



Progressive metamorphism of Permian siliceous limestone and dolomite - a complete sequence around a monzonite intrusion, Marble Canyon, Diablo Plateau, west Texas

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PROGRESSIVE METAMORPHISM OF PERMIAN SILICEOUS LIMESTONE AND DOLOMITE—A COMPLETE SEQUENCE AROUND A MONZONITE INTRUSION, MARBLE CANYON, DIABLO PLATEAU, WEST TEXAS

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INTRODUCTION

The Marble Canyon elliptical intrusion ranges in composition from syenite at the center to olivine-bearing monzonite with a discontinuous biotite gabbro border phase near the contact. The contact aureole contains the complete sequence of previously described anhydrous mineral phases resulting from temperature gradients in metamorphosed siliceous limestone and dolomite.

This is the first discovery in the United States of a complete sequence of minerals described by Bowen (1940) and Tilley (1923) as occurring with increasing temperatures in siliceous limestones and dolomites. The polymorphic forms of dicalcium silicate Ca_2SiO_4 , α (bredigite), β (larnite), and γ occur together in the contact zone in Marble Canyon and were described by Bridge (1966a, b).

LOCATION AND SETTING

Marble Canyon is in the east rim of the Diablo Plateau in Culberson County, Trans-Pecos Texas, 30 miles north of the town of Van Horn and two miles west of State Highway 54. The canyon was cut by an intermittent stream flowing eastward down the Diablo fault scarp, which marks the east boundary of the Diablo Plateau. The mouth of the canyon is about 300 m wide, and its walls range from 60 to 180 m high. The narrow part of the canyon is about 1.5 km long and terminates upstream in an elongate amphitheater roughly 2 km long and 1 km wide.

The center of the elongate amphitheater is a small igneous intrusion surrounded by a bleached contact zone ranging in width from 70 to 180 m. The exposed contact zone includes the Permian Hueco and Bone Spring Formations.

The Hueco Formation is 270 m thick in Marble Canyon (King, 1962, measured section) and unconformably overlies older Paleozoic rocks. The basal Powwow Member of the Hueco is 60 m thick and consists of interbedded clastics and carbonates. The clastic rocks range from coarse chert pebble conglomerate to coarse arkosic sandstone. The upper 214 m of the Hueco consists of massive dolomitic limestone with occasional shale partings, chert nodules, and fossiliferous intervals. The contact zone on the northeast side of the intrusion is in the Hueco, and the Hueco at this locality is an almost pure dolomite. The exposed part of the contact zone at all other localities is in the Bone Spring Formation.

The Bone Spring Formation is 742 m thick and consists of lenticular massive beds of dolomitic limestone interfingering with thin cherty beds of fossiliferous limestone. The thin platy cherty carbonates range in composition from a dolomitic limestone to an almost pure magnesian limestone. The platy limestone is locally interbedded with thin shales.

IGNEOUS ROCKS

The igneous intrusion consists of a central mass of light-colored syenite surrounded by green monzonite (M_1) and a gray monzonite (M_2). Felsic dikes cut the monzonites, syenite and contact rocks (fig. 1).

The central syenite is coarser grained than are the other rocks. Potassium-enriched solutions precipitated thick mantles of orthoclase on the previously formed plagioclase (An_{35}) laths and also filled the interstices between crystals with orthoclase. Deuterically altered biotite is present as an accessory mineral.

The green monzonite surrounding the intrusion contains plagioclase (An_{35}) with a thin mantle of orthoclase. Relatively fresh biotite crystals and scattered grains of partly altered olivine and hornblende are also present as accessory minerals.

The gray resistant monzonite contains large, well oriented laths of plagioclase (An_{35}) free of orthoclase mantles. Smaller crystals of orthoclase are concentrated between laths of plagioclase. The gray monzonite forms a resistant ridge around the intrusion and looks like a dike. The well oriented plagioclase laths and absence of deuterical alteration around the ferromagnesian minerals suggests a late-stage injection as a ring dike around a previously solidified central mass.

The last stages of activity are represented by felsite dikes that cut all older syenite, monzonite and gabbro in the Marble Canyon intrusion. The Cave Peak intrusion is about a mile from the Marble Canyon intrusion and probably formed at the same time.

Field relationships, such as the position of the intrusion with respect to the Diablo escarpment, and bleached surfaces along joints also indicate that, at the time of emplacement, the intrusion was near enough to the surface so that the vapor pressures were low.

A discordant contact and local horizontal extensions of the marble over the igneous body indicate that the emplacement of the intrusion was accompanied by stoping, and that the intrusive rock did not rise much above the present floor of Marble Canyon.

Faulting along the marble-gabbro contact in several places is indicated by slickensides on the contact and by fault gouge between the gabbro and marble.

The Cave Peak intrusion (Warner and others, 1959), about three-quarters of a mile northeast of the Marble Canyon intrusion, is composed of breccias of rhyolite and trachyte porphyry, nonbrecciated felsite (largely rhyolite), and a central core of granite. Associated with this intrusion are several rhyolite dikes, the largest of which cuts across the entrance to Marble Canyon and dips toward the Marble Canyon intrusion.

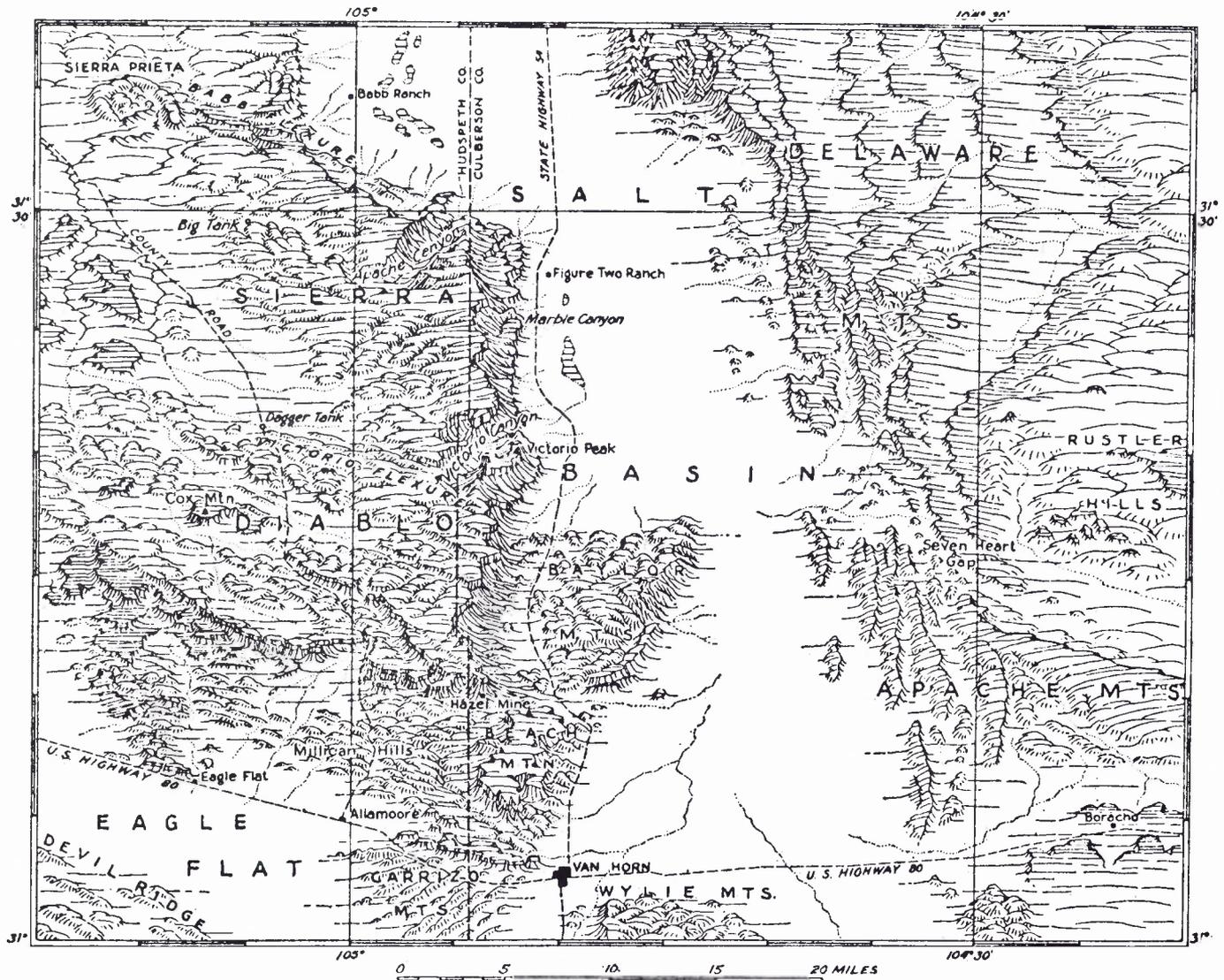


Figure 1. Physiographic map of Sierra Diablo region. Marble Canyon is just south of $31^{\circ}30'$ latitude, cut into the Sierra Diablo escarpment (slightly modified from King, 1942).

PETROLOGY OF METASEDIMENTS

The mineral assemblage in rocks from the metasediment contact aureole is dependent upon the bulk composition of the rock, the distance from the igneous-metasediment contact, and the nearness of open fractures. The original composition ranged from quartz, present as large chert nodules, to almost pure limestone and dolomites. The mineral assemblage near fractures is either a higher temperature or lower P_{CO_2} assemblage than the minerals a few centimeters away from open fractures, as the bulk composition is constant. Hydrous minerals, produced during and after cooling of the contact rocks when water reacted with previously formed silicate, are present in and along fractures in the metasediments.

Several sample traverses were made across the contact aureole to determine the mineral distribution in the contact zone. Two of these traverses include all the observed products from the decarbonation reactions among quartz, calcite, and dolomite.

Samples from one of the sample traverses (Section 1) were silica-rich dolomitic limestones. Samples from the other sample traverse (Section 2) were silica-poor dolomitic limestones (fig. 1, south end

of intrusion). The silica is present as chert nodules and silicified fossils.

Section 1 was sampled by starting at the contact and core drilling at an angle of about 7° from the horizontal in beds that dipped at an angle of about 14° away from the contact.

Section 2 was sampled at intervals of from 1 to 3 m up a 30° slope and at right angles to the exposed metasediment-igneous surface contact.

Some of the same decarbonation reactions occur in both sections 1 and 2, but the distance from the igneous-metasediment contact to the location in the contact zone where the products of a given reaction are observed is different in each section because the sample traverse angle with respect to the contact interface is different in each section.

The following abbreviations are used for the mineral phases in the formulas: Ak—Akermanite; Mel—Melilite; Di—Diopside; Fo—Forsterite; La—Larnite, Bredigite, and other forms of Ca_2SiO_4 ; Me—Merwinite; Mo—Monticellite; Per—Periclase; Q—Quartz- SiO_2 ; Ra—Rankinite; Sp—Spurrite; Ti—Tilleyite; Wo—Wollastonite. All reactions are arranged in order of increasing decarbonation.

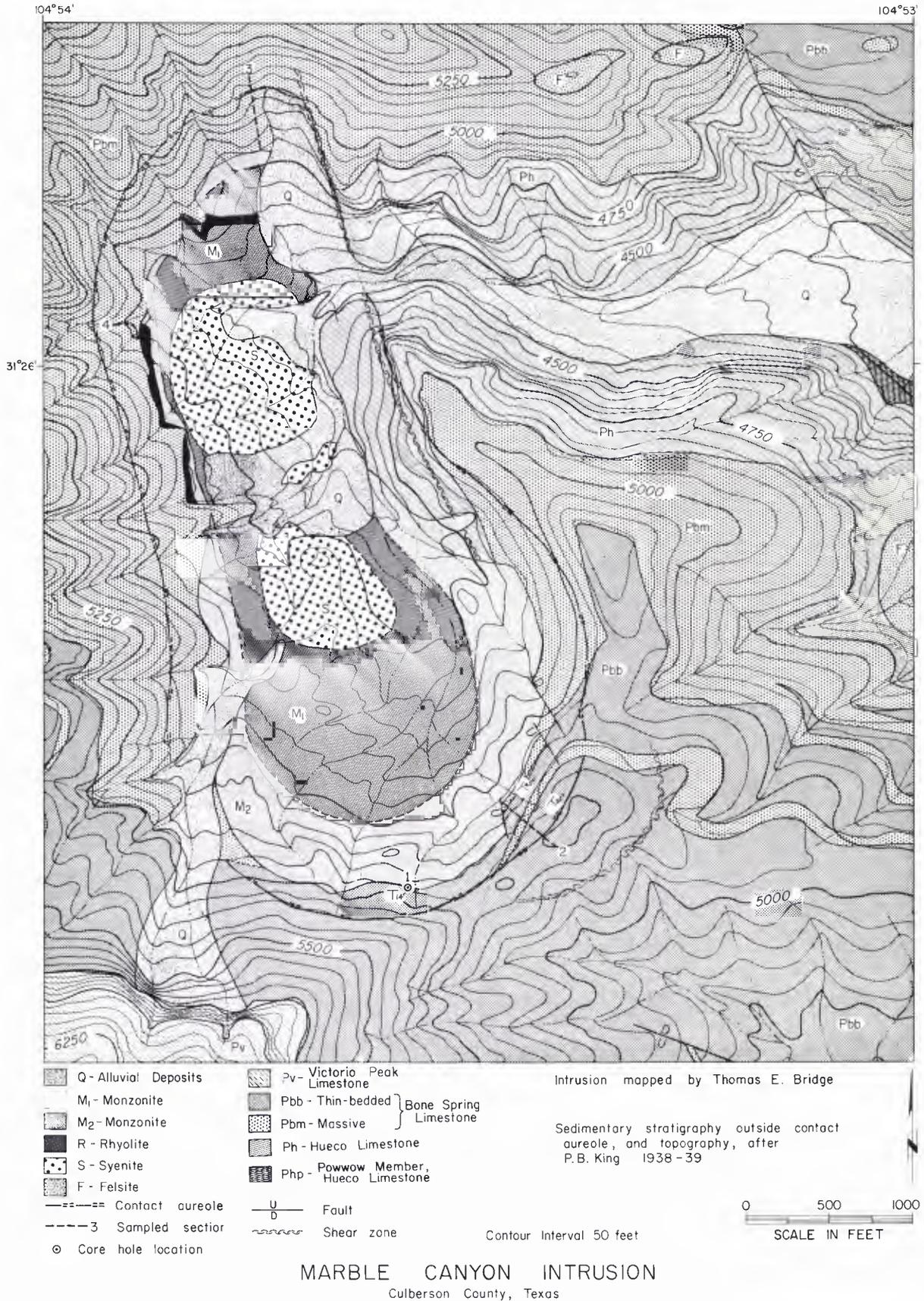


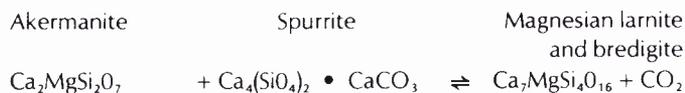
Figure 2. Geologic map of Marble Canyon intrusion and metasediments.

Summary of the sequence of reactions observed in the Marble Canyon contact zone

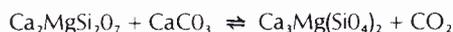
| | Experimental PT Curve | Distance (m) from Contact | |
|---|-------------------------|---------------------------|-----------------------|
| | | Section 1 Observed | Section 2 Observed |
| 1. Dol + 2Q \rightleftharpoons Di + 2CO ₂ | Weeks, 1956 | 32 | 85 |
| 2. 2 Dol + Q \rightleftharpoons Fo + 2Cal + 2CO ₂ | Weeks, 1956 | — | 67 |
| 3. Cal + Q \rightleftharpoons Wo + CO ₂ | Danielsson, 1951 | 28 | 0.3 |
| 4. Dol \rightleftharpoons Per + Cal + CO ₂ | Harker and Tuttle, 1955 | — | 36 |
| 5. Di + Fo + 2Cal \rightleftharpoons 3Mo + 2CO ₂ | Walter, 1963b | 15 | 30? |
| 6. Cal + Fo \rightleftharpoons Mo + Per + CO ₂ | Walter, 1963b | 15 | 30? |
| 7. Cal + Di \rightleftharpoons Mo + Wo | | — | 30? |
| 8. 2Wo + 3Cal \rightleftharpoons Ti + 2CO ₂ | Harker, 1959 | 18? & 16 | 12 |
| 9. 4 Wo + Ti \rightleftharpoons 3Ra + 2CO ₂ | | 17 | 0.6 |
| 10. Mo + Wo \rightleftharpoons Ak | Harker and Tuttle, 1956 | 17 | 0.6 |
| 11. Di + Cal \rightleftharpoons Ak + CO ₂ | Walter, 1963a | 17 | — |
| 12. Ti \rightleftharpoons Sp + CO ₂ | Harker, 1959 | 12 | 0.6 |
| 13. Cal + Ak \rightleftharpoons Me + CO ₂ | Walter, 1963a | 16 | 0.6 |
| 14. Sp \rightleftharpoons La + Cal + CO ₂ | | 12 | — |
| 15. Cal + Ra \rightleftharpoons 2La + CO ₂ | | 12 | — |
| 16. Ak + Sp \rightleftharpoons Magnesian La + CO ₂ | | 12 | — |
| 17. Sp + 2Mo \rightleftharpoons 2Me + Cal | Walter, 1965 | 15 | 0.6 |

Two polymorphic forms of dicalcium silicate (Ca₂SiO₄) have been described as naturally occurring by C. E. Tilley (1929). The minerals were found in a contact zone in Larne, Ireland, and given the names larnite and bredigite. Until 1964, no natural occurrences of these dicalcium silicate minerals had been reported from any locality in the United States.

The presence of small gehlenite inclusions in the larnite and bredigite suggests a reaction between akermanite of the zoned melilite (akermanite borders with gehlenite centers) and spurrite to produce the magnesian dicalcium silicate with about 4 weight/percent magnesium.



The magnesian dicalcium silicate is associated with merwinite which is formed by the reaction between akermanite and calcite.



The grains of dicalcium silicate analyzed from the Marble Canyon rocks contain from 4 to 6 weight/percent magnesium.

The composition of larnite associated with merwinite and gehlenite from sample 23, Marble Canyon, and larnite in sample 90402, Scawt Hill, County Antrim, Northern Ireland, are similar in composition and mineral association. The composition as determined by electron probe analysis is given in Table 1.

Table 1. Composition of larnite associated with merwinite and gehlenite.

| | Marble Canyon 23 | Scawt Hill (1) 90402 | Scawt Hill (2) 90402 |
|--------------------------------|------------------|----------------------|----------------------|
| SiO ₂ | 36.65 | 37.47 | 39.82 |
| Al ₂ O ₃ | 0.11 | 0.26 | 0.32 |
| FeO | 0.63 | 0.21 | 0.82 |
| MgO | 5.95 | 5.51 | 5.43 |
| CaO | 59.28 | (56.55)* | (53.61)* |
| Total | 102.62 | (100.00) | (100.00) |

*Inferred. (The analyzing crystal for calcium was not working.)

Melilite grains with akermanite borders and gehlenite centers are present in the contact rocks and range in size from 0.1 to 0.3 mm. The gehlenite centers in these melilite grains range in size from 0.05 to 0.1 mm, but rarely make up more than 10 percent of the mineral grain. Near the contact the akermanite rims are gone, but merwinite and dicalcium silicate grains contain gehlenite inclusions ranging in size from 0.05 to 0.1 mm. This indicates that the akermanite rims reacted to produce both merwinite and dicalcium silicate. Table 2 gives the composition of minerals associated with the dicalcium silicate near the contact boundary between the metasediments and igneous intrusion.

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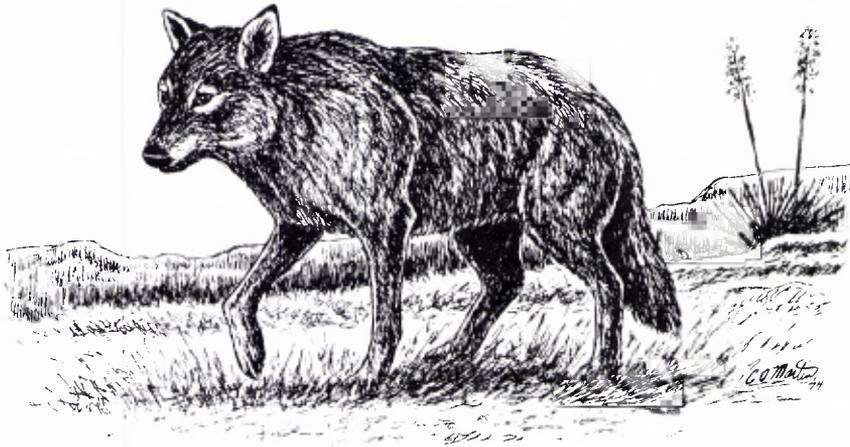
Table 2. Composition of minerals associated with dicalcium silicate near igneous-metasediment contact, Marble Canyon intrusion.

| Mineral | Sample | | | | | | |
|------------|--------|------------------|--------------------------------|------|-------|-------|--------|
| | No. | SiO ₂ | Al ₂ O ₃ | FeO | MgO | CaO | Total |
| Tilleyite | 49 | 23.80 | 2.66 | 0.01 | 0.00 | 56.58 | 83.15 |
| Spurrite | 2-11 | 26.66 | 0.21 | 0.00 | 0.23 | 63.36 | 90.46 |
| | 2-11 | 26.57 | 0.41 | 0.02 | 0.27 | 62.93 | 90.21 |
| Rankinite | S52EB | 50.27 | 0.17 | 0.06 | 0.22 | 49.29 | 100.01 |
| | 49 | 41.67 | 0.12 | 0.00 | 0.04 | 59.86 | 101.68 |
| Akermanite | 49 | 44.69 | 1.32 | 0.73 | 13.20 | 41.36 | 101.30 |
| | S52EA | 42.73 | 7.25 | 0.75 | 11.35 | 39.79 | 101.87 |
| Merwinite | 2-11.0 | 36.31 | 0.16 | 0.31 | 12.48 | 52.92 | 102.19 |
| | 46.9 | 39.37 | 0.05 | 0.51 | 12.01 | 51.52 | 103.46 |

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Gray wolf, *Canis lupus*.



Needle-and-thread plant, *Stipa comata*.