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A MODEL FOR SUBDUCTION ORIGIN AND DISTRIBUTION OF FLUORITE DEPOSITS IN THE WESTERN UNITED STATES

by

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DISTRIBUTION AND AGE OF FLUORITE DEPOSITS IN THE WESTERN UNITED STATES

Fluorite occurs in each of the western states in deposits of varying sizes and importance. Figure 1, which is modified from Peters (1958), shows the distribution of fluorite deposits of hydrothermal origin in the western United States and Mexico. An obvious linear trend of deposits passes through western Montana, Wyoming, central Colorado, New Mexico, west Texas and eastern Mexico. A less clearly defined trend passes through eastern Idaho, western Utah, eastern Nevada, southern California and western Arizona.

These fluorite deposits have two common characteristics: they are middle to late Tertiary in age and are associated with alkalic igneous rocks in places where igneous rocks have been found. Specific examples of dated occurrences are given by McAnulty and others (1963), Kottlowski (1965) and Anderson (1954). Worl (1974) gives many examples of the relationship of fluorite to alkalic igneous rocks.

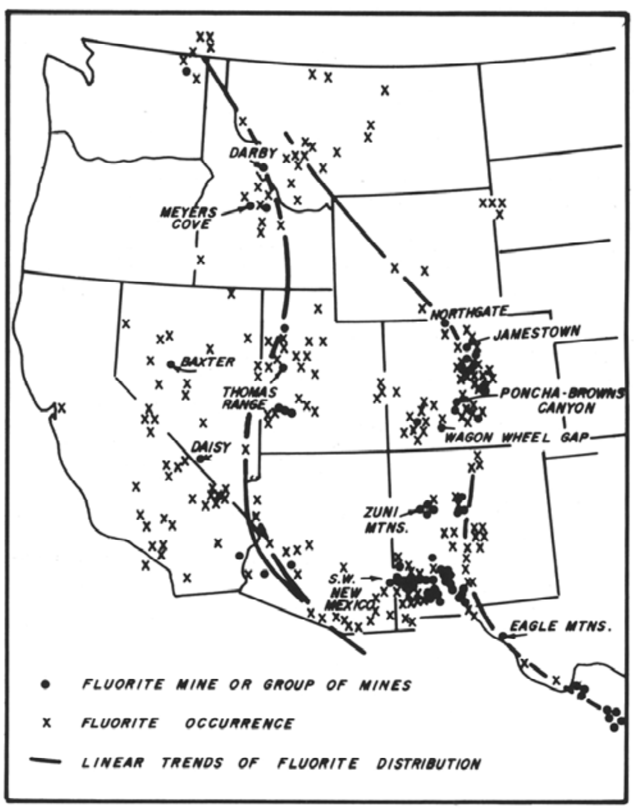

Figure 1. Distribution of fluorite mines and occurrences in the western United States (modified from Peters, 1958). Special attention is drawn to the dots, representing fluorite mines, which exemplify the linear trends of fluorite distribution. The x's represent occurrences in which fluorite may be only a small component.

VOLCANISM AND SUBDUCTION ZONES IN THE WESTERN UNITED STATES

The middle to late Tertiary fluorite deposits are within Tertiary volcanic provinces. These provinces are characterized by rocks of intermediate calc-alkalic composition that are more alkalic toward the interior of the continent in the North and South American Cordilleran Belt (Lipman and others, 1972). The Datil, San Juan, and Challis volcanic fields are examples of such volcanic provinces. The volcanic rocks are comprised of andesite to rhyodacite lavas commonly closely associated with younger, more silicic ash-flow sheets of latite to rhyolite composition. Similar volcanic associations are forming now at the Pacific Ocean margin, where continental plates are overriding oceanic crust in island arc environments (Hatherton and Dickinson, 1969).

Plots of K_2O versus SiO_2 content for a wide variety of early and middle Tertiary igneous rock suites from the western United States (Lipman and others, 1972) fall within the family of trends defined by circum-Pacific calc-alkalic suites that are clearly related to active seismic zones and subduction of oceanic crust (Hatherton and Dickinson, 1969). This chemical similarity in K_2O versus SiO_2 ratio suggests that early and middle Tertiary volcanic rocks of the western United States, like modern volcanic rocks around the Pacific basin, are genetically related to a subduction system.

Hatherton and Dickinson (1969), in studying calc-alkalic rocks overlying subduction zones in the Lesser Antilles, New Zealand, and Indonesia found that for volcanic rocks with 60 percent silica the K_2O content of the rocks increased linearly with increasing depth to the underlying subduction zone. Lipman and others (1972) used this K_2O-depth relationship by determining K_2O content at 60 percent SiO_2 for 70 known early and middle Tertiary igneous rock suites from the western United States. K_2O contents were converted to depth values and plotted on a map of the western United States, and then contoured at 50 km intervals. The plot (Fig. 2) shows two well-defined trends of eastward increasing depths to subduction zones and suggests that early and middle Tertiary subduction of the Pacific Ocean crust beneath western North America was along two imbricate subduction zones dipping eastward at 15° to 20°.

The calc-alkalic igneous rocks, and the more alkalic products, are postulated to originate by melting of the oceanic lithospheric slab along subduction zones beneath continental crust. Upon subduction of the slab, dehydration reactions take place in response to increasing temperature and pressure, and various metamorphic minerals become unstable and dissociate

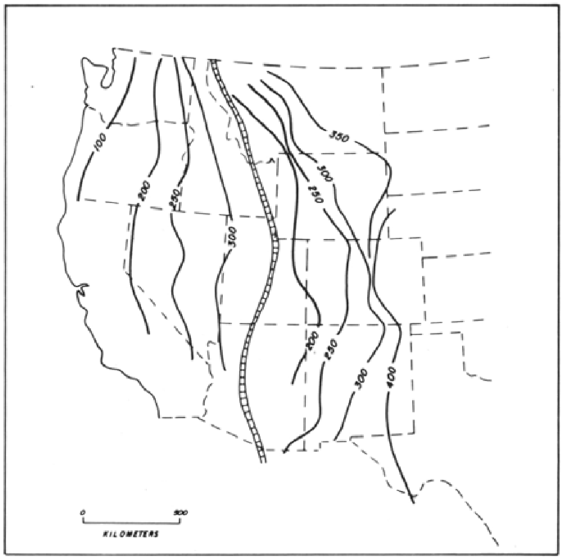

Figure 2. Contoured depths (km) to inferred early and middle Tertiary subduction zones of the western United States. Double line indicates discontinuity in contours. From Lipman and others, 1972.

at depth. Dissociated serpentine, talc, biotite, muscovite and hornblende may react with anhydrous mantle periodotite and water to produce phlogopite (Brown and Fyfe, 1972). Phlogopite is a relatively K-rich mineral which may be stable to a depth of about 300 km (Wyllie, 1973). Melting at depths greater than 300 km would therefore be expected to produce K-rich igneous rocks and may explain the increasing alkalinity of subduction-related igneous rocks continentward from oceanic trenches (Wyllie, 1971). Furthermore, phlogopite may contain up to 6.74 percent fluorine (Allman and Koritnig, 1972).

RELATIONSHIP OF FLUORITE DEPOSITS TO SUBDUCTION ZONES

Comparison of Figures 1 and 2 shows the distribution of middle to late Tertiary fluorite deposits is nearly coincident with the surface projection of the easternmost part of each of the two early to middle Tertiary subduction zones as described by Lipman and others (1972). I suggest that the fluorine in hydrothermal fluorite deposits in the western United States is derived by melting of phlogopite along the deeper parts of Tertiary subduction zones. Because of the ability of alkalic melts to hold fluorine as alkali-fluoride compounds (Kogarko and others, 1968) the melts tend to concentrate fluorine along subduction zones and transport it upward through the mantle. In the crust fluorine volatilizes as SiF_4 (Kogarko and others, 1968) and may pass upward through tensional faults, where it mixes with meteoric water to form HF- and SiO_2-bearing hydrothermal fluids. Fluorite may precipitate from these fluids if physiochemical and structural conditions are favorable.

Fluorite deposits in the western United States are therefore found within or in close proximity to tensional fault zones which overlie the positions of the deepest parts of the two early to middle Tertiary subduction zones. The Rio Grande rift is a good example of an area of calc-alkalic volcanism and tensional faulting having abundant fluorite deposits.

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