during crystallization.

3) In the unenriched phaneritic stocks plagioclase and alkali feldspar is of low structural state. In the enriched phaneritic stock at Empire the plagioclase is of mixed origin, some being of higher structural state, and some of lower. In the enriched porphyritic-aphanitic stocks and dikes all feldspars, both plagioclase and alkali feldspar, are of higher structural state. (Phair and Fisher, 1962). Such differences in structural state of the feldspars are to be expected as a consequence of de-volatilization.

4) Border zones of hydrothermal alteration marked by the ~~sensiti~~ seritization of plagioclase, and the decomposition of mafic minerals in the wall rocks commonly surround, all or in part, the enriched porphyritic-aphanitic stocks. Such zones are lacking from the borders of the phaneritic stocks. Instead the phaneritic stocks are surrounded by thermal aureoles in which recrystallization took place essentially isochemically, and resulted in alkali feldspar of relatively high structural state close to the intrusion. (Hart, 1964). Crystallization of the phaneritic stocks in a relatively closed system is indicated.

5) Particularly within the Central City and Jamestown centers of intrusion the relatively enriched porphyritic-aphanitic stocks and dikes show the effects of albitization - a phenomenon generally considered to be tied to late stage aqueous fluids developed under conditions of relatively low confining pressure.

The separation of an aqueous gas phase from the partly crystallized magma is inferred to have served a dual function in the re-concentration of uranium and thorium:

1) it reacted with the wall rocks selectively releasing uranium and thorium to the magma,

2) it acted as an agent for vertical transfer and reconcentration of uranium and thorium within the magma.

The efficacy of both of these processes would be, among other things, dependent upon the size and shape of the intrusion and upon the attitude of its contacts. The higher average uranium and thorium contents of the porphyritic aphanitic dikes compared to those of porphyritic aphanitic stocks of equivalent composition is attributed to the greater length / width ratio of the dikes which not only exposes greater wall area per volume of magma to the aqueous fluids but also results in a more constricted cross section and hence provides a better "concentrator" for the volatiles rising from depth. The long narrow quartz bostonite dikes in the Central City District, products of extreme crystal fractionation, have length/width ratios in excess of 1000 and are by a wide margin the most enriched intrusives sampled. Also in the Central City District, it was noted that small porphyritic-aphanitic plugs presumed to represent apicies on larger stocks below, averaged higher in uranium and thorium then did the larger stocks themselves, although the bulk compositions were closely similar.

Regardles of factors of shape and size, without appreciable magmatic differentiation, enrichment in uranium and thorium significantly above normal did not take place. The mafic tholeiitic Iron Dike (length 62 km, average width, about 30 meters) and the mafic latite dike near Rollinsville (length 6.4 km, width 2.44 meters) show little or no uranium enrichment in spite of extremely high length/width ratios.

Origin of the uranium and thorium minima and second maxima in the intrusive sequence of the enriched phaneritic stocks.

The uranium and thorium minima evidenced in the members of the intrusive sequences of the enriched phaneritic stocks that immediately followed the initial high uranium and high thorium members probably can be accounted for by a combination of two factors:

1) the magma had been partly devolatilized, having by this time given up part of its volatiles to the earlier members that now comprise the uppermost part of the crystalline hood.

2) the solidified early magma tended to form chill zones against the enriched wall rocks thereby effectively insulating the immediately following members from contact with the original walls.

By the time the buildup of SiO_2 in the remaining magma had attained a critical level, in the range 64-66 percent, fractional crystallization possibly acting in concert with a recharge of volatiles from the deeper parts of the magma chambers, gave rise to the second uranium and/or thorium maximum in the enriched phaneritic rocks. This maximum at 64-66 percent SiO_2 coincides with ~~the~~ uranium and thorium maxima in the porphyritic-aphanitic stocks and dikes taken as a whole.

The CaO-poor late stage differentiates

Petrology.-- The CaO-poor late stage differentiates include bostonite and quartz bostonite, two rock types of special interest because of their exceptionally high contents of uranium and thorium, and their close ties in terms of space, time, and geochemistry to known pitchblende deposits of class II. These rocks are distinguished chemically by extremely low MgO and CaO contents, by differentiation indices in the range 88-94 percent, and by femic indices in the range 1.2-7.4 percent. SiO_2 averages 65.0-67.0 percent in the bostonites and 68-72 percent in the quartz bostonites.

Quartz ranges from 10-25 percent in the quartz bostonites and from 5-10 percent in the bostonites. With decreasing quartz, the bostonites in turn grade into the more calcic trachytes and into syenite. Iron oxides, magnetite plus hematite, make up the only mafic minerals visible in thin seciton. These constituents weather readily and are responsible for a marked change of color from tones of lavender, blue and gray in the fresh rock to purplish brown and red brown on weathered surfaces. Unlike the more calcic porphyries where plagiocalse was the first feldspar to crystallize, crystallization of the CaO-poor bostonite and quartz bostonite began with the precipitation of phenocrysts of alkali feldspar. With further buildup of H_2O and other fluxes in the magma as a result of crystllization, temperatures fell below the dome of the solvus in the system. Ab-Or-quartz and 2 feldspars, lath-like plagioclase along with shorter stubbier semi-euhedral K feldspar crystallized throughout the groundmass of the quartz bostonite. The groundmass shows the typical "bostonite:" texture in which the feldspars, mutually sutured against each other but idiomorphic against quartz, are arranged in divergent to sub-parallel "swirls". The trachitoid arrangement of the groundmass feldspar stands out against the contrasting background provided by the quartz; hence is more obvious in quartz-rich types. The quartz is also destinctive in texture. In the quartz bostonites, it forms large irregular patches showing common extinction throughout that pocketitica~~ll~~y include numerous semi-euhedral groundmass feldspars. Like the fluorite that occupies triangular areas in the interstices between feldspar laths, the quartz in these rocks gives evidence of having crystallized or recrystallized, later than the other rock-forming constituents presumably from an aqueous fluid. Such a medium would account for the large size of the individual patches--each of which represents a single quartz crystal. As previously note~~s~~d, fluorite is relatively common in thin sections of the more uraniferous quartz bostonite. In the less uraniferous quartz bostonite it shows up in mineral separations but not in thin sections, The bostonites, quartz bostonites and related CaO-poor late stage differentiates may be subdivided on the basis of normative Or/Or + Ab ratio into potassic (Or/Or + Ab = 80 - 100 percent), sodi-potassic (Or/Or + Ab = 60-80 percent) and sodic (Or/or + Ab = 30 - 60 percent) types. Feldspar phenocrysts in the potassic and sodi-potassic types are sparse generally making up less than 10 percent of the total rock and consequently give a good approximation of the composition of the first formed feldspars - a useful P-T-X indicator in these rocks. The phenocrysts as plotted on the diagram of Mackenzie and Smith (1956) range in structural state from orthoclase microperthite (here orthoclase cryptoperthite) downward to suborthoclase microperthite intermediate between orthoclase microperthite and microcline perthite. Uranium in the potassic and sodi-potassic quartz bostonite ranges from 18.1 - 69.8 ppm with 5 out of 6 falling in the range 28.4 - 69.8 ppm.

In contrast to the more potassic rocks the sodic bostonite and quartz bostonites have abundant feldspar phenocrysts, and these are of distinctly higher structural state ranging upward from ourthoclase microperthite to sub-sanidine cryptoperthite, Uranium is markedly lower (5.9-13.5 ppm) and decreases with rising structural state. Of the 5 bostonites and quartz bostonites falling in the sodic group 2 have phenocrysts falling in the region slightly above the orthoclase microperthite inversion curve, uranium in these rocks ranges from 11.5-13.4 ppm. These have phenocrysts falling close to or within, the field of sub-sanidine cryptoperthite; uranium in these rocks ranges from 5.9-8.0 ppm.

Rocks of closely similar bulk compositions show wide differences in structural state of their feldspar phenocrysts thereby ruling out variations in rock forming components as a source of these differences. There is no positive correlation between thickness of intrusive and structural state; in fact, if anything, the reverse is true; phenocrysts of the lowest structural state tend to be found in the thinner dikes. Such a relationship would seem to rule out differences in cooling rates as a cause of the variation leaving differences in H_2O content of the magma as the pre-eminent control on the structural state of the feldspar phenocrysts.

In their exceoptionally low contents of normative An and of femic minerals other than iron oxides the bostonite and quartz bostonite magmas closely approached compositions lying within the simplified system Ab-Or-Q-H_2O studied by Tuttle and Bowen (1958). One of the quartz bostonites (p 559) was nearly identical in composition to one of the synthetic mixtures (Q-10F) studied by Tuttle and Bowen at 3000 kg/cm^2 pressure of H_2O. The degree of crystallization at the time of "quenching" was nearly the same in both cases as indicated by percent phenocrysts in the quartz bostonite and percent crystals in the melt. The composition of the phenocrysts in the quartz bostonite (71 percent Or) and in the melt (75 percent Or) were in good agreement considering the strong curvature of the fractionation curves in this region as drawn by Tuttle and Bowen. This and other less direct lines of evidence led Phair and Fisher (1962) to estimate an H_2O pressure close to 3000 kg/cm^2 and temperatures close to 690°C in the quartz bostonite magma at the close of the period of phenocryst formation and at the beginning of ther period of intrusion. Such H_2O pressures are appreciable in rocks of hypabyssal origin and help to explain the high liquidity of the magma, which enabled it to form long narrow dikes. One quartz bostonite dike has a length of 8.4 km and an average width of only 1.8 meters. Without H_2O and other fluxes magmas in the composition range range represented by these CaO-poor late stage differentiates would be among the most viscous of those silicate melts that approximate the compositions of natural rocks.

Lacking hydrous minerals to lock up H_2O it was inevitable that an aqueous gas phase separate early and in relatively large volume in these magmas. A paucity of MgO in the magma prevented the formation of significant quantities of hydrous femic minerals. The relatively high H_2O content is inferred to have given rise to relatively high pressures of O_2 within the magma as a result of dissociation and leakage of the H_2 as formed. The relatively high PO_2 is reflected in the formation of hematite in addition to magnetite ~~in~~ as an original constituent in the groundmass.

The relatively high PO_2 is believed to have had two important effects:

1) it presented the formation of iron-rich biotite in accordance with the experimental results of E~~n~~ugster and Wones (1962)

2) it oxidized much of the uranium contained in the magma to U^{6+} in which state it readily complexes to form the uranyl ion UO_2^{+2}. The uranyl ion in turn forms more complicated complex ions, such as ~~particularly~~ uranium carbonate combinations which are stable in aqueous solution over a relatively wide pH range. In addition, the hexavalent uranium forms compounds with common anions that are highly soluble in aqueous solutions.

As a result of the oxidation of much of the contained U^{+4} to U^{+6} the paths of uranium and thorium which had paralleled each other throughout the differentiation history diverged, and large quantities of uranium relative to thorium were drastically drawn off into the aqueous fluids from which the vein forming solutions were derived.

Significance of high ZrO_2.-- In addition to their high contents of uranium and thorium, the bostonites and quartz bostonites are characterized by unusually high ~~leach~~ levels of zirconia. Results of chemical analyses on seven bostonites and quartz bostonites from the Central City district ranged from 0.05 to 0.19 percent (=1900 ppm) ZrO_2 (Table 20). For six out of the seven samples uranium increased approximately linearly with increasing ZrO_2, a correlation that implies one or more host minerals common to both elements. The one exception had a very low U content for a quartz bostonite (8.2 ppm). In the other six samples, the U/ZrO_2 ratio ranged from 0.035 to 0.076 indicating that if the mineral zircon was the main host for the uranium, it would be strongly radioactive, hence completely metamict and structurally degraded. Such metamict material is apt to be semi opaque, cloudy, and with poorly defined and variable optical properties; hence it was not identified in either thin section study or in heavy mineral separations. Identifiable zircon of lower radioactivity was common. The close association of uranium with ZrO_2 in these rocks was confirmed in acid leaching experiments to be described.

In contrast to the uranium, thorium shows no systemmatic relationship to ZrO_2. The Th/ZrO_2 ratios in the six samples ranged from 0.127 to 0.417 indicating total thorium levels far in excess of those that can be accomodated in even the most radioactive zircon at temperatures of vein formation. Separate hosts for the greater part of the uranium and for the greater part of the thorium are indicated. Separate host minerals for most of the uranium and thorium are also indicated by the results of mineralogical studies to be described and by the results of the acid leaching experiments on these fine-grained rocks.

The high ZrO_2 contents of the quartz bostonite dikes in the Central City district is particularly significant in as much as the pitchblendes from the associated veins appear to be unique among the world's vein-type uraninites and pitchblendes for their unusually high ZrO_2 contents. ZrO_2 ranged from 4.8 to 5.4 percent in quantitative spectrographic analyses of 3 pitchblende samples from the Wood-East Calhoun mines (Sims and Sheridan, 1964, p. 19). ZrO_2 as high as 7.59 was reported by Hillebrand (1891 p. 65-66) in pitchblende from the same area on Quartz Hill in the Central City District. Such high contents of ZrO_2 are well within the experimental limits of solid solution of ZrO_2 in UO_2 (Frondel 1958). Optical and x-ray diffraction studies of the pitchblende ores has failed to reveal the presence of any zirconium containing minerals other than the pitchblende itself.

Within the Central City District uraninite-bearing pegmatite Silver Plume granite has been cut by the workings of the Lillian Mine, in Russel Gulch south of Quartz HIll. The most radioactive sample of the broken granite piled up around the collar of the shaft contained 0.19 percent (=1900 ppm) uranium and 74 ppm thorium. Isotopic Pb/U age determinations (Stern, Phair and Newell, 1971) yielded a concordant 1400 m.y. age confirming the correlation of the pegmatite with the Silver Plume granite, a correlation previously inferred in the bases of uncrushed texture by Sims (written communication, 1960).

Several lines of evidence point to the uraninite-bearing Silver Plume granite pegmatite and associated intrusives correlated with it as potential sources for at least part of the high U and ZrO_2 contents of the quartz bostonites, and of the associated vein pitchblendes 1) The Precambrian pegmatite lies about 60 meters across the strike from an early Tertiary pitchblende bearing vein worked by the Iron Mine. It lies about 1800 meters due south of the main pitchblende bearing area on Quartz Hill

2) The Precambrian pegmatite lies very close to a spur off the Pewabic quartz bostonite dike. The main center of intrusion of Quartz bostonite to which the long linear dikes are either radial or circumferential extended from the lower slopes of Quartz Hill underground to Pewabic Mountain where outcrops of the quartz bostonite define a broad curving belt. The part of the belt on Pewabic Mountain is close to another outcrop of uraninite bearing pegmatite covering several acres in outcrop near the head of Virginia Canyon. At one point this pegmatite was worked for its uraninite content, but the attempt proved unprofitable.

3) Uraninite and zircon in the pegmatite from the Lillian Mine form a peculiarly intimate association. Excellent euhedral cubes of uraninite are intergrown with well crystallized zircon. The uraninite euhedra cut across all growth zones of the zircon indicating that they completed crystallization prior to the start of crystallization of the zircon. The zircon is milk white and strongly metamict. Photomicrographs of the zircon-uraninite intergrowths are given in Plate I of Gottfried, Jaffe and Senftle (1959)

Uranium and thorium host minerals in the quartz bostonite.--Norman Herz investigated the distribution of radioactive sources in the quartz bostonites (written communication, 1952). Using alpha-sensitive stripping films on uncovered thin sections, he noted strong alpha activity associated with zircon and allanite and very strong alpha activity associated with scattered grains of isotropic thorite. Lesser concentrations of radioactivy were associated with apatite and with scattered point sources below the limits of resolution and with disseminations commonly faintly brownish in color distributed along cracks and grain boundaries. In the aggregate these unidentifiable point sources and disseminations contributed an appreciable fraction of the total alpha track population.

Herz separated the accessory minerals from quartz bostonite sample P394 (essentially the same as P118) using heavy liquid and magnetic methods. Sample P394 was chosen because of its unusual freedom from alteration although it ranks among the less radioactive quartz bostonites in the Central City District. It was collected underground in a crosscut in the East Calhoun Mine. In the course of these mineral separations, the identifications of the radioactive sources, apatite, zircon, allanite, and thorite were verified by measurement of refractive indices and other properties in oils under the microscope. The data follow:

Preliminary separations Sample P394

sample after sieving to 165-250 mesh weighed 262.60 grams.

Total light fraction S.G. < 2.8 = 261 g = 99.4 percent

Total heavy fraction S.G. > 2.8 = 1.60 g = 0.61 percent

The very small heavy mineral fraction (0.61 percent of the rock) provides further quantitative proof of the highly leucocratic character of the quartz bostonite dikes. Moreover, of this heavy fraction only 0.09 percent, in terms of the total rock, were found to consist of accessory minerals other than iron oxides. The iron oxides made up 85 percent of the heavy mineral crop and 0.52 percent in terms of the total rock. The data are as follows:

Using the Franz Isodynamic separator with the channel set in a vertical to steeply dipping position, The 1.605 g heavy mineral subsample that made up 0.61 percent of the rock was subdivided into three fractions:

very strongly magnetic (magnetite	0.14 percent
strongly magnetic (hematitic material)	0.38 percent
remainder, mainly clean grains	0.09 percent
	0.61

The remainder constituting 0.09 percent of the total rock was in turn separated into moderately magnetic and non-magnetic fractions using the Franz Isodynamic Separator. Each of these fractions was further subdivided using Methylene Iodide S.G. = 3.2. Individual grains were hand picked for optical study. The results are given in Table 21.

Acid leaching studies

To assess the leachability of uranium and thorium in some typical intrusives, and to provide chemical evidence on the host minerals of these elements, ten gram samples of 13 intrusives including eight quartz bostonites were finely crushed; each was leached in one liter of cold ~~114~~ 1+4 HCl for 24 hours with continuous stirring. In the 8 quartz bostonites from 6.1 to 58.5 percent of the original uranium, and from 29.9 to 79.5 percent of the original thorium were removed in the process (Table 22). In all instances the leaching of thorium in excess of uranium led to a marked decrease in the Th/U ratios of the rock powders after leaching. Table 23.

In general, the leaching patterns confirmed the conclusions based upon the results of the mineralogical and chemical studies of the unaltered rock. The high leachability of thorium in the $\overset{1+4}{\cancel{\text{H4}}}$ HCl solutions reflects the instability of its major host minerals in such a medium. Allanite and metamict thorite decompose readily in dilute HCl leaving a gel made up largely of SiO_2. The break down of allanite would be expected to release rare earths in considerable excess over thorium; the semi-quantitative spectrographic analyses on the dissolved solids in the $\overset{1+4}{\text{H4HCl}}$ filtrate provide an order of magnitude measure of that excess (Table 24). The decomposition of thorite would be expected to release significant, but lesser, quantities of rare earths. Consequently, the Th/R.E. ratio will change in both the unaltered rock and in the leaching solutions in accordance with the ratio allanite/thorite.

As in the unaltered rocks uranium, but not thorium, increases with ZrO_2 in the solids obtained after evaporating the H4 1+4 HCl solutions to dryness, but separate sample suites from Jamestown and Central City define separate U-ZrO_2 curves. The increase in uranium with increase in ZrO_2 is particularly marked in the Central City district. Similarly, when the uranium content of the unaltered quartz bostonite is plotted against percent of original U leached, separate curves are defined for the Jamestown and Central City districts. For reasons unknown, the percent of original uranium leached declines with increase in original U content along both curves. Thorium shows no such relationships. Based upon the present samples, the leachability of uranium in the uranium-rich quartz bostonites from the Jamestown intrusive center is nearly twice that of the quartz bostonites in the Central City district. It is possible to draw the inference from the relatively low leachability of the uranium and from the high Th/U ratios of the Central City quartz bostonites compared to those at Jamestown that a larger proportion of the original uranium present in the Central City magma had been drawn off into the hydrothermal solutions that formed the numerous associated pitchblende deposits leaving behind a less mobile fraction. However, such an explanation needs independent corroboration.

The bostonites and quartz bostonites as low grade ores of uranium and thorium

Based upon the uranium and thorium data then available (Phair, 1952) it was estimated that quarrying the entire surface outcrop of the largest strongly radioactive quartz bostonite intrusion in the region, the Pewabic body as exposed on the slopes of Pewabic and Bellevue Mountains in the Central City District, would make available only about 15 tons of uranium and 100 tons of thorium for each 10 feet of depth mined. Such tonnage of uranium and thorium by themselves would appear to have little short term or middle term significance.

For the long term, however, the fact that leaching in dilute acid releases along with part of the uranium and thorium, equivalent or greater quantities of Ce, La, Nd, and Zr together with generally lesser quantities of Pb, Zn, Cu and Ag (Table 24) would seem to make the rocks potential future resources for these valuable metals taken as a group. Of these metals released, Ag is the lowest by a factor of 10 to 100 fold; nevertheless, it reaches a maximum the order of 96 oz. per ton of the dissolved solids according to the semiquantitative spectrographic data (Table 24).

A prime economic consideration is the rate at which acid is consumed by reaction with rock forming minerals. Nepheline, calcic plagioclase and biotite are either gelatinized or dissolved by reaction with acid. As one example, solution of the 15 percent normative nepheline present in the nepheline monzonite (P915) from the phaneritic stock accounts for the greater part of the 20.4 percent weight loss noted in this sample after leaching (Table 22). The change in composition after leaching and the composition of the dissolved solids (Table 25) confirm the solution of nepheline. The high rate of acid consumption would seem to impose a restriction upon any future use of nepheline bearing alkalic rocks many of which are exceptionally high in U, Th and rare earths, in extraction methods based upon acid leaching. Besides consuming acid, the solution of large quantities of rock forming minerals dilutes the concentration of the valuable metals in the dissolved solids and complicates their recovery.

The bostonites and quartz bostonites lack the reactive rock-forming minerals nepheline, biotite, and calcic plagioclase, hence the rate of acid consumption is exceptionally low. Total weight losses after leaching in these rocks (Table 22) are variable but average about 25% of the weight loss measured for the nepheline monzonite (P915) and 50% of the weight loss measured for the hornblende granodiorite (P640). Consequently, the bostonites and quartz bostonites are attractive from the point of view of acid leaching, not only for their relatively high leachable contents of valuable metals but also for their relatively low acid consumption. Most of the acid used up in leaching these rocks results from the solution of iron oxides. (Table 25).

Effects of hydrothermal alteration

A suite of altered quartz bostonite samples collected from an outcrop in the Central City district at a point where the abandoned tramline crosses the Nigger Hill dike provides a demonstration of the leachability, mobility and short range reconcentration of uranium and thorium under hydrothermal conditions.

The dike, at this point, is approximately 84 cm. thick and is hydrothermally altered and bleached. The bleaching results from the leaching of 25 percent of the original iron oxides. The remaining iron oxide has been redistributed as black platy specularite, in part as disseminations, but mainly in veinlets that stem off a highly radioactive small pod located four inches from the contact of the dike with altered granite gneiss and pegmatite. The pod consists of slickinsided quartz and limonite in part coated with a strongly radioactive black opaque of unknown mineralogy. Whereas the mass of the bleached bostonite (P94) averages 214 ppm U and 1050 ppm Th compared to an average of 692 ppm U and 2850 ppm Th for the fresh rock from the same dike, the radioactive coat together with about 1 m.m. of adhering rocks was found by chemical analyses to contain 0.27 percent uranium (=2700 ppm) and 0.93 percent thorium (=9300 ppm). The fact that the excess of thorium over uranium present in the unaltered rock (Th/U = 4.1) is preserved in the radioactive coat (Th/U = 3.4) is strong evidence that the radioactive coat is in a strict sense a residual concentrate from the rock itself and not an exogenic addition.

The fact that thorium is lacking from the hydrothermal veins in the region is further evidence of a residual origin for the radioactive coat. The process is visualized as one in which the mobile uranium, that elsewhere in the pitchblende belt was able to leave the source rock and/or source magma and enter the vein forming solutions, was here arrested in flight by coprecipitation with thorium and iron oxides.

Though the chemistry of the altering hydrothermal solutions is not known, certain of their effects parallel those of the ~~H4~~ 1+4 HCl solutions. ~~Their~~ Thus P94 which was pre-leached by the natural solutions showed only 1/2 to 1/3 the total weight loss of the fresh quartz bostonites when leached in ~~H4~~ 1+4 HCl. (Table 24). The hydrothermal alteration resulted in an almost complete replacement of Na_2O by K_2O (12.43 percent) and the small quantity of Na_2O remaining (1.59 percent) was farther reduced to (0.41 percent) by the leaching in ~~H4~~ 1+4 HCl. At the same time, the leaching in ~~H4~~ 1+4 HCl increased the K_2O content slightly from 12.43 to 12.7 percent. (Table 25).

As a general, though by no means invariant rule, hydrothermal alteration sufficient to bleach any of the Front Range porphyries by removal of iron diminishes the uranium content by 25-50 percent. These levels of uranium leachability are comparable to those measured in ~~H4~~ 1+4 HCl solutions. Where the rock is bleached and the original disseminated iron minerals are reconstituted more or less in place into fewer but larger crystals of pyrite, the uranium content may stay the same or actually increase. The lower mobility of the uranium in such cases probably results from the onset of reducing conditions.

Magmatic uranium potential and the delineation of areas favorable to pitchblende deposition

Regions outside the Central Front Range.--Using 7 ppm uranium as the cutoff between "normal" and enriched igneous rocks tables 1-18 show that enriched Mesozoic-Cenozoic intrusives are almost entirely restricted to the Front Range-Wet Mountains axis. The intrusives sampled in the ranges to the west are largely calc alkalic, lack CaO-poor late stage differentiates and show the relatively low range of uranium contents appropriate to such rock series. The intrusives sampled in the bordering parts of the Colorado Plateau are of two types, calc alkalic and alkali-calcic potassic; both series are low to very low in range of uranium concentrations. Throughout this broad region characterized by low contents of magmatic uranium pitchblende deposits of any type are scarce and the few that do occur are not closely associated with Mesozoic-Cenozoic intrusives.

Within the Wet Mountains the Mount Fairview stock near Rosita and the rhyolite quartz porphyry plug at the Antrum mine near Quesida show moderate levels of uranium enrichment. However, ore deposition in the veins of the associated thorium district apparently took place under conditions that were unusually oxidizing. Consequently uranium moved completely out of the veins and associated altered wall rocks whereas thorium was residually concentrated. A compilation of analyses shows that the Th/U ratio of the altered wall rocks can reach as high as 1000. This environment can only be judged unfavorable to the deposition of pitchblende. No pitchblende deposits or occurrences are known in the region and uranium minerals of any sort are exceedingly scarce.

Intrusives in parts of the Front Range outside of the Colorado Mineral Belt-Porphyry Belt have been sampled at ~~Apple~~ cripple Creek to the south, in the Manhattan-Home district to the north and at Whitehorn along the western margin of the Front Range. The intrusives at ~~Apple~~ Cripple Creek make up an alkalic, sodic, series and show the moderate of enrichment common to such series. Two andesites were found to contain 10.4 and 14.4 ppm uranium, 3 syenites 6.4, 7.0 and 9.0 ppm uranium, and 3 phonolites 14.4, 18.4, and 26.0 ppm uranium. Because the same rocks were not analyzed for major constituents, these data are not reported in the tables.

In the Manhattan-Home district, two porphyry dikes having the high SiO_2 contents characteristic of calc-alkalic rocks have the low uranium contents 1.9 and 1.4 ppm U expected of such rocks. The nearest pitchblende deposit, the Copper King Mine, is more than 10 miles distant from the nearest of these dikes.

The Whitehorn stock, located along the western margin of the Front Range and east of Salida is a relatively mafic complex made up, like most of the stocks to the west, of calc alkalic rocks. Also, like the more westerly rocks , it exhibits the normal low range of uranium contents (0.8-3.5 ppm).

Subheading

The Central Front Range

~~Province~~ Previous sections have described the geochemical and mineralogical relationships that tend to link deposits and showings of uranium minerals of classes 1 and 2 in the Central Front Range to a chemically and mineralogically distinct late stage differentiates distinguished by very low contents of MgO and CaO. The CaO-poor intrusives share a widespread characteristic with the veins, the presence of fluorite, and two specific characteristics, high uranium and high ZrO_2, with a specific constituent of certain of those veins, the pitchblende.

Significant though these geochemical ties may be in terms of genesis, the usefulness of magmatic uranium potential in defining areas favorable for finding pitchblende deposits must rest primarily upon space relationships. The validity of the space relationships, in turn, depend upon adequate areal sampling of intrusives and veins.

In addition to some 250 samples of intrusives of all kinds on which both rock analyses and precise uranium and thorium analyses were obtained, some 150 others were analyzed by reconnaissance methods for uranium. The maximum uncertainty in these reconnaissance determinations was about ± 10 ppm; though useless for defining trends of differentiation of rocks in the "normal" low range, they provide limiting information in working out degrees of enrichment above 20 ppm. These analyses are indicated by ranges rather than single figures in the tables that follow.

162 other intrusives were analyzed for uranium with a precision of about ± 2 ppm in the range 1-10 ppm, intermediate between the precisions of the separate methods noted above. These data are of limited usefulness in the "normal" low range, but are decidedly helpful in the enriched range. Such data is reported as whole numbers without decimals in the tables that follow.

In all, some 114 samples of CaO-poor late stage differentiates were analyzed by one or more methods, and are listed in the tables Quartz bostonite and bostonite make up most of the total, but also included are certain sodic albitized leucogranodiorites in the Central City district and a few alaskites quartz monzonites in the Chicago Creek area. Although gaps in the sampling pattern exist, the numbers of samples collected from any one district can be expected to reflect in a general way, the abundance of CaO-poor intrusives, mainly dikes.

The veins, accessible workings, and dumps of several thousand mines and prospects scattered throughout the Front Range mineral belt have been examined since World War II, in part sporadically by prospectors, and in part systemmatically by numerous geologists of the U.S. Geological Survey and of the Atomic Energy Commission. Because of the sensitivity of the radiation detectors used, the distribution of uranium and thorium throughout the belt is probably known in greater detail than is that of any other element. Few areas of similar size elsewhere have been as exhaustively prospected. The sampling of the veins in the region seems to rest on what is perhaps an unusually solid statistical base.

The magmatic uranium potentials of a particular area or district, as here defined, is proportional to the product of an intensive factor, the average uranium content of the magma as ~~are~~ measured in the rocks, that it produced; multiplied by an extensive factor, the relative volume, or abundance of the measured rocks. Because relative magma volumes at depths must be judged from the volume of rock at the surface, and because the average uranium contents of many intrusives must be based upon analyses of single samples, costs and manpower being what they are, the magmatic uranium potentials are the best approximations that can be made based upon present sampling and the geology as presently known. The separate mining districts in the Front Range segment of the Colorado Mineral Belt are ranked according to their magmatic uranium potentials determined in the manner described above in Table .

The hydrothermal uranium potential of a given district is a measure of its potential economic importance and is based on the number ~~in terms of minable uranium.~~ and [illegible] of known uranium deposits The data listed and ranked in Table 27 are those judged particularly meaningful on the basis of detailed results presented by Sims and coworkers on the staff of the U.S. Geological Survey (Sims and others, 1963A, 1963B, 1964). For inclusion in Table 27, a class 1 uranium deposit must have been found to contain at least some ore averaging 0.01 percent uranium or better. For inclusion, uranium deposits of class 2 must contain at least some ore averaging 0.05 percent uranium or better; most contain appreciable ore exceeding 0.10 percent uranium. Other things being equal, districts with a history of uranium productions are weighted more heavily in the rankings than are those without such a history, whether or not the uranium ore was actually shipped.

In figure 1, rank based upon hydrothermal uranium potential is plotted against rank based upon magmatic uranium potential. Though the scatter of the points representing the separate districts from the line representing perfect fit is large, the positive rising trend is clearly evident. The scatter of the points is to be expected in view of the nature and limitations of the data which like much other geologic correlation is inherently permissive. Agreement in rank between the magamtic and hydrothermal potential is excellent for the districts of highest and lowest ranks, but is much less clear cut throughout the middle range.

Under the assumption that districts lying well above the line of perfect fit (rank in magmatic uranium pottential >> rank in economic uranium potential) have unfulfilled economic promise, future prospecting should be directed towards the Gold Hill, North Gilpin County, Alice, Chicago Creek, and Dumont districts -- all districts considered to be not particularly attractive in the past. Of these, the Gold Hill district is considered to offer the most promise because of the relatively high abundance of strongly uraniferous CaO-poor intrusives in that area.

For those districts lying well below the straight line in which rank based upon magmatic uranium potential falls far short of rank based upon hydrothermal uranium potential, a number of explanations are possible, one of which is, of course, that the inferred relationship simply does not apply in those cases. Another explanation is possible in the case of the Caribou Mine, where the pitchblende was encountered at depths of about 1000 feet (304.8 meters) in the mine -- perhaps genetically related uraniferous intrusives are present at depth, but have not been found because they are not exposed in the mine workings or at the present erosion surface. From what is known of the provincial magmatic differentiation patterns, however, the possible presence of CaO-poor late stage intrusives in this particular enviornment (alkali-calcic potassic) seems remote.

The uranium minerals in the mines of the Fall River district occur primarily in northwesterly trending veins at points at which those veins cut calc-silicate rocks high in ferrous iron -- two attributes characteristic of deposits of class 3. Though included by Sims and others (1964) with deposits of type 2, they conceivably could be of different origin.

The Central City District

The Central City district is unique among all districts in the Front Range for the volume of CaO-poor late stage differentiates present, for the very high levels of uranium and thorium contained in many of those CaO-poor intrusives, for the number of showings of uranium ore present, and for the tonnage of pitchblende of class 2 actually mined in the past. The pitchblende occurs in gold-silver-base metal veins of varied mineralogy and paragenetically was among the earliest of the metallic constituents to precipitate. The deposition of the pitchblende appears to have followed closely the intrusion of the uraniferous CaO-poor intrusives, namely bostonite and quartz bostonite that closed the cycle of igneous activity in the district.

The relationships between the intrusive and the pitchblende deposits in the Central City district were investigated by Phair (1952) using the less accurate uranium and thorium data on the igneous rocks then available. The conclusions of that report have been generally substantiated, and in many instances sharpened, by (1) subsequent geochemical work based upon uranium and thorium data of increased accuracy as reported in this paper and, (2) by the detailed field work of Sims and coworkers (1963 A) who described many new occurrences of pitchblende from the district most of which were spatially associated with CaO-poor late stage differentiates.

Stocks, plugs, and dikes are scattered through out the broad area of mineralization. All intrusives in this district are relatively low in CaO compared to their counterparts elsewhere in the Mineral Belt-Porphyry belt with CaO becoming vanishingly small in many quartz bostonites. Wells (1960) divided the monzonite and monzonite porphyry of Bastin and Hill (1917) into granodiorite and minor quartz monzonite and bostonite. This classification is chemically sound. A model a classification would move the granodiorite towards monzonite owing to the high proportion of alkali feldspar ~~remitting~~ resulting from the solid solution in these relatively high temperature K-feldspars of substantial quantitities of the alb~~r~~ite module. Actually no classification of these rocks is wholly satisfactory. The quartz contents of the granodioritic rocks as in most alkali calcic sodic rocks in are relatively low (11-13 percent, Table) and only slightly exceed~~s~~ the 10% generally considered to be the cut off between the monzonite-syenite and granodiorite-granite lines of descent. Those monzonite porphyry dikes of Bastin and Hill (1917) that Wells re-named bostonite are perhaps better classified as leuco granodiorite. Like bostonite they are CaO-poor, but unlike bostonite they lack the typical bostonite texture, contain plagioclase phenocrysts in addition to those of alkali feldspar, and are commonly strongly albitized.

The principal bostonite and quartz bostonite intrusives form ~~from~~ long, narrow dikes up to 8.4 kilometers long and 3 to 8 feet wide. Varieties Vancetier containing less than 5 percent phenocrysts are very highly uraniferous (30-70 ppm U), those containing 5-15 percent phenocrysts are high high~~ly ura~~nferic to intermediate in uranium contents, and those containing more than 15 percent phenocrysts tend to be weakly to moderately uraniferous. Most, but not all, of the bostonite and quartz bostonite dikes are limited to the western half of the district, whereas granodiorite is concentrated in the eastern half.

The Central City district is also notable for the immense number, and varied mineralogy of the vein deposits included within its boundaries . The veins follow a swarm of NE-SW trending faults that are generally short but in some instances range up to 3.2 km in length. As noted by Sims and others (1964 p. 73) the district ranks first in metal production among all mining districts in the Front Range. It has had a total output valued at about $100 million of which gold makes up 85 percent, silver nearly 10 percent, and base metals plus uranium makes up the remaining 5 percent. Sims and others (1963A) estimated the total uranium production of the district as about

110,000 lbs. of U_3O_8, most of which came from the Wood and Kirk mines on Quartz Hill.

The mesothermal nature of the ores was confirmed by the range of sphalerite formation temperatures obtained by Sims and others 1961. A well developed areal zonation first described by Bastin and Hill (1917) and delineated in greater detail by Sims and others (1963A) centers about a core of pyrite ore south of Central City, an area characterized by the largest volume of intrusives. Successive outer zones more or less concentr~~ates~~ic to the pyritic core consist of a transitional zone characterized by copper and an outer base metal zone. Gold is concentrated in the transitional and base metal ores. Silver is present in transitional ores but is more concentrated in the base metal ores. Uranium is found in all three ore zones but is more abundant in the ore of the transitional and base metal zones than in the pyritic zone.

The uranium bearing mines make up a belt and several smaller clusters. The main pitchblende bearing belt is about 1200 metres long by 500 metres wide with its longer axis trending a little west of north across Quartz Hill sub parallel to the more northerly trending of the associated quartz bostonite dikes belonging to the Wood system. Approximately 40 veins cut the pitchblende belt of which some 17 have been extensively worked. Four of these veins have a history of pitchblende production and at least 8 others have yielded ore samples containing more than 0.10 per cent uranium. Throughout the pitchblende belt nearly all of the pitchblende was found at points less than 1000 ft (304.8 metres) from one of the highly uraniferous quartz bostonite dikes; most came from points less than 500 ft. (152.4 metres) distant.

The close association between the pitchblende deposits and the quartz bostonite dikes is particularly significant genetically in as much as the NNW trend of the pitchblende belt transects at a wide angle the NE-SW trend of the associated veins and of the boundaries between the ore zones. The one constant factor controlling the depositing of the pitchblende appears to have been a quartz bostonite magma source at depth from which ~~both~~ the dikes now exposed at the surface and the pitchblende bearing solutions were derived. The main magma chamber is inferred to have extended at depth from a center on the lower slopes of Quartz Hill, from which the Wood system of dikes originates, southward to a center of intrusions on Pewabic Mountain, from which the uraniferous dikes of the Pewabic system radiate. The magma chamber like the dikes which it fed was probably long and narrow. The main Wood dike as traced to the north west out of the Central City district is 8.4 km long and must have been fed from an extensive chamber.

Outside the Quartz Hill area in Russell Gulch approximately along the trend of the main pitchblende belt as projected some 3500 ft. (1066.8 metres) to the south are two pitchblende bearing mines, the Iron and the Old Town. Both are located less than 350 ft. (106.7 metres) from a NNW-trending branch dike from the highly uraniferous Pewabic quartz bostonite dike and less than 1000 ft. (304.8) metres from the main Pewabic dike itself. Less than 800 ft. (243.8 metres) to the east of these mines is the Lillian mine, the shaft of which was driven into the Precambrian uraninite-bearing Silver Plume granite pegmatite described earlier.

Near the southwestern corner of the Central City district pitchblende has been found in the Gold Rock vein. This vein lies at a distance no greater than 300 ft. (91.4 metres) and, at its point of closest approach, less than 50 ft. (15.2 metres) from the weakly uraniferous California bostonite dike.

Near the northwestern boundary of major mineralization in the Central City district north of ~~Eurks~~ Eureka Gulch on Nigger Hill are 3 uranium bearing mines, the Carroll, Two Sisters and Claire Marie. Uranium ore is known to have been shipped from the first two of these mines. The 3 mines are clustered closely together about the point of confluence of the two main NW trending branches of the very highly uraniferous Nigger Hill quartz bostonite dike. All uraniferous parts of the three veins lie within 500 ft. (152.9 metres) of one or the other of the two quartz bostonite dikes.

Southwest of the uranium bearing mines on Nigger Hill ~~are~~ is the Rara Avis vein the uranium bearing parts of which lie within 500 ft. (152.4 metres) of the very highly uraniferous Prosser Gulch quartz bostonite which trends NE-SW. Along the extension of the Prosser Gulch dike as projected about 400 ft. (152.4 metres) to the NNE is the shaft of the uranium bearing Bullion vein. Neither of the mines on these two veins has a history of production so far as is known.

Near the eastern limit of the mineralized area in the Central City district on the slopes of Justice Hill is the Bonanza mine from which uranium ore is known to have been shipped. The vein lies within 1000 ft. (304.8 metres) of the highly uraniferous Pewabic quartz bostonite dike. Southwest of the Bonanza mine are the uraniferous Cherokee and Little Annie mines. These mines ~~lie within~~ are as [illegible] 2200 ft. (670.6 metres) [illegible] of the Pewabic quartz bostonite dike and less than 750 ft. (228.6 metres) from a plexus of short dikes mapped as bostonite by Sims and others (1963) that cut the Banto a Hill granodiorite pluton. These dikes are CaO-poor, moderately uraniferous, and are among those, perhaps, best described as leucogranodiorite. No ore is known to have been shipped from the two mines.

The Blackhawk no. 2 Lode on Silver Hill is the only uraniferous mine in the district not associated with CaO-poor late stage intrusive dikes, nor, in fact, is it associated with intrusives of any kind. The nearest bostonite dike as exposed at the surface was mapped by Wells (1960) nearly 300 ft. (914.4 metres) distant in a northwesterly direction. A few tons of uranium were said to be mined, but not shipped, from the Blackhawk no. 2 Lode. Sims and others (1963A).

The analyses presented in the tables show that the quartz bostonite dikes in the Central City district are among the most radioactive igneous rocks (as distinct from igneous segregations and pegmeatites) so far reported. They appear to be unusually closely linked genetically via space, time, and geochemical bridges to actual deposits of pitchblende. Uraniferous solutions derived from the crystalizing quartz bostonite magma at depth apparently merged with the more regional gold-silver-base metal bearing solutions and after traveling no great distance from their source precipitated along with abundant pyrite as reducing conditions set in during the early stages of vein formation. Consequently most of the uranium is now found in relatively close association with the steeply dipping CaO-poor dikes that are the surface expression of the deeper uranium source magma (Phair 1952). Sims and others (1963B, p. 53) who mapped the ore deposits tested and adopted the above mode of origin for the uranium in the Central City district.

Some concentrations of uranium minerals found in particularly close association with hydrothermally bleached quartz bostonite probably reflect the short range transport and recrystallization of uranium leached from the dikes after their solidification. Sims and others (1963B p. 104) inferred that quartz bostonite was the source for nearby concentrations of the uranium sulfate, zippeite in the Diamond Joe Tunnels just south of the Central City district. In an earlier section the reconcentration of both uranium and thorium in strongly radioactive coatings on altered quartz bostonite in the Nigger Hill dike was described. Though high grade uranium pods can be expected to result from the leaching process, the volume of bleached bostonite present is usually small. In such cases mass balance considerations require that the volume of uranium minerals so formed also can only be small, and therefore probably non-commercial.

U. S. GOVERNMENT PRINTING OFFICE : 1959 O - 511171
867-193

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U. S. Geological Survey
OPEN FILE REPORT 75-501
This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards of nomenclature.

Table 1A 'Early Mafic Magmas: Chemical Data
Central Front Range; East of the Continental Divide.

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O^+	H_2O^-	MnO	P_2O_5	CO_2	U_{ppm}	Th_{ppm}
normal tholeiitic basalt (Nockolds 1954)	50.83	2.03	14.07	2.88	9.06	6.34	10.42	2.23	0.82	0.91	—	0.18	0.23	—	—	—
Iron Dike:																
GP110 (early "quench")	48.6	2.0	13.0	1.7	9.6	4.8	9.7	2.2	0.62	2.0	1.1	0.20	0.46	<0.05	2.6	
P905 coarser	49.0	3.2	12.9	3.2	11.8	4.2	8.0	2.8	1.5	2.3	0.34	0.20	0.52	<0.05	2.5	5.8
P1329	49.1	3.4	14.0	1.7	12.4	4.8	7.9	3.0	1.5	0.80	0.60	0.18	0.51	<0.05	0.4	2.5
P904	49.5	3.1	13.0	4.1	10.5	4.9	8.6	2.2	1.1	1.9		0.20	0.46	0.40	1.0	—
P1409	49.4	2.8	13.4	3.6	11.1	4.4	7.6	2.9	1.6	0.36	2.0	0.21	0.45	0.09	1.2	1.3
P1410	49.4	2.7	13.3	2.8	11.6	5.0	8.5	2.5	1.2	0.26	2.0	0.21	0.44	<0.05	1.2	0.3
average Tholeiitic andesite (Nockolds 1954)	51.43	2.60	13.05	3.36	9.74	5.28	9.78	3.18	1.04	0.87	—	0.19	0.48	—	—	
Valmont Dike (Emmons et al 1896)	48.25	0.89	16.73	3.99	6.28	5.77	8.32	3.24	4.08	1.72		—	0.68	—	—	
Table Mountain Flows:																
#50 Earliest flows (Emmons et al 1896)	49.69	0.85	18.06	2.64	6.19	5.23	8.24	2.90	3.90	0.91		0.13	0.81	—	—	
#47 Lower Cap (Emmons et al 1896)	52.59	0.84	17.91	3.81	5.18	4.11	7.24	2.94	3.83	1.24		tr	0.14	—	—	
Upper Cap:																
P1401	52.7	0.80	16.3	5.8	2.7	3.5	6.8	3.0	4.0	2.3	1.8	0.18	0.58	<0.05	3.8	6.8
P1404	53.8	0.80	16.6	5.0	3.5	3.3	6.6	3.2	4.4	1.1	0.91	0.17	0.58	<0.05	2.9	13.8
P1400	53.9	0.78	16.8	4.8	3.6	3.4	6.5	3.0	4.1	1.2	1.0	0.18	0.59	<0.05	4.0	7.1
P1403	54.0	0.78	16.6	5.0	3.5	3.6	6.4	3.2	4.2	1.0	1.0	0.10	0.58	<0.05	3.9	1.4
Av. latite (Nockolds 1954)	54.02	1.18	17.22	3.83	3.98	3.87	6.76	3.32	4.43	0.78	—	0.14	0.49	—	—	
P1408 Dike, contact	52.3	0.86	16.1	3.0	6.0	3.7	6.0	3.4	4.8	1.5		0.20	0.64	0.20	3.5	7.9
P906 " interior	52.4	0.88	15.6	3.9	5.7	3.8	6.5	3.1	4.5	1.8		0.20	0.64	0.60	3.6	17.9

Table 1B Early Mafic Magmas: Normative Data
Central Front Range, east of the Continental Divide

		(1)		(2)		(3)		(4)		(5)		(6)				
	Q	or	ab	an	ne	C	ap	il	mt	hm	di	hy	ol	cc		D.I.
normal tholeiitic basalt (Nockolds, 1954)	3.5	5.0	18.9	25.9	—	—	0.5	3.8	4.2	—	37.3		—	—		27.4
Iron Dike:																
GP110 (Early "quench")	7.9	3.3	18.3	23.9	—	—	1.3	5.8	7.2	—	16.8	12.6	—	—		29.5
P905 coarser	3.2	7.8	23.6	18.6	—	—	1.3	6.1	4.6	—	14.6	17.3	—	—		34.6
P1329 "	—	8.9	25.1	20.3	—	—	1.3	6.5	7.5	—	12.8	19.7	2.7	—		34.1
P404 "	7.3	6.7	18.3	22.2	—	—	1.3	5.9	6.0	—	11.9	17.4	—	0.9		32.3
P1409	2.1	9.4	24.6	18.6	—	—	1.0	5.3	5.3	—	13.2	18.0	—	0.2		36.2
P1440	4.1	7.2	21.0	21.4	—	—	1.0	5.2	4.2	—	15.0	19.8	—	—		32.3
average tholeiitic andesite (Nockolds 1954)	3.2	[illegible]	27.2	18.1	—	—	1.1	5.0	4.9	—	33.5		—	—		36.5
Valmont Dike (Emmons et al. 1896)	—	24.5	14.1	18.9	7.1	—	1.7	1.7	5.8	—	14.1	—	10.4	—		45.7
Table Mountain Flows																
#50, Earliest Lavas (Emmons et al. 1896)	—	22.8	19.4	24.5	3.1	—	2.0	1.7	3.7	—	9.8	—	13.1	—		45.3
#49 Lower Cap (Emmons et al 1896)	—	22.2	24.6	24.5	—	—	0.3	1.5	5.6	—	8.5	11.2	—	—		46.8
P1401 Upper Cap.	3.8	24.5	25.1	18.9	—	—	1.3	1.5	7.2	0.8	8.6	4.7	—	—		53.4
P1404 " "	2.4	26.1	27.2	17.8	—	—	1.3	1.5	7.2	—	9.0	5.5	—	—		55.8
P1400 " "	4.3	24.5	25.1	20.3	—	—	1.3	1.5	7.0	—	6.6	7.1	—	—		53.9
P1403 " "	3.2	25.0	27.2	17.2	—	—	1.3	1.5	7.2	—	8.2	6.5	—	—		55.4
av. latite, (Nockolds 1954)	0.5	26.1	27.8	19.2	—	—	1.2	2.3	5.6	—	16.6		—	—		54.4
P908 Dike Contact	—	28.4	28.0	14.5	0.3	—	1.3	1.7	4.4	—	8.5	—	10.2	0.5		57.5
P906 " interior	—	26.7	26.2	15.3	—	—	1.3	1.7	5.6	—	7.7	11.9	0.7	1.4		52.9

Table 2A Intrusives of the Phaneritic Stocks: Chemical Data Central Front Range, east of the Continental Divide

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O^+	H_2O^-	MnO	P_2O_5	CO_2	U_{ppm}	Th_{ppm}
N.E. Subprovince																
Hornblende granodiorite stock, Jamestown:																
P1414, S. Contact Zone	56.3	0.78	16.1	4.0	3.8	2.7	6.5	3.1	4.5	0.94	0.46	0.15	0.50	0.12	4.0	6.4
P640, W. Contact Zone	57.0	0.72	16.1	4.9	3.4	2.8	6.0	3.2	3.8	—	—	0.16	0.44	—	3.5	14.8
P1455 interior	61.5	0.50	16.8	3.1	2.0	1.8	4.1	4.2	4.3	0.85	0.34	0.10	0.29	0.10	4.6	7.6
P909 interior	61.8	0.50	16.3	2.7	2.6	1.8	4.2	4.3	4.1	0.87		0.08	0.28	0.52	5.5	17.9

Table 2B Intrusives of the Phaneritic Stocks: Normative Data
Central Front Range, East of the Continental Divide

	Q.	or	ab	an	ne	c	ap	il	mt	hm	di	hy	ol	cc		DI
N.E. Subprovince																
Hornblende granodiorite Stock, Jamestown																
P144, S. Contact Zone	6.2	26.7	26.2	16.7	–	–	1.3	1.5	5.8	–	9.1	4.8	–	0.2		59.1
P640, W. Contact Zone	9.4	22.2	27.2	18.3	–	–	1.0	1.4	7.0	–	6.8	5.0	–	–		58.9
P1455, interior	10.0	25.6	35.6	17.0	–	–	0.7	0.9	4.4	–	0.7	4.7	–	0.2		71.2
P909, interior	10.4	24.5	36.1	13.1	–	–	0.7	0.9	3.9	–	5.8	3.6	–	–		71.1

Table 3A Intrusives of the Phaneritic Stocks: Chemical Data
Central Front Range, east of the Continental Divide

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O^+	H_2O^-	MnO	P_2O_5	CO_2	U_{ppm}	Th_{ppm}
North Central Subprovince																
Monzanite Stock																
Audubon-Albion																
P1302, Mafic Syenogabbro	49.1	1.0	12.9	3.3	7.1	10.8	8.9	2.2	2.6	0.48	0.08	0.17	0.64	<0.05	0.8	4.5
W453 Syenogabbro (1)	50.37	1.53	17.38	1.91	6.06	6.16	8.25	3.16	3.60	0.43	0.14	0.13	0.54	0.08		
P1306 mafic ne-monzanite	51.3	1.20	17.2	4.7	3.8	2.8	7.8	3.2?	5.40	1.1	0.39	0.22	0.75	<0.05	2.2	14.4
W218 ne-monzanite (1)	53.14	0.95	21.75	1.35	2.79	1.58	7.14	4.46	5.07	1.27	0.05	0.08	0.32	0.15		
W65 ne-monzanite (1)	56.62	0.48	21.34	1.18	2.18	0.29	5.64	4.91	5.63	0.50	0.06	0.06	0.36	0.27		
W401 monzanite (1)	56.88	1.02	19.78	2.94	2.39	0.63	5.88	4.69	5.00	0.01	0.12	0.15	0.30	0.30		
P1305 monzonite	58.5	0.49	19.3	2.7	1.7	0.94	4.6	3.5	6.9	0.17	0.16	0.20	0.22	<0.05		
P1301 qtz-brg monz	59.6	0.68	18.4	3.0	2.2	1.2	4.6	4.6	5.0	0.0	0.28	0.14	0.27	<0.05	1.0	3.6
W326 monzonite (1)	61.73	0.43	20.50	0.61	1.45	0.60	3.20	6.21	5.06	0.20	0.06	0.10	0.07	tr	3.0	13.9
W120 Syenite (1)	62.27	0.12	21.70	0.61	0.41	0.04	1.94	5.84	6.86	0.44	0.09	tr	tr	tr		
W230 alkalic granite (1)	68.20	0.14	16.44	0.77	0.42	0.02	0.58	3.70	9.66	0.06	0.11	0.06	tr	0.05		
Rocks of Special Origin:																
P1303 biotite pyroxenite	44.7	2.0	8.7	3.9	8.9	14.4	10.3	0.57	4.0	1.7	0.0	0.22	0.22	<0.05	0.8	2.4
P1304 biotite pyroxenite	43.5	1.6	7.1	8.1	9.2	12.0	13.7	0.82	2.1	0.54	0.13	0.19	0.47	<0.05	0.8	4.4

(1) analyses from Wahlstrom (1940)

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Table 38 Intrusives of the Phaneritic stocks: Normative Data
Central Front Range, east of the Continental Divide

	Q	or	ab	an	ne	C	ap	il	mt	hm	di	hy	ol	Wo	cc	DI
North Central Subprovince																
Monzonite Stock Audubon-Albion																
P1302 mafic Syenogabbro	—	15.6	18.3	17.5	—	—	1.3	2.0	4.9	—	18.5	4.5	16.2	—	—	33.9
W453 Syenogabbro mafic	—	21.1	19.9	22.8	3.7	-	1.3	2.9	2.5	—	13.7	—	11.4	—	—	44.7
P1306 nc-monzonite	—	31.7	19.4	16.7	4.3	-	2.0	2.3	6.7	-	13.0	-	3.4	-	-	55.3
W218 nc-monzonite	T	30.0	21.5	24.2	8.8	-	0.7	1.8	2.1	-	7.6	-	1.9	-	-	58.6
W65 nc-monzonite	-	33.4	32.5	19.7	4.8	-	0.7	1.7	1.9	-	4.2	—	—	-	—	70.7
W401 monzonite	0.5	29.5	34.3	18.1	—	-	0.7	2.0	4.2	-	4.4	—	—	0.2	0.7	69.3
P1305 monzonite	1.9	44.6	27.3	16.7	—	-	0.3	0.8	3.9	-	4.8	0.6	—	—	-	71.8
P1301 qtz-brg monz.	4.1	29.5	38.8	14.7	—	-	0.7	1.4	4.4	-	4.0	1.7	—	—	-	72.3
W326 monzonite	T	29.5	50.8	13.3	0.8	-	—	0.8	0.9	-	2.1	—	1.5	—	—	81.2
W120 Syenite	—	40.6	45.1	9.4	2.3	1.2	—	0.1	0.9	-	—	—	—	—	-	88.0
W230 alkalic granite	9.4	56.7	30.9	—	—	-	—	0.3	0.7	-	—	0.5	—	1.0	-	97.0

Table 1A Intrusives of the Phaneritic Stocks: Chemical Data
Central Front Range, east of the Continental Divide

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O^+	H_2O^-	MnO	P_2O_5	CO_2	U ppm	Th ppm
North Central Subprovince																
Monzonite Stock																
Caribou																
C4 monzonite (1)	51.43	0.85	19.35	5.32	4.70	3.05	7.09	3.54	3.52	0.35	0.08	—	0.60	—	—	--
C3 monzonite (1)	52.10	0.94	17.35	4.63	4.16	3.14	7.15	3.39	3.77	0.13	0.06	0.10	0.71	+.1		
P921 monzonite	53.0	0.82	18.0	4.5	4.5	3.0	6.9	3.9	4.2	0.46		0.20	0.64	0.15	2.2	6.2
C2 monzonite (1)	53.95	0.76	19.56	3.86	4.23	2.35	6.58	3.36	3.88	0.68	0.30	0.17	0.60	0.85		
P922 monzonite	54.0	0.74	17.5	3.9	4.1	2.5	5.6	3.6	5.6	0.67		0.16	0.66	1.0	0.7	6.8
P920 monzonite	55.5	0.75	17.5	2.8	5.3	2.2	5.7	3.9	5.0	0.59		0.18	0.62	<0.05	2.8	4.4
C1 qtz-bg. monzonite (1)	56.64	0.81	17.00	3.11	5.06	2.74	6.20	3.16	3.40	0.70	0.31	0.20	0.44	—		
Rocks of Special origin																
P919 Mica peridotite	45.7	0.62	7.3	3.6	7.3	18.3	6.9	0.72	2.8	2.5		0.22	0.20	3.2	1.3	4.3
North Bryan Mountain Stock																
P918A monzonite	53.5	0.98	16.2	3.9	5.5	3.4	7.0	3.2	4.0	0.76		0.18	0.68	0.20	1.4	7.0
P111 granite	68.0	0.36	15.4	1.9	1.4	0.64	2.2	3.2	5.6	0.58	0.14	0.04	0.13	0.12	7.2	35.4
P418 granite border-phase	69.6	0.34	14.7	1.6	1.6	0.63	2.0	3.1	5.9	0.45		0.06	0.14	0.14	7.6	26.0
P110 inclusions	71.0	0.36	14.5	1.7	1.0	0.46	1.5	2.9	5.8	0.42	0.06	0.10	0.08	<0.05	6.7	31.0

(1) analyses from Bastin and Hill (1917)

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Table 13 Intrusives of the Phaneritic Stocks: Normative Data
Central Front Range, east of the Continental Divide

	Q	or	ab	an	ne	C	ap	il	mt	hm	di	hy	ol	cc		DI
North Central Sub province																
Monzanite Stock																
Caribou																
C3 monzonite (1)	—	22.2	28.8	26.1	—	—	1.7	1.8	6.7	—	7.1	2.8	3.0	—		51.1
P921 monzonite	—	25.0	32.5	19.2	0.3	—	1.7	1.5	6.5	—	7.4	—	5.3	0.4		57.8
P922 monzonite	—	33.4	30.4	15.0	—	—	1.7	1.4	5.6	—	1.4	6.6	1.7	2.3		63.8
P920 monzonite	—	29.5	33.0	15.6	—	—	1.3	1.4	4.2	—	7.6	1.7	5.8	—		62.5
C1 qtz-brg. monz.(1)	7.6	20.0	26.7	22.2	—	—	1.0	1.5	4.4	—	4.8	10.4	—	—		54.3
North Bryan Mountain Stock																
P418A monzonite	0.5	23.4	27.2	17.8	—	—	1.7	1.7	5.6	—	10.0	10.8	—	—		51.6
P1111 granite	22.1	33.4	27.2	10.0	—	0.3	0.3	0.6	2.4	—	—	2.2	—	—		82.7
P418 granite border phase	23.6	35.0	26.2	8.6	—	[illegible]	0.3	0.6	2.3	—	0.5	2.6	—	—		84.8
P1113 inclusions	28.2	31.5	24.6	6.7	—	0.4	0.3	0.8	2.3	0.2	—	1.1	—	—		84.0

(1) analyses from
Bastin and Hill (1917)

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Table 5A Intrusives of the Phaneritic stocks: Chemical Data
Central Front Range, east of the Continental Divide

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O^+	H_2O^-	MnO	P_2O_5	CO_2	U_{ppm}	Th_{ppm}
South Central Subprovince																
Qtz-brg Monzonite Stock																
Bryan Mountain																
P1107 qtz-brg monz.	54.7	1.2	16.0	7.7	4.3	2.4	6.1	4.2	2.1	0.46	0.18	0.27	0.40	<0.05	5.4	31.0
P1108 quartz monz.	59.4	0.72	16.8	4.5	4.1	2.5	4.0	3.4	2.6	1.0	0.30	0.10	0.37	0.21	2.9	14.0
P1109 quartz monz	59.6	0.72	16.7	5.1	3.8	2.2	4.0	3.5	2.4	1.2	0.33	0.06	0.44	0.07	2.8	—
P1314 qtz-brg monz	60.6	0.57	16.7	3.1	2.0	3.9	4.0	4.4	3.6	0.24	0.38	0.12	0.33	<0.05	2.1	18.0
P1311 qtz-brg monz.	61.5	0.58	16.7	3.5	1.9	1.6	4.6	4.8	3.4	0.0	0.42	0.15	0.36	<0.05	2.4	18.1
P1313 qtz-brg. monz	62.1	0.54	17.7	3.1	1.7	1.6	3.9	4.8	3.7	0.07	0.26	0.10	0.36	<0.05	2.0	20.5
P1105 qtz-brg. monz	66.6	0.34	16.7	2.4	0.66	0.31	1.2	6.1	4.8	0.30	0.18	0.07	0.08	<0.05	48.0	135.0
P1310 quartz monz.	67.1	0.33	16.3	2.2	0.68	0.52	1.7	5.7	4.4	0.35	0.35	0.09	0.20	0.30	2.3	34.8
P1312 quartz monz	64.6	0.20	15.7	1.4	0.68	0.37	1.3	4.6	5.3	0.12	0.39	0.04	0.03	<0.05	4.3	31.4
P1106 granite (E. contact)	76.8	0.11	12.2	1.7	0.08	0.09	0.12	3.4	5.0	0.38	0.10	0.04	0.10	<0.05	5.8	58.0

Table 5B Intrusives of the Phaneritic stocks: Normative Data
Central Front Range, east of the Continental Divide

	Q	or	ab	an	nc	C	ap	il	mt	hm	di	hy	ol	cc		D.I
South Central Subprovince																
Qtz.-brg. monzonite Stock																
Bryan Mountain																
P1107 qtz.-brg. monz	8.1	12.2	35.6	18.6	–	–	1.0	2.3	11.1	–	9.1	1.9	–	–		55.4
P1108 quartz monz	17.2	15.6	28.8	16.7	–	2.1	1.0	1.4	6.5	–	–	9.0	–	0.5		61.6
P1109 quartz monz	18.7	14.5	29.3	17.0	–	2.1	1.0	1.5	7.4	–	–	6.9	–	–		62.5
P1314 qtz.-brg. monz.	7.9	21.1	37.2	15.3	–	–	0.7	1.1	4.4	–	3.5	8.3	–	–		66.2
P1311 qtz.-brg. monz.	10.2	20.0	40.3	14.2	–	–	1.1	1.2	5.1	–	6.8	1.3	–	–		70.6
P1313 qtz.-brg. monz.	10.9	21.7	40.3	16.1	–	–	1.0	0.9	4.4	–	0.4	3.8	–	–		78.1
P1105 qtz.-brg. monz.	10.5	28.4	51.3	4.2	–	–	0.3	0.6	1.2	–	0.6	0.5	–	–		90.2
P1310 quartz monz	13.7	26.1	48.2	5.8	–	–	0.3	0.6	1.6	–	–	1.8	–	0.6		93.9
P1312 quartz monz	19.5	30.6	38.8	6.4	–	0.1	–	0.5	1.6	–	–	0.9	–	–		88.8
P1106 granite (E. contact)	37.8	29.5	28.8	–	–	1.2	0.3	0.1	–	1.8	–	0.2	–	–		96.1

Table 6A Intrusives of the Phaneritic stocks: Chemical Data
Central Front Range, east of the Continental Divide

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O^+	H_2O^-	MnO	P_2O_5	CO_2	U ppm	Th ppm
South Central Subprovince																
Monzonite Stock																
Empire																
P570 ne-monzonite	49.4	1.0	15.6	6.1	5.1	3.7	8.6	4.1	4.0	—	—	0.24	0.83	—	11.5	—
P915 ne-monzonite	50.7	0.90	17.3	4.2	4.2	5.0	7.3	5.5	4.6	0.46		0.22	0.68	0.20	16.8	52.2
P917 ne-monzonite	52.0	0.84	17.8	4.0	3.9	2.3	6.5	6.0	4.8	0.54		0.22	0.56	0.22	18.0	66.0
P1317 ne-monzonite	52.5	0.82	18.4	4.2	3.4	2.7	6.3	5.5	4.3	0.11	0.22	0.20	0.72	<0.05	13.2	73.3
P1323 ne-monzonite	52.8	0.79	18.6	4.2	3.2	1.9	6.8	4.3	5.0	1.0	0.31	0.20	0.52	<0.05	10.6	42.9
P914 monzonite	54.2	0.70	18.5	3.7	3.4	1.9	6.4	5.2	4.1	0.76		0.18	0.40	0.40	13.0	33.0
P1318 monzonite	54.2	0.76	19.6	3.5	2.7	1.6	6.1	4.7	4.7	0.67	0.19	0.22	0.43	<0.05	8.7	44.8
P913 monzonite	54.4	0.81	18.5	3.6	3.3	2.1	6.5	4.3	4.3	0.70		0.16	0.50	0.36	5.6	18.3
P1320 qtz-bearing monz.	62.9	0.37	18.4	2.4	1.4	0.89	3.7	4.8	4.0	0.31	0.39	0.08	0.31	<0.05	3.8	34.9
P1321 leucosyenite	65.1	0.22	18.2	1.2	1.0	0.27	0.93	5.2	7.5	0.08	0.27	0.06	0.04	<0.05	15.4	49.9
Rocks of Special origin:																
P1324 Pyroxenite intrusive breccia	36.9	2.1	9.3	9.1	4.7	9.0	15.3	2.8	1.5	0.74	0.29	0.32	2.1	0.31	3.6	30.1
P1325 Pyroxenite intrusive breccia	41.6	1.6	9.6	5.4	7.4	11.2	14.4	1.2	2.9	0.95	0.25	0.27	2.1	0.09	3.4	12.9
P916 Hb-lamprophyre	42.6	1.4	13.1	6.1	8.5	6.6	13.7	2.7	2.0	1.1		0.36	1.4	0.66	5.0	25.0
P1331 Hb-rich schlieren	44.0	1.9	13.3	7.2	7.2	5.4	11.8	3.0	2.6	1.3	0.16	0.41	1.2	0.93	4.4	31.0
P1322 "hornblendite" incl.	45.6	1.3	10.8	6.2	7.4	6.8	13.4	2.9	2.2	0.76	0.34	0.33	1.2	0.11	—	—
E-34 diorite cumulate(1)	47.00	1.31	16.56	6.19	5.36	4.54	11.93	3.29	1.5	0.65	0.15	0.24	0.87	0.19	—	-
P1315 monzonite peg.	53.9	0.36	20.1	5.5	2.3	0.25	4.2	6.4	3.2	1.2	0.10	0.07	0.02	0.02	77.0	265.0

(1) from Braddock (1972)

Table 6B Intrusives of the Phaneritic stocks: Normative Data
Central Front Range, east of the Continental Divide

	Q	or	ab	an	ne	C	ap	il	mt	hm	di	hy	ol	cc		D.I.
South Central Subprovince																
Monzonite stock																
Empire																
P570 ne-monzonite	—	23.9	19.9	12.2	8.0	—	2.0	2.0	8.8	—	20.0	—	2.0	—		51.8
P915 ne-monzonite		27.2	18.9	8.9	15.0	—	1.7	1.7	6.0	—	17.0	—	1.8	0.5		
P917 ne-monzonite		28.4	21.8	7.5	15.8	—	1.3	1.7	5.8	—	16.0	—	0.5	0.5		
P1317 ne-monzonite		25.6	27.8	12.5	10.2	—	1.7	1.5	6.0	—	11.5	—	2.4	—		
P1323 ne-monzonite		29.5	26.7	16.7	5.1	—	1.3	1.5	6.0	—	10.7	—	1.5	—		
P914 monzonite		24.5	35.1	14.7	4.8	—	1.0	1.4	5.3	—	9.4	—	1.7	0.9		
P1318 monzonite		27.8	32.0	18.3	4.3	—	1.0	1.5	5.1	—	7.3	—	2.4	—		
P913 monzonite		25.6	36.2	18.6	—	—	1.3	1.5	5.3	—	6.2	1.4	2.0	0.8		
P1320 qtz-brg. monz	11.0	23.9	40.3	16.7	—	—	0.3	0.8	3.5	—	0.6	2.7	—	—		
P1321 leuco-syenite	3.6	44.5	44.0	3.9	—	—	—	0.5	1.9	—	0.5	1.0	—	—		

Table 7A. Porphyritic stocks; groundmass largely aphanitic: Chemical Data
Central Front Range, east of the Continental Divide

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O^+	H_2O^-	MnO	P_2O_5	CO_2	U_{ppm}	Th_{ppm}
Centers of intrusion:																
Northeastern mountain front																
sill near Lyons																
P1405 adamellite	68.7	0.14	16.0	1.0	1.1	0.55	3.4	2.9	3.7	1.2	0.39	0.06	0.12	0.78	4.0	5.4
P1406 adamellite	68.7	0.13	16.2	1.1	0.88	0.55	3.2	2.8	3.7	1.05	0.31	0.07	0.12	0.89	3.8	4.4
sill near Altona																
P1408 quartz latite	66.0	0.32	16.4	2.6	1.6	1.5	3.4	2.4	3.5	2.0	0.82	0.08	0.24	0.21	3.6	8.6
P1427 quartz latite	66.8	0.31	16.0	1.4	1.6	1.3	2.8	3.0	3.6	0.95	0.65	0.10	0.23	0.72	2.9	7.8
Jamestown																
P732 sodic leuco gr.	66.4	0.21	17.0	2.1	2.6	0.42	0.52	4.6	4.7	—	—	0.03	0.12	—	18.0	18.9
Sunset																
P532 sodic syenite	59.5	0.59	16.5	4.0	3.0	1.4	2.8	5.5	4.2	—	—	0.16	0.31	(0.63)(1)	6.6	14.4
P535 sodic syenite	58.6	0.58	16.2	3.6	3.7	1.0	3.2	5.2	4.1	—	—	0.30	0.25	(2.5)(1)	6.6	14.4
P526 sodic granite	63.8	0.48	16.5	3.3	2.0	0.88	2.5	5.2	4.0	—	—	0.24	0.19	(0.11)(1)	6.4	26.0
P511-1 sodic quartz syenite	63.5		17.0	1.8	1.3	0.68	3.4	5.3	4.0	0.56	0.18	0.14	0.18	0.54	—	—
Apex																
P1000 sodic quartz syenite	60.5	0.54	17.4	3.3	3.2	1.1	3.9	4.7	3.6	0.80	0.12	0.11	0.28	0.71	7.4	24.0
P1103 sodic leuco syenite	64.0	0.31	17.5	2.1	0.66	0.39	2.4	5.2	7.0	0.27	0.13	0.17	0.08	<0.05	7.1	24.0
P1001 sodic granite	66.0	0.31	16.6	2.2	1.7	0.66	2.0	5.0	3.9	0.78	0.08	0.05	0.14	0.61	4.7	40.0

(1) loss on ignition

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This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards or nomenclature.

Table 7A (cont.) Porphyritic stocks, groundmass largely aphanitic
Central Front Range, east of the Continental Divide

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O^+	H_2O^-	MnO	P_2O_5	CO_2	U_{ppm}	Th_{ppm}
Centers of intrusion:																
Central City																
P400 sodic granite	64.8	0.38	16.90	2.2	2.2	0.58	2.4	5.6	3.8	—	—	0.09	0.15	—	9.3	35.7
P807 sodic granite	65.1	0.56	17.6	1.7	0.48	0.21	1.1	6.0	4.3	0.92	0.28	0.07	0.21	<0.05	14.1	31.7
P42 sodic granite	66.78	0.32	16.05	1.69	2.09	0.46	1.65	5.49	4.74	0.32	0.10	0.09	0.13	0.04	7.8	32.2
Idaho Springs																
P348 sodic syenite	59.8	0.68	17.2	3.2	1.9	1.0	4.3	5.3	5.2	0.35	0.15	0.22	0.17	0.06	11.5	45.0
P1456 sodic syenite	62.4	0.44	17.6	2.2	1.5	0.68	3.0	6.0	5.1	0.15	0.35	0.16	0.15	0.09	9.6	20.6
Dumont-Fall River																
P822 sodic granodiorite	62.6	0.51	17.1	2.6	1.6	1.0	3.7	6.1	3.4	0.38	0.10	0.08	0.25	0.36	3.6	21.0
P574 sodic granite	66.2	—	16.5	1.4	1.6	0.95	1.9	5.2	4.5	0.97	0.0	0.09	0.11	0.14	3.2	17.5
Empire																
P912 sodic granodiorite	62.3	0.52	16.4	2.6	1.7	1.2	3.0	4.9	3.8	1.2		0.10	0.30	0.94	5.9	29.0
1-107 Hb granodiorite por. (1)	58.1	0.79	18.4	4.3	2.8	2.0	4.6	4.1	1.7	2.4		0.08	0.48	0.05	—	—
4-125D " " " (1)	62.09	0.51	17.62	2.66	2.09	1.35	5.29	4.34	2.81	0.35	0.12	0.14	0.29	0.02	—	—
5-2 " " " (1)	63.6	0.50	16.6	2.7	3.0	1.6	3.8	3.0	3.1	1.2		0.02	0.32	0.0	—	—
4-165B " " " (1)	63.8	0.58	16.2	2.7	2.4	1.5	5.0	3.5	3.2	0.44		0.10	0.44	0.01	—	—
4-167B bi. granodio. por. (1)	65.4	0.39	16.8	2.6	2.0	1.08	3.23	3.3	3.6	0.74		0.02	0.29	0.0	—	—
4-196 " " " (1)	66.32	0.38	16.22	2.23	1.94	1.05	2.35	3.76	3.76	1.10	0.29	0.05	0.23	0.01	—	—
10-1 " " " (1)	68.62	0.27	15.82	1.20	1.34	0.67	2.98	3.75	3.66	0.45	0.11	0.03	0.14	0.31	—	—
10-318 " " " (1)	69.4	0.30	16.2	1.5	0.93	0.57	1.6	4.6	3.8	0.98		0.02	0.18	0.01	—	—

(1) from Braddock (1969)

Table 7B Porphyritic stocks, groundmass largely aphanitic : Normative Data Central Front Range, east of the Continental Divide

	Q	or	ab	an	ne	C	ap	il	mt	hm	di	hy	ol	wo	cc	DI
Centers of Intrusion:																
Northeastern mountain front																
Sill near Lyons																
P1405 adamellite	31.6	21.7	24.6	11.1	—	3.2	0.3	0.2	1.4	—	—	2.5	—	—	1.8	77.9
P1406 adamellite	33.2	21.7	23.6	9.4	—	4.2	0.3	0.1	1.6	—	—	2.2	—	—	2.0	78.5
Sill near Altona																
P1408 qtz. latite	29.5	20.6	20.4	14.7	—	3.3	0.3	0.6	2.3	—	—	4.9	—	—	0.5	70.5
P1407 qtz. latite	29.3	21.1	25.1	8.6	—	4.1	0.3	0.6	2.1	—	—	5.0	—	—	1.6	75.6
Jamestown																
P732 sodic leuco gr.	18.9	22.8	38.8	7.5	—	3.5	—	0.5	3.0	—	—	3.6	—	—	—	85.5
Sunset																
P532 sodic syenite	4.3	25.0	46.6	7.8	—	—	0.7	1.2	5.8	—	3.4	3.3	—	—	—	75.9
P535 sodic syenite	4.7	24.5	44.0	8.6	—	—	0.7	1.1	5.3	—	2.2	5.7	—	—	—	73.2
P526 sodic granite	12.1	23.9	44.0	9.7	—	—	0.7	0.9	4.9	—	0.6	2.4	—	—	—	80.0
P541-1 sodic quartz syenite	10.2	23.9	44.5	10.8	—	—	0.3	0.9	2.5	—	4.4	—	—	0.2	—	78.6
Apex																
P1000 sodic quartz syenite	9.6	21.1	39.8	15.9	—	—	0.7	1.1	4.9	—	1.4	4.0	—	—	—	70.5
P1133 sodic leuco syenite	3.3	41.1	44.0	3.9	—	—	0.3	0.6	1.6	—	2.2	—	—	1.9	—	88.4
P1001 sodic granite	16.5	22.8	42.4	9.2	—	—	0.3	0.6	3.2	—	—	3.0	—	—	—	81.9

Table 7B (Cont.) Porphyritic stocks, groundmass largely aphanitic: Normative Data
Central Front Range, east of the Continental Divide

	Q	or	ab	an	ne	c	ap	il	mt	hm	di	hy	ol	wo	cc	DI
Centers of Intrusion																
Central City																
P400 sodic granite	11.8	22.3	47.2	10.0	—	—	0.3	0.8	3.2	—	0.9	1.7	—	—	—	81.3
P527 sodic granite	10.9	25.6	50.8	5.6	—	1.0	0.3	1.0	—	2.7	—	0.7	—	—	—	87.5
P42 sodic granite	12.3	27.3	46.6	5.3	—	—	0.3	0.6	2.5	—	1.9	2.2	—	—	—	86.2
Idaho Springs																
P348 sodic syenite	1.7	30.6	44.5	8.1	—	—	0.3	1.4	4.6	—	5.4	—	—	2.3	—	76.9
P1456 sodic syenite	2.5	30.0	50.8	6.1	—	—	0.3	0.8	3.2	—	4.7	—	—	0.7	0.2	83.3
Dumont-Fall River																
P822 sodic quartz syenite	7.2	20.0	51.3	9.4	—	—	0.7	0.9	3.7	—	2.5	0.1	—	—	—	78.6
P574 sodic granite	13.3	26.7	44.0	7.8	—	0.2	0.3	0.6	2.1	—	—	3.6	—	—	—	84.0
Empire																
P912 sodic granodiorite	14.3	22.3	41.4	7.2	—	1.6	0.7	1.1	3.7	—	—	3.3	—	—	2.1	78.0
1-107 Hb granodiorite por. (1)	16.6	10.0	34.5	18.6	—	3.0	1.1	1.5	6.2	—	—	5.4	—	—	0.1	61.1
4-165D " " " (1)	14.2	16.6	36.6	20.4	—	—	0.7	1.0	3.9	—	2.7	3.0	—	—	—	67.4
5-2 " " " (1)	23.8	18.3	25.1	16.4	—	2.3	0.8	1.0	3.9	—	—	6.5	—	—	—	67.2
1-165B " " " (1)	19.3	19.6	29.4	18.8	—	—	1.0	1.1	3.9	—	2.2	2.7	—	—	—	68.3
1-164B Bio. granodio. por. (1)	24.8	21.3	27.7	13.6	—	2.5	0.7	0.7	3.8	—	—	3.4	—	—	—	73.8
4-196 " " " (1)	23.7	22.2	31.7	9.9	—	2.4	0.5	0.7	3.2	—	—	3.9	—	—	—	77.6
10-1 " " " (1)	26.5	21.6	31.6	11.5	—	1.5	0.3	0.5	1.7	—	—	2.7	—	—	0.7	79.7
10-31B " " " (1)	24.5	22.4	38.9	6.5	—	2.2	0.4	0.6	2.2	—	—	1.4	—	—	—	85.8

(1) from Braddock (1969)

Table 8A Porphyritic Dikes, groundmass largely aphanitic, intermediate [illegible] Chemical Data
Central Front Range, east of the Continental Divide

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O^+	H_2O^-	MnO	P_2O_5	CO_2	U_{ppm}	Th_{ppm}
Centers of Intrusion:																
Jamestown																
P523 rhyolite	72.2	0.02	15.6	0.8	1.6	0.14	1.6	3.6	4.0	—	—	0.05	0.06	(0.34)(1)	1.8	4.5
Sunset-Ward																
P557 Sodic Syenite	60.2	0.74	17.2	3.5	2.0	1.3	3.6	5.6	4.2	0.82	0.38	0.15	0.29	0.07	5.4	15.7
P910 granodiorite	66.5	0.28	16.8	1.4	2.0	1.0	3.6	3.3	3.1	1.2		0.10	0.18	0.56	3.2	16.3
P529 granodiorite	68.0	0.27	14.7	2.2	3.8	0.92	2.5	3.9	2.6	—	—	0.12	0.21	(0.64)(1)	3.4	6.3
Sugarloaf																
P903 Sodic quartz syenite	63.4	0.48	17.1	2.9	1.2	1.0	2.6	5.7	4.4	0.50		0.10	0.24	0.49	5.8	21.0
Nederland																
P540 granodiorite	59.7	0.65	15.4	3.8	3.6	1.9	3.1	4.6	3.9	—	—	0.14	0.39	(2.1)(1)	5.0	14.4
Central City																
P1101 Sodic granite	64.8	0.39	17.4	2.5	1.1	0.50	2.6	6.0	3.0	0.47	0.20	0.12	0.18	0.41	11.4	19.7
P809 Sodic granite	65.6	0.45	16.6	3.0	0.98	0.37	1.5	5.8	4.2	0.60	0.17	0.07	0.18	0.08	7.5	35.5
P808 Sodic granite	65.6	0.40	17.0	3.3	0.22	0.38	0.41	5.2	4.9	1.48	0.62	0.02	0.10	<0.05	19.0	46.1
P370 Sodic granite	68.3	0.12	15.5	1.1	2.6	0.27	1.3	4.5	4.3	[illegible]	[illegible]	0.10	0.06	(1.2)(1)	11.0	30.0
Idaho Springs																
P350 Sodic Syenite	65.1	0.27	18.0	2.6	1.2	0.12	0.49	6.9	4.2	—	—	0.06	0.10	(0.35)(1)	11.6	36.0
P310 granite	70.0	0.16	13.2	2.1	5.0	0.24	1.4	2.0	5.2	—	—	0.16	0.14	(0.12)(1)	4.9	14.4
Dumont-Fall River																
P351 Sodic Quartz syenite	60.0	0.60	18.0	6.3		1.2	1.9	5.8	3.4	—	—	0.16	0.26	(2.2)(1)	9.4	38.0
P562 Sodic quartz syenite	60.4	0.33	17.0	6.6		0.15	3.0	5.4	3.9	—	—	0.17	0.15	(2.6)(1)	12.2	30.5
P724 Sodic granite	67.2	0.26	15.8	1.9	1.2	0.62	2.0	4.6	3.6	1.2	0.22	0.14	0.24	0.88	4.6	14.4

(1) loss on ignition

Table 8B Porphyritic Dikes, groundmass, largely aphanitic, intermediate CaO: Chemical Data: Central Front Range, east of the Continental Divide

	Q	or	ab	an	ne	c	ap	il	mt	hm	di	hy	ol	cc	D.I.
Centers of intrusion															
Jamestown															
P523 rhyolite	31.0	23.9	30.4	8.1	—	2.3	—	—	1.2	—	—	2.6	—	—	85.3
Sunset-Ward															
P557 Sodic Syenite	4.1	25.0	47.2	9.4	—	—	0.7	1.4	4.9	0.2	2.3	1.0	—	—	76.3
P910 granodiorite	27.3	18.3	27.8	13.3	—	3.2	0.3	0.6	2.1	—	—	4.6		1.3	73.4
P529 granodiorite	26.4	15.6	33.0	11.7	—	1.1	0.3	0.6	3.3	—	—	7.6	—	—	75.0
Sugarloaf															
P903 Sodic quartz syenite	8.5	26.1	48.2	7.8	—	0.1	0.7	0.9	2.8	1.0	—	2.5	—	—	82.8
Nederland															
P540 granodiorite	9.4	22.8	38.8	10.0	—	—	1.0	1.2	5.6	—	2.0	6.2	—	—	71.0
Central City															
P1101 Sodic granite	12.5	17.8	50.8	11.7	—	—	0.3	0.8	2.5	—	0.2	1.1	—	—	81.1
P809 Sodic granite	12.1	25.0	49.3	6.7	—	—	0.3	0.8	2.1	1.6	—	1.0	—	—	86.4
P808 Sodic granite	15.3	28.9	44.0	1.4	—	2.6	—	0.5	—	3.3	—	0.9	—	—	88.2
P370 Sodic granite	20.5	25.6	38.2	6.4	—	1.0	—	0.1	1.6	—	—	4.5	—	—	84.3
Idaho Springs															
P350 Sodic Syenite	7.7	25.0	58.2	2.5		1.1	—	0.5	3.2	0.3	—	0.3	—	—	90.9
P310 granite	32.3	30.6	16.8	6.1	—	2.0	—	0.3	0.3	3.0	—	—	8.0	—	79.7
Dumont-Fall River															
P351 Sodic quartz syenite	8.2	20.0	49.2	7.5	—	1.9	0.7	1.2	5.1	0.6	—	3.0	—	—	77.4
P562 Sodic quartz syenite	7.2	22.8	45.6	10.9	—	—	—	0.6	4.6	—	3.6	1.4	—	—	75.7
P724 Sodic granite	21.8	21.1	39.8	9.2	—	1.0	0.3	0.5	2.8	—	—	2.0	—	—	81.7

Table 9A Late stage CaO-poor differentiates : Chemical Data
Central Front Range, east of the Continental Divide

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O^+	H_2O^-	MnO	P_2O_5	CO_2	Uppm	Thppm
Centers of Intrusion:																
Jamestown-Gold Hill																
P633 quartz bostonite	68.5	0.07	16.1	2.3	1.4	0.26	0.64	4.3	5.5	—	—	0.02	0.04	(0.98)(1)	38.3	57.1
P559 quartz bostonite	69.4	0.05	15.8	3.0	1.5	0.31	0.42	4.0	5.6	—	—	0.02	0.04	(1.0)(1)	41.9	45.7
P548 potassic quartz bostonite	69.6	0.05	15.7	1.1	1.4	0.28	0.18	0.70	10.2	—	—	0.02	0.06	(0.94)(1)	57.8	43.1
P629 quartz bostonite	70.4	0.05	15.4	1.6	1.0	0.03	0.60	5.7	4.7	—	—	0.03	0.03	(0.18)(1)	22.5	43.9
Sunset																
P506 bostonite	65.3	0.14	17.0	2.4	29	0.11	0.20	5.4	5.4	—	—	0.04	0.09	(0.15)(1)	8.2	47
Rollinsville-N. Elpin																
P597 quartz bostonite	68.8	0.10	16.6	1.6	1.1	0.14	0.08	3.0	7.6	—	—	0.03	0.05	(0.83)(1)	18.9	63.0
P599 quartz bostonite	68.9	0.15	16.4	1.9	1.9	0.01	0.08	5.4	5.0	—	—	0.02	0.06	(0.06)(1)	13.5	13.0
Central City																
P368 bostonite	63.1	0.20	19.6	1.8	0.86	0.17	0.15	5.2	6.6	—	—	0.01	0.03	(1.3)(1)	11.2	36.0
P399 bostonite	65.5	0.45	17.6	1.9	2.8	0.24	0.35	5.4	5.0	—	—	0.01	0.21	(0.4)(1)	13.5	55.2
P118 quartz bostonite	67.36	0.01	16.44	1.18	2.39	0.19	0.30	5.94	5.90	0.37	0.73	0.08	0.15	0.0	32.5	90.0
P825 Potassic quartz bostonite	68.1	0.08	16.7	1.1	0.13	0.26	0.09	0.32	12.0	0.91	0.09	0.04	0.05	<0.05	24.3	122.7
P168 quartz bostonite	68.56	0.14	15.88	3.06	1.19	0.10	0.00	4.80	5.44	0.64	0.20	0.03	0.04	0.01	69.8	255.8
P824 quartz bostonite	69.0	0.14	15.4	3.3	0.15	0.06	0.13	4.6	6.3	0.67	0.16	0.10	0.05	0.06	74.6	350.0
Idaho Springs																
P350 bostonite	65.1	0.24	18.0	2.6	1.2	0.12	0.49	6.9	4.2	—	—	0.06	0.10	(0.39)(1)	10.7	36.0
P465 bostonite	65.4	0.12	16.6	0.9	2.8	0.25	0.16	3.6	7.9	—	—	0.26	0.05	(1.9)(1)	138.6	190.5
P591 bostonite	65.5	0.10	16.2	3.4	1.6	0.16	0.37	3.8	6.8	—	—	0.14	0.05	(1.4)(1)	46.9	157.5
P36 quartz bostonite	70.8	0.08	14.6	1.9	2.8	0.06	0.06	2.1	7.3	—	—	0.20	0.08	(0.08)(1)	13.8	28.1
P832 quartz bostonite	72.4	0.10	15.6	0.9	0.11	0.04	0.37	5.6	4.6	0.33	0.10	0.0	0.06	<0.05	7.0	36.8

(1) loss on ignition

Table 9A (Cont.) Late stage CaO-poor differentiates: Chemical Data
Central Front Range, east of the Continental Divide

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O^+	H_2O^-	MnO	P_2O_5	CO_2	U_{ppm}	Th_{ppm}
Centers of Intrusion:																
Empire - Lawson																
P642 bostonite	64.6	0.15	19.2	1.8	1.2	0.06	0.24	6.0	6.2	—	—	0.03	0.06	(0.46)(1)	13.0	32.5
P586 altered quartz bostonite	70.6	0.18	16.4	2.7	1.2	0.06	0.02	0.28	5.4	—	—	0.03	0.06	(3.2)(1)	13.4	76.0

(1) loss on ignition

Table 9B Late stage CaO-poor differentiates: Normative Data
Central Front Range, east of the Continental Divide

	Q	Or	ab	an	ne	c	ap	il	mt	hm	di	hy	ol	cc	D.I.
Centers of Intrusion:															
Jamestown - Gold Hill															
P633 quartz bostonite	20.7	32.3	36.2	3.1	–	2.0	–	–	3.2	–	–	1.5	–	–	89.2
P559 quartz bostonite	23.0	33.4	34.1	1.9	–	2.3	–	0.15	4.4	–	–	0.9	–	–	91.3
P548 potassic quartz bostonite	24.9	60.6	5.8	0.8	–	3.2	–	–	1.6	–	–	2.3	–	–	91.3
P629 quartz bostonite	17.8	27.8	48.2	2.5	–	–	–	–	2.3	–	0.5	0.3	–	–	93.8
Sunset															
P506 bostonite	11.4	31.7	45.6	1.1	–	1.9	–	0.3	3.5	–	–	3.3	–	–	88.7
Rollinsville - N. Gilpin															
P597 quartz bostonite	21.7	45.1	25.2	0.3	–	3.4	–	0.1	2.3	–	–	1.6	–	–	92.0
P599 quartz bostonite	17.8	29.5	45.6	–	–	2.1	–	0.3	3.5	–	–	3.3	–	–	92.9
Central City															
P368 bostonite	7.0	39.0	44.0	0.8	–	3.6	–	0.5	2.1	0.3	–	0.4	–	–	89.6
P399 bostonite	13.1	29.5	45.6	0.8	–	3.1	0.3	0.8	2.8	–	–	3.5	–	–	88.2
P118 quartz bostonite	8.1	35.0	50.3	0.6	–	–	0.3	–	1.9	–	–	3.8	–	–	93.4
P825 potassic quartz bostonite	19.6	71.2	2.6	0.6	–	3.0	–	0.1	–	1.1	–	0.6	–	–	93.4
P108 quartz bostonite	19.5	32.8	40.3	–	–	2.0	–	0.3	3.5	0.6	–	0.2	–	–	92.6
P824 quartz bostonite	17.9	37.2	38.8	0.6	–	0.8	–	0.1	–	3.4	–	0.1	–	–	93.9
Idaho Springs															
P350 bostonite	7.7	25.0	58.2	2.5	–	1.1	–	0.5	3.2	0.3	–	0.3	–	–	90.9
P465 bostonite	11.4	46.7	30.4	0.8	–	1.8	–	0.3	1.4	–	–	5.2	–	–	89.5
P581 bostonite	16.4	40.1	32.0	1.9	–	1.9	–	0.1	4.9	–	–	0.7	–	–	88.5
P36 quartz bostonite	28.5	43.3	17.8	0.3	–	3.1	–	0.2	2.8	–	–	4.0	–	–	89.6
P832 quartz bostonite	21.4	27.2	47.1	1.9	–	0.7	–	0.1	–	1.0	–	0.1	–	–	95.7

Table 9B (cont.) Late stage CaO-poor differentiates: Normative Data
Central Front Range, east of the Continental Divide

	Q	Or	ab	an	ne	C	ap	il	mt	hm	di	hy	ol	cc		D.I.
Centers of intrusion																
Empire-Lawson P642 bostonite	5.1	36.7	50.9	1.1	—	2.1	—	0.3	2.6	—	—	0.7	—	—		92.7

Table 10 Front Range exclusive of East-Central Region: Chemical Data

	County	SiO2	TiO2	Al2O3	Fe2O3	FeO	MgO	CaO	Na2O	K2O	H2O+	H2O-	MnO	P2O5	CO2		U ppm	Th ppm	Th/U
Front Range North																			
Manhattan-Home District																			
P1326 hornblende feldspar porphyry dike	Larimer	66.7	0.32	16.2	2.1	1.4	1.2	2.8	4.6	3.2	1.0	0.34	0.12	0.17	0.24		1.9	4.5	2.37
P1327 quartz porphyry dike	"	67.8	0.12	16.1	0.84	0.44	0.58	2.5	4.1	2.8	1.3	0.48	0.05	0.04	2.2		1.4	3.5	2.50
Front Range, West-Central																			
Montezuma Stock, Roberts Tunnel																			
661+15	Summit	62.1	0.77	16.1	3.1	2.9	2.0	3.5	3.3	3.4	1.3	0.4	0.04	0.44	0.14		7.2	28.5	3.96
361+00	"	63.6	0.68	16.4	1.6	3.0	1.5	3.0	3.2	4.9	0.86	0.03	0.10	0.32	<0.05		5.8	12.2	2.10
134+00	"	65.4	0.77	15.6	2.3	2.5	1.6	3.2	3.3	4.1	0.74	0.02	0.10	0.34	<0.05		6.6	20.0	3.03
651+10.5	"	65.4	0.68	15.7	2.5	2.4	1.6	3.4	3.2	3.9	0.74	0.02	0.07	0.36	<0.05		8.2	30.0	3.66
671+00	"	65.7	0.63	15.4	2.5	2.1	1.5	2.8	3.2	3.8	1.2	0.04	0.04	0.32	0.18		9.8	30.4	3.10
582+50	"	65.7	0.66	15.8	2.0	2.2	1.3	3.2	3.2	4.2	0.72	0.10	0.09	0.30	0.10		6.0	17.8	2.97
564+00	"	66.0	0.77	15.3	2.3	2.4	1.5	3.4	3.3	3.6	0.74	0.02	0.12	0.32	<0.05		6.4	21.2	3.31
690+13	"	67.4	0.59	15.1	1.6	1.2	1.1	1.1	3.0	5.0	0.83	0.06	0.05	0.07	<0.05		3.2	14.8	4.62
412+39	"	75.4	0.21	13.1	0.76	0.76	0.30	1.7	2.9	4.0	0.47	0.02	0.10	0.07	<0.05		12.2	24.8	2.03
Breakenridge sill																			
Br-1, Near Wellington Mine	Summit	60.0	0.80	15.8	2.4	3.6	2.5	4.3	3.2	3.1	2.1	0.22	0.14	0.46	1.3		3.0	19.5	6.50
Br-3 Gk.9, South end reservoir	"	64.4	0.43	16.0	1.2	2.5	1.1	2.3	4.9	4.3	1.3	0.32	0.13	0.26	0.75		4.6	17.9	3.89
Br-6 east side reservoir	"	68.0	0.34	15.6	2.1	1.2	1.0	2.2	4.7	3.4	0.92	0.18	0.13	0.24	0.05		4.2	15.0	3.57
Front Range, Southwest																			
Whitehorn Stock, north & of Salida																			
BH-2 dense border phase? SE Contact alt.	Chaffee	56.1	1.2	23.4	7.4	2.0	1.9	0.18	1.4	4.6	0.99	0.24	0.03	0.13	<0.05		3.5	21.0	6.00
BH-1 interior	Chaffee	57.8	0.98	17.4	3.4	4.2	3.0	6.1	3.0	2.7	0.91	0.17	0.14	0.40	<0.05		0.8	7.9	9.87
BH-5 interior	Fremont	58.2	0.94	17.2	3.8	3.6	2.5	5.6	3.1	3.0	0.84	0.16	0.18	0.46	<0.05		1.3	4.9	3.78
BH-6 interior	Fremont	59.7	0.83	17.6	3.0	3.5	2.3	5.5	3.2	3.0	0.89	0.44	0.15	0.44	0.66		1.3	5.8	4.46
BH-3 interior	Fremont	60.9	0.73	16.8	2.7	3.2	2.5	5.1	3.4	3.0	0.85	0.16	0.13	0.30	0.14		1.5	7.8	4.81
BH-7 interior	Chaffee	63.9	0.56	16.9	2.1	2.3	1.9	4.2	4.1	2.9	0.75	0.18	0.11	0.22	0.06		1.4	4.9	3.50
BH-4 dense border phase NE Contact	Fremont	64.5	0.52	17.4	2.3	2.0	1.3	4.1	3.2	3.6	0.89	0.23	0.10	0.26	<0.05		1.8	7.0	3.89

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This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards or nomenclature.

Table 11 Wet Mountains: Chemical Data

Sample	Rock Type and Location	County	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O^+	H_2O^-	MnO	P_2O_5	CO_2	F	U_{ppm}	Th_{ppm}	Th/U
Wet Mountains:																				
	Stock at MT Fairview, Rosita Hills,	Custer																		
WM425A	Syenogabbro		47.9	1.6	17.3	4.7	5.4	5.3	9.9	3.2	2.8	0.9	0.09	0.18	0.77	<.05	—	4.1	6.4	1.56
WM423B	Syenogabbro		44.3	1.3	17.8	3.8	5.4	4.0	9.9	4.2	3.1	0.81	0.07	0.20	0.83	0.08	—	9.0	10.8	1.20
WM703	Syenogabbro		49.4	1.41	16.8	4.5	5.2	4.4	8.9	4.0	3.2	0.30	0.49	0.14	0.75	0.11	—	3.6	9.5	2.63
WM704	Trachy monzonite, dense		53.7	0.94	17.0	3.9	3.4	2.5	6.3	3.6	3.9	1.11	0.41	0.14	0.48	2.1	—	2.6	9.5	3.65
WM700	syenomonzonite		54.7	1.0	18.7	3.7	2.8	2.3	5.5	4.9	4.6	0.83	0.27	0.18	0.51	0.09	—	4.8	17.1	2.81
WM705	fine border, chill phase		60.7	0.74	16.0	4.5	1.6	2.7	3.1	4.4	3.8	1.6	0.27	0.10	0.44	<0.05		3.4	9.8	2.88
WM422A	" " " "		62.2	0.60	16.1	3.1	2.4	1.9	3.6	4.1	3.9	1.1	0.32	0.12	0.45	0.08	—	3.4	9.6	2.82
WM702	Andesite inclusion in Syeno gb.		58.2	0.89	21.0	3.7	0.96	1.0	3.9	4.2	4.5	0.36	0.47	0.07	0.31	<0.05	—	2.9	25.0	8.62
WM701	Bunker andesite		58.6	0.87	17.5	3.3	2.5	2.1	4.8	4.9	4.4	0.20	0.33	0.16	0.36	<0.05		5.0	19.0	3.80
WM421	Bunker andesite		58.7	0.74	18.0	3.4	2.0	1.7	4.2	5.3	4.3	0.54	0.19	0.16	0.35	<0.05	—	5.6	12.3	2.20
	Lamprophyres cut Volcanics																			
	MT Tyndell	Custer																		
WM428			46.9	1.5	14.5	4.4	6.0	9.4	9.3	3.7	1.9	1.3	0.14	0.18	0.41	0.08	—	2.4	3.6	1.50
WM430			46.5	1.4	14.4	4.7	5.4	10.2	9.4	3.6	2.0	1.6	0.05	0.19	0.78	<0.05	—	5.6	4.0	0.71
	Rhyolite quartz porphyry																			
	plug near Antrim Mine	Custer																		
WM709			73.1	0.08	12.8	1.6	0.20	0.40	0.50	2.9	4.2	1.7	2.3	0.19	0.00	<0.05	—	14.4	38.0	2.64
WM708			74.7	0.07	13.4	0.80	0.72	0.00	0.33	5.3	4.3	0.59	0.51	0.17	1.00	<0.05	—	12.8	39.2	3.06
WM316			75.8	0.05	12.95	1.01	0.20	0.20	0.31	4.05	4.03	0.66	1.15	0.13	0.01	0.01	0.18	19.2	39.0	2.03
WM4182			75.1	0.06	13.3	0.59	0.16	0.26	0.34	3.6	4.2	0.9	1.1	0.14	0.00	<0.05	—	13.1	35.5	2.71
	plug east of Querida																			
WM431			76.9	0.06	12.7	0.53	0.11	0.07	0.21	2.8	4.1	0.34	0.9	0.12	0.02	<0.05		22.0	23.5	1.07

nomenclature.

Table 12 Sangre De Cristo Range : Chemical Data

	County	SiO2	TiO2	Al2O3	Fe2O3	FeO	MgO	CaO	Na2O	K2O	H2O+	H2O-	MnO	P2O5	CO2	Uppm	Thppm	Th/U
Stockton Cottonwood Peak																		
WSW of Silver Cliff Colo																		
1: WM649	Custer	55.7	1.0	17.8	4.0	3.9	2.8	5.5	4.0	3.3	0.91	0.07	0.05	0.72	0.17	1.1	8.0	7.27
WM 648	"	58.5	0.90	17.0	2.1	3.8	2.8	4.8	4.1	3.4	0.97	0.05	0.10	0.55	0.05	1.1	5.0	4.54
WM651	"	58.5	1.0	17.4	3.2	3.8	2.2	4.8	4.2	3.7	0.55	0.03	0.13	0.65	<0.05	1.4	9.1	6.50
WM650	"	73.5	0.27	14.2	1.0	0.78	0.44	1.4	4.2	3.9	0.48	0.04	0.03	0.09	<0.05	2.2	15.6	7.09
WM 647	"	73.9	0.21	13.8	0.85	0.32	0.18	0.82	4.0	4.4	0.65	0.25	0.05	0.03	0.21	1.7	14.1	8.29

Table 13 Park Range : Chemical Data

	County	SiO2	TiO2	Al2O3	Fe2O3	FeO	MgO	CaO	Na2O	K2O	H2O+	H2O-	MnO	P2O5	CO2	Uppm	Thppm	Th/U
Mosquito - Range:																		
Alma district, flank of Mt.																		
Bross near head of Buckskin Gl.																		
Al-2	Park	55.7	0.96	17.4	4.6	4.4	3.0	7.0	3.1	2.3	1.1	0.08	0.16	0.64	<0.05	1.7	4.3	2.53
Al-1	Park	67.4	0.42	16.6	1.6	1.9	1.2	3.3	3.5	3.4	0.67	0.06	0.09	0.18	<0.05	1.4	6.2	4.43
Ten-Mile Range																		
Climax area, Colo. 91.																		
Cl-1 3 mi North of Climax	Summit	66.8	0.34	15.5	1.9	1.4	1.2	1.8	3.9	3.6	1.5	0.70	0.08	0.23	0.68	3.8	8.8	2.31
Cl-2 5 mi North of Climax	Summit	67.0	0.38	14.9	1.8	1.5	1.1	2.0	4.0	3.4	1.3	0.59	0.09	0.22	1.1	3.7	11.2	3.03

Table 14 Sawatch Range: Chemical Data

	County	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O^+	H_2O^-	MnO	P_2O_5	CO_2	U ppm	Th ppm	Th/U
Central Region [illegible]																		
Stock near Twin Lakes																		
ME-1 South part, East of Winfield	Chaffee	69.6	0.45	15.5	1.8	1.5	1.0	2.8	4.1	2.9	0.52	0.05	0.06	0.19	<0.05	1.6	9.9	6.19
TZ-1 North part, West of Twin L.	Lake	70.1	0.36	14.6	1.7	1.4	1.0	2.4	4.1	3.3	0.55	0.13	0.05	0.16	<0.05	2.4	6.1	2.54
ME-2 North part, [illegible] west of Twin	Lake	70.3	0.43	15.2	1.7	1.3	1.0	2.8	4.1	3.0	0.40	0.04	0.06	0.18	<0.05	2.1	10.0	4.76
ME-3 North part, [illegible] E. of [illegible]	Lake	70.6	0.36	15.2	1.3	1.4	0.80	2.9	3.7	2.8	0.68	0.06	0.08	0.12	0.10	3.0	5.9	1.97
[illegible]																1.9	10.8	
6 110																1.0	5.8	
Collegiate Range																		
Mt. Princeton batholith																		
Pr-3 Mt Princeton quartz monz. St. Elmo	Chaffee	66.6	0.64	15.7	2.2	2.0	1.4	3.4	3.4	3.9	0.79	0.08	0.08	0.21	<0.05	3.9	19.5	5.00
Pr-2 " " " chalk Ck	"	67.3	0.54	15.4	2.0	1.8	1.2	3.1	3.4	4.4	0.79	0.07	0.08	0.18	<0.05	5.9	31.0	5.25
Pr-1 Antero granite, nr. Mt. Shavano	"	75.3	0.19	13.7	0.63	0.52	0.22	0.78	4.0	4.4	0.50	0.06	0.05	0.03	<0.05	6.9	22.0	3.19

Table 15 San Juan Mountains: Chemical Data

	County	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O^+	H_2O^-	MnO	P_2O_5	CO_2	U ppm	Th ppm	Th/U
Eastern San Juans																		
Quartz latite plugs																		
GL-5 Klondike mountain, plug	Arch	59.4	0.93	15.9	3.8	3.4	3.1	4.6	3.4	3.9	1.1	0.40	0.12	0.30	0.11	3.6	12.7	3.53
GL-3 Bear Creek, dike	Mineral	61.4	0.50	15.4	3.2	1.9	1.6	4.8	2.7	4.2	1.6	1.2	0.11	0.25	1.3	3.2	10.6	3.31
GL-4 Cat Creek, plug	Conejos	62.4	0.83	16.2	3.0	2.7	2.2	4.1	4.0	3.6	0.73	0.30	0.10	0.28	<0.05	1.2	7.2	6.00
GL-7 E. Slope Jackson Mtn, plug	Arch.	63.0	1.0	15.9	3.3	1.8	1.8	2.3	5.0	4.2	0.65	0.30	0.08	0.62	<0.05	2.6	4.0	1.54
GL-1 Piedra Peak, plug	Mineral	64.0	0.62	16.2	3.8	1.6	1.8	3.7	3.7	3.0	0.73	0.86	0.09	0.27	<0.05	2.0	5.4	2.70
GL-6 Baughman Creek, plug	Mineral	64.1	0.69	16.3	3.9	1.5	1.4	3.5	4.0	3.0	0.92	0.70	0.10	0.27	<0.05	1.2	4.1	3.42
GL-8 E. of Square Top Mtn. plug.	Arch.	67.0	0.55	15.6	2.4	1.8	1.5	2.4	4.0	4.0	0.63	0.23	0.08	0.24	<0.05	3.0	8.2	2.73

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Table 12   Eastern Border of the Colorado Plateaus: Chemical Data

	County	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O^+	H_2O^-	MnO	P_2O_5	CO_2	L.I	U ppm	Th ppm	Th/U	
Elk Mountains																				
Stocks and Laccoliths.																				
ML-2 near Maroon Lake	Pitkin	67.7	0.41	15.1	1.9	1.7	1.2	2.1	3.7	4.1	1.0	0.56	0.05	0.26	0.15		3.7	8.8	2.37	
ML-1 " "	"	68.0	0.41	15.3	1.5	1.7	1.0	2.2	3.8	4.6	0.93	0.17	0.04	0.25	<0.05		3.7	11.2	3.03	
M-3 Marble, eastern part	Gunn.	64.7	0.61	16.5	1.5	2.5	1.4	3.3	4.0	3.5	1.7	0.17	0.12	0.26	<0.05		1.6	9.1	5.69	
M-1 " Contact Zone	"	64.9	0.57	16.3	2.8	1.4	1.3	3.9	3.5	3.2	1.3	0.58	0.11	0.27	<0.05		1.6	4.7	2.94	
M-2 ", Crystal River	"	65.4	0.57	16.4	1.9	2.2	1.3	3.5	3.8	3.4	1.3	0.13	0.12	0.32	<0.05		1.8	8.3	4.61	
West Elk Mountains																				
Stocks and Laccoliths																				
Intrusion West of Crested Butte																				
K-3, interior, S. of Ohio Pass.	Gunn.	63.8	0.55	15.9	2.5	1.8	1.7	3.4	3.2	3.3	1.8	1.8	0.08	0.24	0.74		2.2	6.8	3.09	
K-2, Kebler Pass	"	63.9	0.54	15.2	2.0	2.0	1.0	4.4	3.0	3.2	2.0	0.45	0.12	0.22	2.4		2.9	9.0	3.10	
K-1, northern Contact Zone,	"	65.8	0.52	15.2	1.7	2.1	1.3	2.8	3.6	3.1	1.9	0.20	0.10	0.22	1.9		3.5	9.2	2.63	
Intrusion ENE of Crawford																				
Cr-1, South of Coal Mtn.	Delta	62.5	0.58	17.3	3.1	2.0	1.2	5.1	4.3	2.3	1.1	0.08	1.1	0.64	<0.05		1.3	2.5	1.92	
Cr-2 " " "	"	63.0	0.57	17.1	3.0	2.2	1.4	5.0	4.0	2.6	0.96	0.14	0.16	0.28	<0.05		1.4	4.3	3.07	
Elkhead Mountains																				63,
Western region																				35
HP-88-67 Fortification Dike, base	Moffat	53.0	1.2	11.7	3.1	3.0	6.9	7.5	2.5	4.9	0.90	1.3	0.11	0.83	2.6		2.0	1.7	0.85	28
HP-7-67 Biotitic olivine trachyte, sheet	"	57.3	1.1	13.6	3.6	2.5	4.6	5.0	3.5	4.5	0.88	0.82	0.10	0.72	1.5		2.4	3.9	1.62	
HP-8A-67 Fortification Dike, zeolitic T.	"	60.7	0.74	13.2	3.2	1.6	4.4	3.6	2.6	6.6	0.68	0.82	0.07	0.27	0.72		2.0	2.0	1.00	
Northeastern region																				
HP-6-67 East Gibraltar Dike	Routt	61.1	0.78	14.7	2.9	1.8	3.9	4.5	4.2	3.5	0.70	1.2	0.07	0.44	<0.05		2.4	1.8	0.75	

Table 17 Chemical Characteristics of Early Intrusive Suites in the Northeastern Segment of the Front Range porphyry belt estimated at the Peacock Index

	Peacock Index	Correlative estimates at the Peacock Index							Magma Type
	(Percent SiO_2)	CaO	Na_2O	K_2O	Na_2O/K_2O	D.I.①	U ppm	Th ppm	
CENTRAL FRONT RANGE, EAST									
North Central Subprovince:									
Jamestown stock	55.5	7.0	2.1	4.1	0.70	53.0	3.3	10.0	alkali calcic, potassic transitional into calc alkalic
Central Subprovince:									
Audubon-Albion stock	50.9	8.0	3.3	1.7	0.70	51.0	2.0	10.3	alkalic, potassic transitional to alkali calcic
Caribou stock	52.0	7.1	3.4	3.7	0.87	51.1	~10	~40	alkali calcic, potassic
North Bryan Mountain pluton	53.15	7.1	3.2	3.9	0.82	50.7	1.2	7.0	alkali calcic, potassic
Table Mountain flows	52.45	7.1	3.0	4.1	0.73	50.0	3.8	6.5	alkali calcic, potassic
South Central Subprovince:									
Bryan Mountain stock	54.30	6.3	4.3	2.0	2.15	55.0	5.7	32.5	alkali calcic, sodic
Empire stock	47.6	8.3	4.2	4.1	1.02	53.0	12.2	~50.0	alkalic, sodic

① Thornton-Tuttle (1960) Differentiation Index

Table 18 Uppm and Thppm at the Peacock index of intrusive suites outside the northeastern segment of the Front Range porphyry belt

	Peacock Index (percent SiO_2)	Estimates at the Peacock Index			
		CaO		U ppm	Th ppm
SOUTH WEST SEGMENT OF THE COLORADO PORPHYRY BELT					
CENTRAL FRONT RANGE, WEST					
Montezuma Stock	~54.9	~5.0		~5.0	~20.0
Breckenridge	54.5	6.5		2.6	24.0
PARK RANGE					
Alma-Climax	58.7	5.85		2.0	5.5
SAWATCH RANGE					
Mt. Princeton batholith	57.5	6.9		3.5	10.5
BORDER OF THE COLORADO PLATEAUS					
Elk Mountains	59.7	5.8		<1.0	~3.8
West Elk Mountains	59.3	5.4		~0.4	<4.0
REGIONS OUTSIDE THE PORPHYRY BELT					
SOUTHERN FRONT RANGE: EAST					
Cripple Creek	48.9	8.0		4.0	28.0
SOUTHERN FRONT RANGE: WEST					
Whitehorn Stock	58.5	5.4		1.0	6.0
WET MOUNTAINS					
Mt. Fairview Stock	50.9	7.8		3.9	14.8
SANGE DE CRISTO RANGE					
Cottonwood Stock	52.0	6.4		1.0	6.6
EASTERN SAN JUAN RANGE, plugs and dikes	55.4	6.3		~4.6	~14.0
BORDER OF THE COLORADO PLATEAUS					
Elkhead Mountains	52.15	7.2		1.9	1.6

Table 19 Heavy minerals in quartz bostonite, P354

Specific Gravity	Mineral	Ferromagnetism	Refractive Indices	Other properties	Relative abundance
SG > brmo. SG < MI	apatite and Carbonate apatite	non magnetic	$n = 1.602-1.620$	Colorless to red or yellow	abundant
	biotite	intermediate	$n \sim 1.64$	deep green platy	sparse
SG ≅ MI	Sodian augite	intermediate	$n_\alpha \sim 1.685$ $n_\gamma \sim 1.697$	weakly pleochroic in green X∧C = 8° elongation (−)	abundant
	epidote	intermediate	$n_\alpha = 1.729$ $n_\gamma = 1.740$		common
	fluorite	intermediate	$n = 1.435$	Colorless to faint purple	sparse
	tourmaline	intermediate	$n \sim 1.64$	uniaxial(−) X = reddish, Z = opaque	trace
SG > MI	Zircon	nonmagnetic	clear $n_\omega = 1.959$ $n_\varepsilon = 1.980$ metamict $n_\omega = 1.918$ $n_\varepsilon = 1.954$	uniaxial +, colorless to brown zoned	Common
	allanite	intermediate	$n_\alpha \sim 1.68$ $n_\gamma = 1.72$	locally isotropic pleochroic X = yellow brown Z = reddish brown	Common
	thorite	intermediate	isotropic (metamict) $n \sim 1.79-1.805$	Colorless to orange	Common

Table 20 Change in Th/U ratios of igneous rocks after leaching in 1+4 HCl

Sample	Rock Type	Intrusive Center	Th/U ratios	
			before leaching in 1+4 HCl	after leaching in 1+4 HCl
	Phonolite stocks			
P640	hornblende granodiorite	Jamestown stock	3.0	2.08
P915	nepheline monzonite	Empire stock	2.5	2.12
	Porphyritic-aphan. stocks and dikes			
P42	Sodic granite	Central City	4.3	0.9
P400	Sodic granite	Central City	4.0	1.27
P370	Sodic granite	Central City	2.4	0.71
	CaO-poor late-stage differentiates			
P54(E11.)	quartz bostonite	Central City	4.9	4.2
P108	quartz bostonite	Central City	4.1	2.2
P118	quartz bostonite	Central City	4.2	3.6
P379	quartz bostonite	Central City	2.6	0.47
P581	quartz bostonite	Idaho Springs	4.1	1.3
P559	quartz bostonite	Jamestown-Gold Hill	1.1	0.6
P548	quartz bostonite	Jamestown-Gold Hill	1.04	0.59
P633	quartz bostonite	Jamestown-Gold Hill	1.5	1.1

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(1)	(2) Percent of total weight lost on leaching	(3) μg U in original 10g sample	(4) μg U in residue	(5) μg U in filtrate	(6) μg U in residue + μg U in filtrate	(7) Percent of original U leached	(8) μ Th in original 10g sample	(9) μ Th in residue	(10) μ Th in filtrate	(11) μ Th in residue + μ Th in filtrate	(12) Percent of original Th leached
granodiorite											
P640	10.4	40.0	33.0	12	45.0	17.5	121	69	52	121	57
nepheline monzonite											
P915	20.4	166	112	36	148	32.5	416	213	245	458	51.2
sodic granite											
P42	5.6	64	45	34	79	34.8	295	40	246	286	86.4
P480	5.4	54	51	40	91	37.3	337	65	305	370	80.7
P470	6.8	108	66	44	110	38.8	258	50	222	272	84.6
quartz monzonite											
P134 (all)	1.4	214	177	32	209	17.3	1050	736	214	950	20.4
P108	4.2	642	606	84	690	12.4	2850	1365	1547	2912	52.1
P116	5.1	208	143	68	211	31.8	984	518	407	925	41.4
P349	4.8	164	154	26	180	6.1	424	159	335	494	62.5
P581	7.1	498	315	212	527	34.7	2070	424	1747	2171	79.5
P559	5.4	410	170	242	412	58.5	437	100	274	374	77.1
P548	4.5	570	368	180	548	35.4	543	217	259	476	63.4
P633	5.3	466	237	204	441	44.1	708	253	371	624	64.3

Table 21 Percentages of original uranium and thorium leached in 1+4 HCl
all samples digested for 24 hours on a steambath. Columns (3) and (6) give mass balance for uranium. Columns (8) and (11) give mass balance for thorium.

Table ~~20~~ 22 Uranium, thorium and zirconia in quartz latite from the Central City district.

Sample	U ppm	ZrO_2 ppm (1)	U/ZrO_2	Th ppm	ZrO_2 (1)	3.3 Th/ZrO_2
P8	43.0	600	0.072	199.2	600	0.332
P17	91.0	1200	0.076	500	1200	0.417
P94	17.6	500	0.035	70.5	500	0.127
P108	69.6	1800	0.039	255.8	1800	0.142
P112	8.2	1900	0.003	24.8	1900	0.013
P119	32.5	700	0.046	90.0	700	0.129
P133	42.0	1100	0.038	190.0	1100	0.173

(1) chemical analyses by A. M. Sherwood, Chemist, US Geol. Survey.

Table 23 Selected minor elements (ppm) in dissolved solids in filtrates from 1+4 HCl leach of 10 gram samples of igneous rocks

Sample # Rock Type	Chemical Analysis (1) U	(2) Th	Semiquantitative spectrographic analyses (nearest figures in series 3000, 1000, 300, 100 etc.) Ce	La	Nd	Y	Zr	Pb	Zn	Ag	Cu	Total dissolved solids (g)
granodiorite												
P640	11.5	524	300	300	0	30	100	100	100	1	100	1.04
nepheline monzonite												
P915	17.6	1201	300	1000	100	100	30	300	0	1	1000	2.04
soda granite												
P42	60.7	4392	300	300	100	100	300	100	300	1	300	0.56
P400	74.1	6481	1000	300	300	100	100	300	300	3	300	0.54
P370	64.7	3265	1000	1000	300	100	300	300	0	3	300	0.68
quartz bostonite												
P94 (alt)	188.4	1126.3	1000	1000	300	30	1000	3000	300	30	1000	0.19
P128	200.0	36833	1000	1000	3000	30	1000	300	100	3	300	0.42
P118	133.3	6026	1000	3000	300	100	300	300	1000	10	300	0.51
P397	54.2	7042	3000	3000	1000	300	100	100	700	3	1000	0.43
P581	292.6	2460.6	1000	3000	300	100	3000	300	100	10	100	0.71
P554	448.1	5074	300	300	0	30	3000	300	300	3	300	0.24
P546	400.0	5755	300	300	0	30	1000	1000	300	30	1000	0.45
[illegible]	3819	7000	300	1000	100	100	300	300	100	3	300	0.53

1) direct chemical analysis of filtrates

2) analyses of solids after filtrates were evaporated to dryness

	Nepheline Monzonite			Quartz Bostonite																	
	P915			P393			P94			P106			P118			P559			P633		
	before leaching in 1+4 HCl	after leaching in 1+4 HCl	elements in filtrate semiquant.(1)	before leaching in 1+4 HCl	after leaching in 1+4 HCl	elements in filtrate semiquant.(1)	before leaching in 1+4 HCl	after leaching in 1+4 HCl	elements in filtrate semiquant.(1)	before leaching in 1+4 HCl	after leaching in 1+4 HCl	elements in filtrate semiquant.(1)	before leaching in 1+4 HCl	after leaching in 1+4 HCl	elements in filtrate semiquant.(1)	before leaching in 1+4 HCl	after leaching in 1+4 HCl	elements in filtrate semiquant.(1)	before leaching in 1+4 HCl	after leaching in 1+4 HCl	elements in filtrate semiquant.(1)
SiO_2	50.7	53.7	M	65.5	67.6	3	67.0	69.5	10	68.56	70.1	10	67.36	70.8	3.0	64.4	72.1	3.0	68.5	72.7	3.0
Al_2O_3	17.3	15.8	M	17.6	16.2	3	15.56	15.2	M	15.88	15.7	10	16.44	16.4	3.0	15.8	15.9	10	16.1	16.0	10
Fe_2O_3	4.2	6.3	10	1.9	1.8	M	2.10	1.2 (2)	M	3.06	2.9	M	1.18	1.6	M	3.0	1.4	M	2.3	1.4 (2)	M
FeO	4.2	1.3		2.8	<0.05		0.85			1.19	<0.05		2.39	<0.05		1.5	<0.05		1.4		
MgO	3.0	3.7	1	0.24	0.17	0.3	0.05	<0.05	0.3	0.10	0.06	0.3	0.19	0.07	0.3	0.31	0.18	1.0	0.26	0.08	1.0
CaO	7.3	7.6	10	0.35	0.16	1.0	0.36	<0.05	3.0	0.00	<0.05	1.0	0.30	<0.05	3.0	0.42	<0.05	10	0.64	<0.05	10.0
Na_2O	5.5	3.6	10	5.4	6.0	1.0	1.57	0.41	3.0	4.90	4.9	3.0	5.14	5.1	3.0	4.0	4.3	3.0	4.3	4.6	3.0
K_2O	4.4	5.1	1	5.0	5.2	1.0	12.43	12.7	1.0	5.44	5.5	1.0	5.40	5.6	1.0	5.6	5.7	1.0	5.5	5.7	1.0
TiO_2	0.90	0.78	0.1	0.40	0.42	0.03	0.02	0.13	0.03	0.14	0.13	0.03	0.01	0.09	0.03	0.05	0.04	0.03	0.07	0.07	0.03
P_2O_5	0.64	0.41	1.0	[illegible]	[illegible]	0.3	0.037	0.01	0.3	0.04	0.00	0	0.15	0.01	0.3	0.04	0.00	0	0.04	0.034	0
MnO	0.22	0.34	0.03	0.01	0.00	0.1	0.05	0.00	0.1	0.03	0.01	0.1	0.08	0.00	0.3	0.02	0.00	0.03	0.02	0.01	0.1

1) Semiquantitative spectrographic analyses, reported to nearest number in series 10, 3, 1, 0.3, 0.1 etc.
M = major, >10.0 percent

2) All iron reported as Fe_2O_3

Table 24 Major constituents (in weight percent) in rocks before and after leaching 10 gram samples in 1+4 HCl and in dissolved solids in filtrates

Tab. 25 CaO-poor late stage differentiates in the Central Front Range: distribution and contents of uranium and thorium

Sample	Location	U ppm	Th ppm
	Jamestown District		
P633	Castle Gulch	35.3	57.1
P629	Spruce Gulch	22.5	43.9
P732	Stock, porphyry mountain	18.1	18.9
P632	Spruce Gulch	12.2	70.0
P630	Spruce Gulch	20	–
	average	22.2	47.5
	Gold Hill District		
P559	Bighorn Mountain	41.9	45.7
P623	Bighorn Mountain	42.0	64.0
P548	Rowena	57.8	43.0
P626	North of Rowena	54	–
	average	48.9	50.9
	Sunset-Ward District		
P506	Sunset	8.2	47.0
	North Gilpin County		
P599	Rollinsville	13.5	13.0
P560	Rollinsville	13.6	61.0
P355	Freeman Gulch, Apex	30.0	62.0
P354	Miner's Gulch Apex	30-50	[illegible]
P356	Freemans Gulch, Apex:	10-30	
	average	19.0	45.3

Sample	Location	U ppm	Th ppm
	Alice District		
P597	Pile Hill, northeast of Alice	18.9	63.0
P571	Lombard Mine (interior)	14	–
P572	Lombard Mine (contact)	9	–
P573	West of Lombard Mine	10	–
	average	13.0	63.0
	Fall River		
P351	Woodpecker Gulch	9.4	38.0
PE35	Hoosac Gulch	8.7	15.6
PE20	Hamlin Gulch	11.4	–
P578	Upper Fall River	6	–
	average	8.9	26.8
	Central City		
	California dike,		
P112	King's Flat	8.2	24.8
P335	Nevadaville	14.4	38.9
P115	West of Glory Hole	<20	–
P114	South of National Mine Shaft	<20	–
P366	West of Hidden Treasure Mine	<20	
	average	11.3	31.8

Table 25 (Cont.)

Sample	Location	U ppm	Th ppm	Sample	Location	U ppm	Th ppm
	Empire district				Chicago Creek area		
P536	north Empire Gulch	13.9	76.0	P817	Soda Creek	27.5	—
	Freeland-Lamartine			P818	between Soda Ck and Barbour Fk.	17.0	—
P415	N+E mine	132.6	190.8	P819	as above	18.0	—
P563	north of Freeland	10	—	P827	Chicago Ck, Maximillian Gl.	7.3	—
P564	north of Freeland	8	—		average	17.5	3[illegible]
P441	Freeland (interior)	10-30	—				
P442	Freeland (contact)	10-30	—				
P443	Lamartine, Gomer Mine	10-30	—				
	average	?					
	Idaho Springs district						
P36	W. end of town, roadcut	13.8	26.1				
P458	near Soda Creek, roadcut	25.7	23.8				
P832	1 Mi. east of Soda Creek, Hwy 6-40	7.0	36.8				
P833	as above, but upper dike	8.9	—				
P440	Little Bear Creek	<20	—				
	average	13.3	29.6				
	Chicago Creek area						
P350	Soda Creek	11.6	37.0				
P594	Between Soda and Chicago Creeks	31.5	—				
P595	as above	15.5	—				
P596	as above	12.0	—				

Table 25 (Cont.)

Sample	Location	U ppm	Th ppm	Sample	Location	U ppm	Th ppm
	Central City (Cont.)				Central City (Cont.)		
	Nigger Hill dike (Cont.)				Pewabic dike (Cont.)		
P103	Nigger Hill	155-175	270	P430	Pewabic Mountain	20-40	–
P109	100 feet from Apex Road	50-70	–	P438	East Pewabic Mountain	10-30	–
P110	Southeast end of dike	80-100	–	P439	Middle Pewabic Mountain	10-30	
P14	N80E from Beedk Hill	120-140	220		average	36.4	170
P15	as above	50-70	270		Miscellaneous Small dikes		
	average	55.9	264.7	P599	Eastern Central City	13.5	55.2
	Pewabic dike			P806	Illinois Gulch	19.0	46.0
P825	near Justice Hill	24.3	122.7	P833	Eastern Central City	15.6	59.2
P3	Pewabic Mountain	43.0	199.2	P807	S. tip, Gregory Hill Stock	14.1	31.7
P133	Eastend, near S. Willis Fork	42.0	190.0	P813	near Cherokee Mine	8.4	–
P125	SW arm Pewabic Center	40-60	–	P823	Nigger Hill	14.1	32.[illegible]
P126	Pewabic Mountain	35-55	–	P802	Eastern Central City	19.4	–
P132	Eastend, contact	[illegible]	–		average	14.9	44.[illegible]
[illegible]	above S. Willis Gulch	20-40	–				
P431	Bellevue Mountain	15-35	–		Dumont district		
P432	as above,	15-35	–	P567	Ohio Creek	39	–
P421	Busy Bee Mine	20-40	–		Lawson district		
P423	West of Busy Bee	40-60	–	P642	Jo Reynold's Mine	13.0	32.5
P424	Forfar Mine	10-30	–	P562	Mill Creek pluton	13.8	30.5
P428	Pewabic Mountain	20-40	–		average	13.4	31.5

Table 25 (Cont)

Sample	Location	U ppm	Th ppm	Sample			
	Central City (Cont.)				Central City (Cont)		
	Topeka dike				Wood dike (Cont.)		
P368	Leavenworth Gulch	11.2	36.0	P340	intersect. Prosser Gulch dike	10-30	-
P120	near Gold Rock Mine	10-30	-	P341	near intersection	10-30	-
P119	near Gold Rock Mine	30-50	-	P343	East Wood at intersection	40-60	
P26	intrusive Center, Quartz Hill	10-30	-		average	35.0	45.1
P27	intrusive Center, Quartz Hill	<20	-		Prosser Gulch Dike		
P48	Quartz Hill	<20	-	P824	Nigger Hill, above reservoir	74.6	350.0
P51	southeast of intrusive Center	30-50	-	P17	Southeast of Bald Mtn. Cemetary	91.0	500.0
P52	Southeast of intrusive Center	40-60	-	P18	Southeast of Bald Mtn. Cemetary	30-50	302.0
	average	11.2	36.0	P121	ridge, north of Prosser Gulch	30-50	—
	Wood dike			P122	as above, contact	40-60	-
P118	Head East Calhoun Mine	32.5	90.0	P124	Prosser Gulch	50-70	-
P396	Crosscut, 1st Level, East Calhoun	—	32.0	P344	Bald Mountain	90-110	
P394	Crosscut, 1st Level, East Calhoun	56.0	16.7	P345	Bald Mountain	60-80	
P395	Crosscut, 1st Level, East Calhoun	29.5	70.0	P342	intersect. West Branch Wood dike	30-50	
P719	Crosscut, 6th Level East Calhoun	22.0	17.0		average	82.8	384.0
P113	Kings Flat, East Branch	10-30	—		Nigger Hill dike		
P111	Kings Flat, West Branch	30-50	-	P108	NW end, West Branch dike	69.8	255.8
P363	East of Eureka Gulch	20-40	-	P107	NW end, West Branch dike	40-60	348.0
P364	East of Eureka Gulch	20-40	-	P374	North of Chase Gulch	52.0	327.5
P384	Southwest of Kirk Mine	10-30	-	P448	North of Eureka Gulch road	46.0	300.0

Table 26 Rank in magmatic uranium potential (Classes 1 and 2) from data in Table and Rank in economic uranium potenti based primarily upon data in Sims and Sheridon (1964) compared for each mining district in the Central Front Range

District	Relative abundance CaO-poor porphyry			Rank		Class of deposits	number of significant U-deposits	Producin U-mine
	average U > 30ppm	average U, 10-30ppm	average U, 1-10ppm	in magmatic U-potential	in economic U-potential			
						1	5	0
Jamestown	low	very high	0	5	2	2	1	1
Gold Hill	high	0	0	2	7	2	3	0
Sunset-Ward	0	0	low	12	12		0	0
Boulder County Tungsten belt	0	0	0	13	12		0	0
Caribou-Eldora	0	0	0	13	8	Trans 2→3	2	1
North Gilpin Co	moderate	very high	0	4	9	2	2	0
Alice	0	high	low	6	10	2	1	0
Fall River	0	low	high	10	6	Trans 2→3	3	1
Central City	very high	very high	0	1	1	2	18	8
Dumont	low	0	0	7	10	2	1	0
Lawson	0	moderate	0	9	3	2	4	1
Empire	0	low	0	11	11	0	0	0
Freeland-Lamartine	low	very high	low	3	4	2	4	1
Idaho Springs	0	moderate	moderate	8	5	2	5	0
Chicago Creek	0	high	low	6	10	2	1	0
Georgetown	0	0	0	13	12		0	0
Silver Plume	0	0	0	13	12		0	0
Argentine	0	0	0	13	12		0	0
Montezuma	0	0	0	13	12		0	0
Breckenridge	0	0	0	13	12		0	0

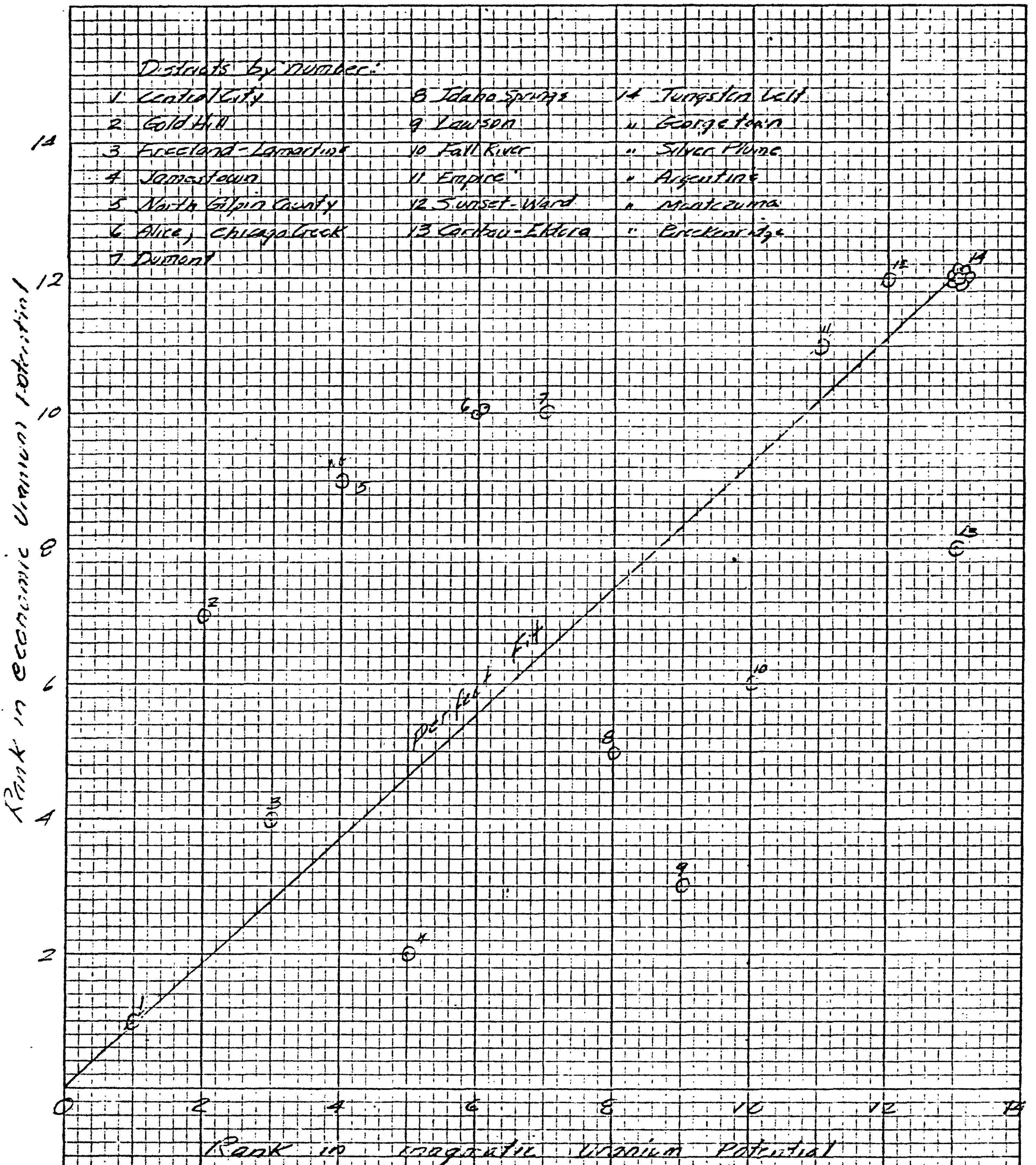

Figure 1 Nature of the correlation of areal economic potential based upon number and grade of uranium deposits of Classes 1 and 2 with areal magmatic potential based upon number of Colo-pac late stage differentiates and their average uranium content