HEAVY MINERALS IN THE TERTIARY INTRUSIVES OF CENTRAL COLORADO

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Introduction

The Tertiary intrusives of Central Colorado have interested geologists and prospectors since the early mining days in this region when it was found that quartz veins and copper carbonate ores were commonly associated with the igneous rocks. A relationship between the ore deposits and the intrusives was recognized in various districts but it was not until Crawford's excellent paper in 1924[1] that an attempt was made to trace the mineralizing igneous rocks in all of the surrounding districts to a common source in the large Tertiary massive—the Princeton batholith.

During the summers of 1931–1932, field parties from Northwestern University, with the co-operation of the U. S. Geological Survey, have been engaged in mapping the pre-Cambrian formations of the Sawatch Range. In connection with this work heavy mineral analyses of small granite areas of uncertain age have proven fairly successful in correlating them to one or the other of the two main pre-Cambrian batholithic intrusions of the region.[2] Similar analyses of the post-Cambrian intrusives were made at this time, and as the Princeton batholith, as well as several of the smaller outcrops studied by Crawford, occur within the Sawatch Range, it was decided to extend the work on heavy minerals to include all of the Tertiary rocks mentioned by Crawford.

The value of such analyses is readily apparent. Work on heavy minerals of the igneous rocks is still in the experimental stage. Should the mineral associations shown by these analyses agree with Crawford's conclusions based on petrographic studies, the value of this comparatively rapid means of making correlations is strengthened. On the other hand, it offers an entirely different approach to the problem of correlation of the Tertiary intrusives and in case of agreement with other methods, offers support to the previous correlation—that the various, widely separated outcrops have a common origin with the Princeton batholith.

[1] Crawford, R. D., A Contribution to the Igneous Geology of Central Colorado: *Am. Jour. Sci.*, 5th ser., vol. **7**, pp. 365–388, 1924.

[2] Report of the Committee on Accessory Minerals of Crystalline Rocks, National Research Council, *Ann. Rept.*, pp. 2–5, **1932.**

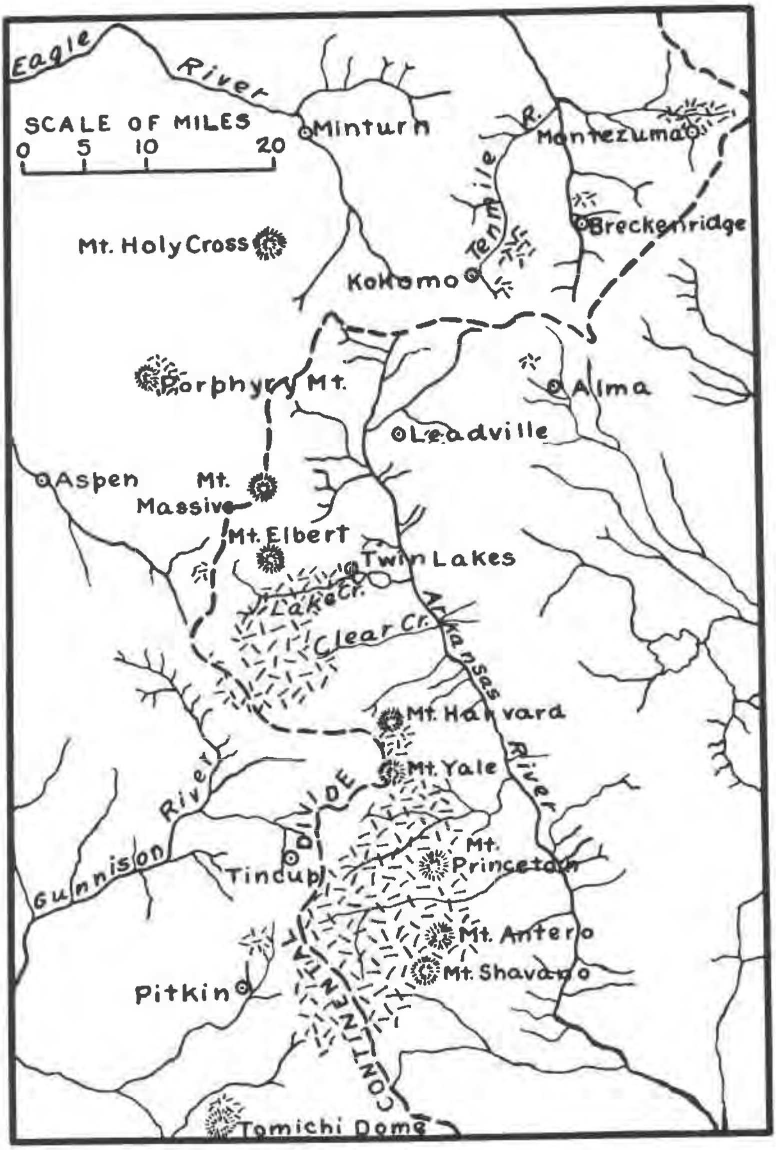

FIG. 1. Sketch map showing distribution of Tertiary intrusives. (After Crawford.)

Methods of Separation

In Figure 1, after Crawford, the outcrops of the igneous rocks, presumably of Tertiary age, are shown. To those mentioned by Crawford have been added a few new outcrops discovered in the course of the mapping in the Sawatch Range. Specimens were collected from the following localities, all of which are indicated on the sketch map:

Breckenridge	Mount Princeton
Alma	Mount Antero
Montezuma	Mount Yale
Leadville	Tomichi Dome
Ten Mile Creek	Red Mountain Creek
Twin Lakes	Crested Butte
Clear Creek	South Fork Lake Creek

Specimens approximately 4 by 4 inches were crushed to pass a 100-mesh and not a 200-mesh sieve. The heavy minerals were then separated by the use of bromoform of gravity of 2.84. The percentages of the heavy minerals in the rock specimens are shown in column I of Table I. Magnetite was removed from the separates by means of a horseshoe magnet with a thin paper collar. The ratio of magnetite to the other heavy minerals is shown in columns II and III of Table I. The remaining heavy minerals, after the separation of magnetite, were mounted in Canada balsam and studied under the polarizing microscope. Sixteen to twenty separate counts were made on each specimen and the averages in percentages are given in Table II.

Discussion of the Tables

Nine specimens are from the Princeton batholith. These were selected in traverses across the outcrop to represent peripheral as well as central zones. The other specimens are from twenty different localities, an attempt being made in each case to select fresh, representative rock.

A general survey of the tables reveals a surprising lack of variety in the heavy minerals, the same few being repeated in nearly all of the analyses. Such minerals are apatite, biotite, ilmenite, titanite, and zircon. Hornblende is represented in all but four. Epidote, pyrite, and hematite occur in a few and are probably secondary. The large amounts of pistachite in T-23, T-27, and T-35 are apparently after hornblende and might be added to the hornblende percentages.

The second striking fact brought out by the analyses is the lack of such minerals as tourmaline, monazite, fluorite, beryl, and sillimanite, all of which have been reported from the igneous rocks

Table I. Percentage of Magnetite in Heavy Mineral Separates

		I Total heavy minerals in specimen	II Magnetite	III Other heavy minerals
T-1	Twin Lakes porphyry, Clear Creek	0.173	75.72	24.28
T-2	Lincoln porphyry, Evans Gulch	0.113	24.77	75.23
T-3	Princeton batholith, St. Elmo	1.640	50.43	49.57
T-6	Princeton batholith, E. of St. Elmo	1.684	60.45	39.55
T-8	Princeton batholith, E. of St. Elmo	1.962	45.38	54.62
T-10	Princeton batholith, E. of St. Elmo	2.000	66.25	33.75
T-12	Princeton batholith, M. Cottonwood Creek	0.983	72.43	27.57
T-14	Princeton batholith, S. slope Mt. Yale	0.253	83.01	16.99
T-17	Princeton batholith, E. slope Mt. Yale	1.451	59.95	40.05
T-20	Princeton batholith, W. of St. Elmo	1.042	61.17	38.83
C-111	Princeton batholith, S. Cottonwood Creek	1.021	93.00	7.00
T-21	Tomichi Dome	0.289	69.88	30.12
T-23	Gray porphyry, Mosquito Creek	0.493	32.53	67.47
T-26	Quartz Creek porphyry	2.431	54.81	45.19
T-27	Twin Lakes porphyry, Red Mt. Creek	0.285	75.44	24.56
T-28	Lincoln porphyry, South fork of Lake Ck.	1.090	84.40	15.60
T-29	Montezuma	0.813	80.19	19.81
T-30	Montezuma	0.885	79.09	20.91
T-31	Breckenridge red granite	0.849	8.94	91.06
T-32	Buckskin Gulch gray porphyry	2.118	55.57	44.43
T-33	Breckenridge coarse porphyry	0.253	83.00	17.00
T-34	Lincoln porphyry, Buckskin Gulch	0.396	89.89	10.11
T-35	Lincoln porphyry, NE. Breckenridge	0.640	75.00	25.00
T-41	Lincoln porphyry, Kokomo	0.897	82.72	17.28
T-43	Granite, Kokomo	0.309	94.49	5.51
T-44	Lincoln porphyry, NE. of Leadville	0.318	91.81	18.19
T-45	Crested Butte	0.430	25.65	74.35
T-46	Porphyry Mountain	0.049	36.46	63.54

of the Front Range in Colorado by Mrs. Boos.[3] Their absence in the more massive facies of the Tertiary intrusives supports the early impression that these rocks were lean in mineralizers or relatively dry magmas. In this respect the Tertiary intrusives are very different from the pre-Cambrian batholiths of the Sawatch

[3] *Idem.* pp. 6–7.

TABLE II. PERCENTAGE OF MINERALS IN HEAVY MINERAL SEPARATES EXCLUSIVE OF MAGNETITE

		Apatite	Biotite	Ilmenite	Pyrite	Titanite	Zircon	Hornblende	Allanite	Pistachite	Garnet	Hematite	Topaz
T-1	Twin Lakes porphyry, Clear Creek	14.75	36.40	3.50		33.76	2.76	6.20	0.73	1.90			
T-2	Lincoln porphyry, Evans Gulch	11.26		3.97	8.06	75.96	0.75						
T-3	Princeton batholith, St. Elmo	6.21	7.32	2.83		21.77	1.70	60.17					
T-6	Princeton batholith, E. of St. Elmo	5.00	7.07	1.64		19.34	0.75	66.20					
T-8	Princeton batholith, E. of St. Elmo	2.34	2.08	12.85		25.14	2.40	53.50	1.69				
T-10	Princeton batholith, E. of St. Elmo	2.95	8.79	2.75		24.09	1.74	59.14	0.54				
T-12	Princeton batholith, M. Cottonwood Creek	5.42	9.12	0.90		36.32	3.52	44.62		0.10			
T-14	Princeton batholith, S. slope Mt. Yale	4.46	9.88	72.17		8.32	1.73	2.46		0.37	0.07	0.54	
T-17	Princeton batholith, E. slope Mt. Yale	2.65	27.08	0.93		19.68	1.01	48.65					
T-20	Princeton batholith, W. of St. Elmo	4.95	1.60	0.73		41.09	2.20	49.43					
C-111	Princeton batholith, S. Cottonwood Creek	3.83		2.31	0.25	59.65	28.06	5.90					
T-21	Tomichi Dome	3.77		8.49		6.60		3.79			16.03		61.32
T-23	Gray porphyry, Mosquito Creek	2.94	0.29	11.69		56.16	0.59	0.59		27.74			
T-26	Quartz Creek porphyry	2.92	4.63	3.02		3.93	0.20	85.30					
T-27	Twin Lakes porphyry, Red Mt. Creek	5.61		70.97	1.09	12.80	2.32	0.48		5.63	0.73	0.37	
T-28	Lincoln porphyry, South fork of Lake Ck.	12.24	35.40	3.63		36.61	2.18	9.58			0.36		
T-29	Montezuma	6.43	3.93	0.43		72.22	3.80	11.11	2.08				
T-30	Montezuma	5.66	33.02			47.89	2.91	10.52					
T-31	Breckenridge, red granite	0.64	0.32	8.42		83.83	2.91	3.88					
T-32	Buckskin Gulch, gray porphyry	6.38	2.69			12.90	1.20	76.83					
T-33	Breckenridge, coarse porphyry	13.82	2.63	71.05			10.53		1.97				
T-34	Lincoln porphyry, Buckskin Gulch	51.65	10.15	24.13		10.42	3.65						
T-35	Lincoln porphyry, NE. Breckenridge	9.92		7.94		47.64	1.49	26.06	1.49	5.46			
T-41	Lincoln porphyry, Kokomo	48.20	15.11	1.70		30.86	3.38	0.75					
T-43	Granite, Kokomo	30.31		11.06		45.78	12.41	0.44					
T-44	Lincoln porphyry, NE. of Leadville	69.97	5.26	8.23		9.10	5.92	0.76					
T-45	Crested Butte	7.59		0.64	82.59	7.42	1.12			0.64			
T-46	Porphyry Mountain	12.20	1.00	6.60		32.40	1.80	39.80	4.00	1.60		0.60	

Range which show abundant evidence in their field relations and in the heavy mineral analyses of being wet magmas.

In a general way the analyses show both a positive and negative similarity between the main mass of the Princeton batholith and the igneous intrusions of the surrounding districts, and, therefore, are not contradictory to the interpretation by Crawford that the intrusions may have had a common source with the Princeton massive. But on the other hand, from the evidence of the tables alone, the basis for such an assumption is scarcely more than suggestive.

In Table II, which gives the percentages of the heavy minerals other than magnetite, attention is called to the following points. Low percentages of ilmenite show in three specimens (T-12, T-14, and T-20) from the peripheral zone of the Princeton massive, whereas T-10, T-12, and T-20, from the same zone, show high percentages of titanite. In other specimens this general ratio of ilmenite to titanite is observed: in T-2 and T-41 from the Breckenridge district, in T-2 and T-41 from outcrops of the Lincoln porphyry, east and northeast of Leadville, in T-32 from Buckskin Gulch, and in T-29 and T-30 from the Montezuma district.

Zircon is present in nearly all of the analyses but T-21 from Tomichi Dome, which will be discussed later. The zircon percentage is seldom less than one or more than four, although notable increases occur in T-33, a coarse porphyry from Breckenridge; and C-111, the Princeton granite near Antero Springs.

Apatite is fairly constant in specimens from the Princeton batholith, ranging between 2.34 and 6.21 per cent. In most of the specimens from the surrounding districts it is much higher, rising above 45 per cent in analyses from the Lincoln porphyry.

Biotite and hornblende show considerable variation in the specimens from the Princeton batholith and those from the surrounding districts. There is, moreover, a general relationship between the two minerals showing high hornblende percentage and a low biotite percentage, or with high biotite a corresponding low hornblende percentage. Such an inference should not be given too much weight, however, in view of the limited number of analyses.

In specimen T-21, from Tomichi Dome, the distribution of the heavy mineral percentages is exceptional. The rock is a fine grained asphanite with only a few, widely scattered phenocrysts. The analysis differs from all others in that a large percentage of the heavy minerals other than magnetite consists of topaz and garnet. This was checked by oil immersion methods and in thin sections.

Conclusions

Heavy mineral analyses of igneous intrusions from twenty-nine localities show a similarity in the limited variety of the minerals and in the lack of such minerals as tourmaline, monazite, fluorite, beryl, and sillimanite, all of which have been reported from igneous rocks of the Front Range. Nine of the specimens are from traverses across the Princeton batholith and the others from various surrounding districts. R. D. Crawford, on the basis of petrographic studies and field relations, suggested that all of these intrusions were probably related to a common magmatic source. The heavy mineral analyses given in the above tables are in no way incompatible with this interpretation and may lend some support to such a correlation.

It is fully realized that the number of analyses is far too small to justify any conclusions based on the tables alone, other than the most generally suggestive or corroborative assumptions. As the work was auxiliary to the pre-Cambrian mapping, time did not permit a more comprehensive study. The data here presented is offered for what it is worth in the hope that the record, although imperfect, may aid in future work along these lines.

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