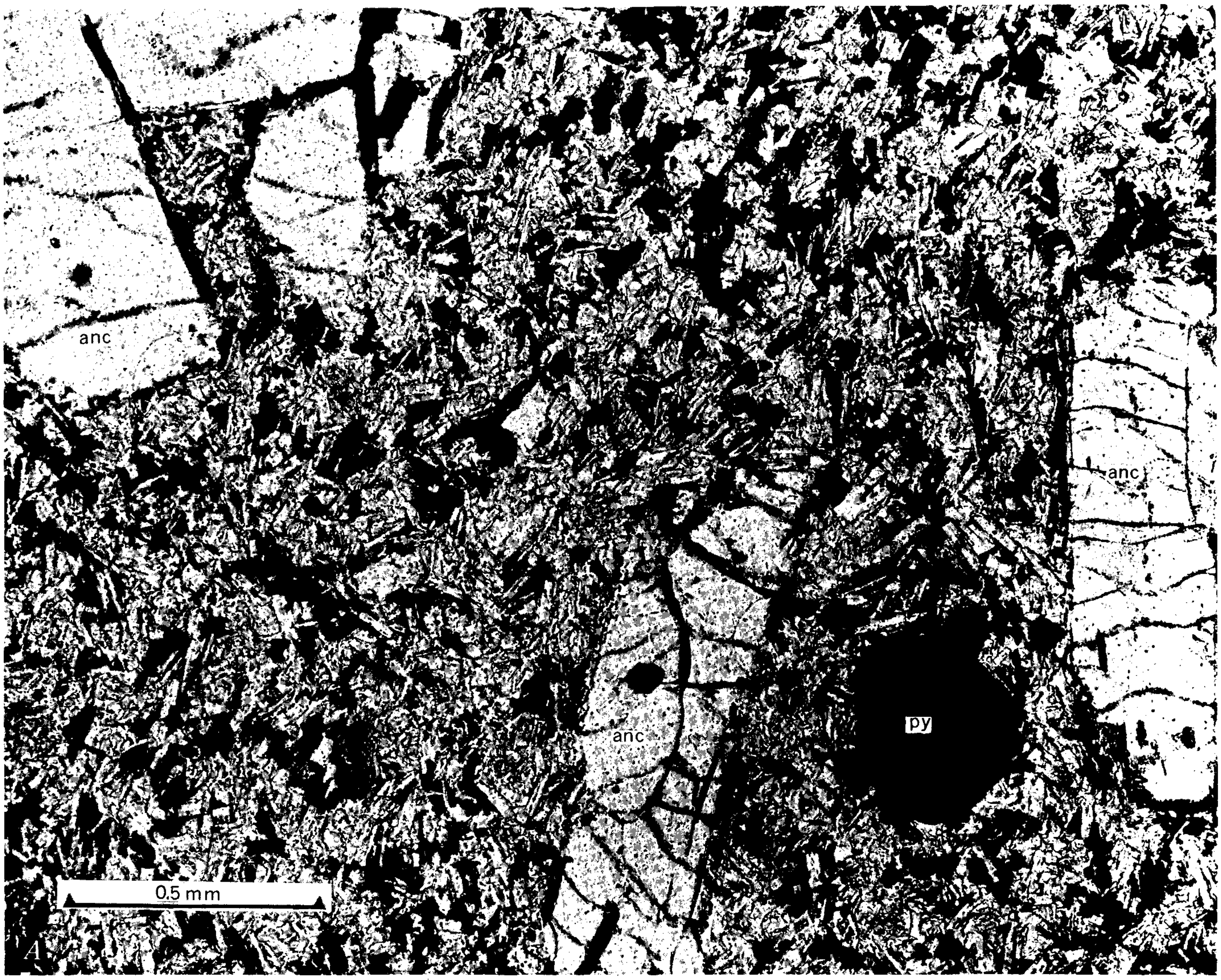
200. SODA RHYOLITE (PANTELLERITE?) FROM LAKE COUNTY, OREGON

By George W. Walker, Menlo Park, Calif.

Reconnaissance mapping has disclosed several widely separated masses of sodium-rich volcanic rocks of middle to late Cenozoic age in south-central Oregon, a region characterized by large volumes of calcic-alkalic volcanic rocks. The most extensive exposures of these rocks are on the flanks of Hart Mountain (secs. 1, 9, and 12, T. 36 S., R. 25 E.) in southeastern Lake County; other masses of sodium-rich rocks, exposed in the upper drainage of Deep Creek (sec. 2, T. 41 S., R. 21 E.) southeast of Crane Mountain, Lake County, probably are extensions of the silicic intrusive and extrusive volcanic rocks of the High Grade district of California (Hill, 1915; Gay and Aune, 1958).

The sodium-rich volcanic rocks occur both as near-surface intrusive masses as much as a mile long and several hundreds of feet wide and as restricted thick flows that emanated from the intrusive centers. All of these rocks are porphyritic, the phenocrysts being enclosed in a fine-grained holocrystalline groundmass (fig. 200.1); commonly the flows are strongly flow banded and locally autobrecciated suggesting a magma of high viscosity.



A

sediments on the Colorado Plateau although some sediments were derived from the Front Range highland. In addition to the flow direction of streams, further evidence that the source areas for Moenkopi sediments were northeast, east, and southeast of the formation is that the average grain size of the rock is progressively smaller and cross stratification is less common to the west and north. Regional stratigraphic relations of the units studied indicate that the fluvial sandstones derived from the Uncompahgre and Front Range highlands are older than those derived from the Mogollon highland.

LOWER PART OF CHINLE FORMATION

The lower part of the Chinle formation consists of variegated bentonitic claystone, siltstone, clayey sandstone, and persistent sandstone and conglomerate beds that have physical characteristics of stream channel and flood plain deposits.

The members and units studied in this part of the formation are given on figure 199.1*B*. Cross-strata dip directions indicate that the streams that deposited the sediments in the members and units studied flowed mainly north, northwest, and west (fig. 199.1*B*). The Mogollon highland was probably the main source area for lower Chinle sediments; the Uncompahgre and Front Range highlands contributed a minor amount of detritus. Sediments of the lower part of the Chinle become coarser southward toward the Mogollon highland and eastward toward the Uncompahgre and Front Range highlands.

UPPER PART OF CHINLE FORMATION

The upper part of the Chinle formation consists of red sandstone and siltstone, and subordinate gray conglomerate and limestone that are believed to represent fluvial, flood-plain, deltaic, and lacustrine deposits. It includes the Owl Rock and Church Rock members of the Chinle in southeastern Utah and northeastern Arizona, the red siltstone part of the Chinle in northwest Colorado, and the upper part of the Dolores formation of southwestern Colorado. The Owl Rock member, which is predominantly limestone and structureless siltstone, was not studied.

Cross-strata dip directions in sandstone units of the upper part of the Chinle indicate that the sediment was derived from positive areas adjacent to the depositional basin (fig. 199.1*C*). The red siltstone and sandstone in the upper part of the Chinle were probably derived largely from older sedimentary rocks exposed on and adjacent to the Uncompahgre and Front Range highlands. Cross-strata orientations in the upper part of the Dolores formation of southwest Colorado, and a local sandstone bed, the Black Ledge, of the Church Rock member in southeast Utah, indicate a source in the Uncompahgre highland. An additional minor source to the west of the west margin of the upper part of the Chinle is suggested by dip orientations in the Hite bed, a local unit in the Church Rock member of southeast Utah.

KAYENTA FORMATION AND UPPER PART OF THE MOENAVE FORMATION

The Kayenta formation consists primarily of red-brown sandstone, siltstone, and claystone that have physical characteristics typical of fluvial and flood plain deposits. The Springdale sandstone member of the underlying Moenave formation is included with the Kayenta in this report because it is similar in lithology and depositional environment. R. F. Wilson (oral communication, 1961) believes that the Springdale sandstone member is laterally equivalent to most of the Kayenta formation of northeastern Arizona.

Cross-strata orientations indicate that the regional drainage in Kayenta and Springdale time was mainly to the west and southwest (fig. 199.1*D*). The Kayenta sediments were probably derived mainly from older sedimentary rocks uplifted along the east margin of the formation. Sediments of the Kayenta formation, in general, decrease in coarseness southwestward from western Colorado.

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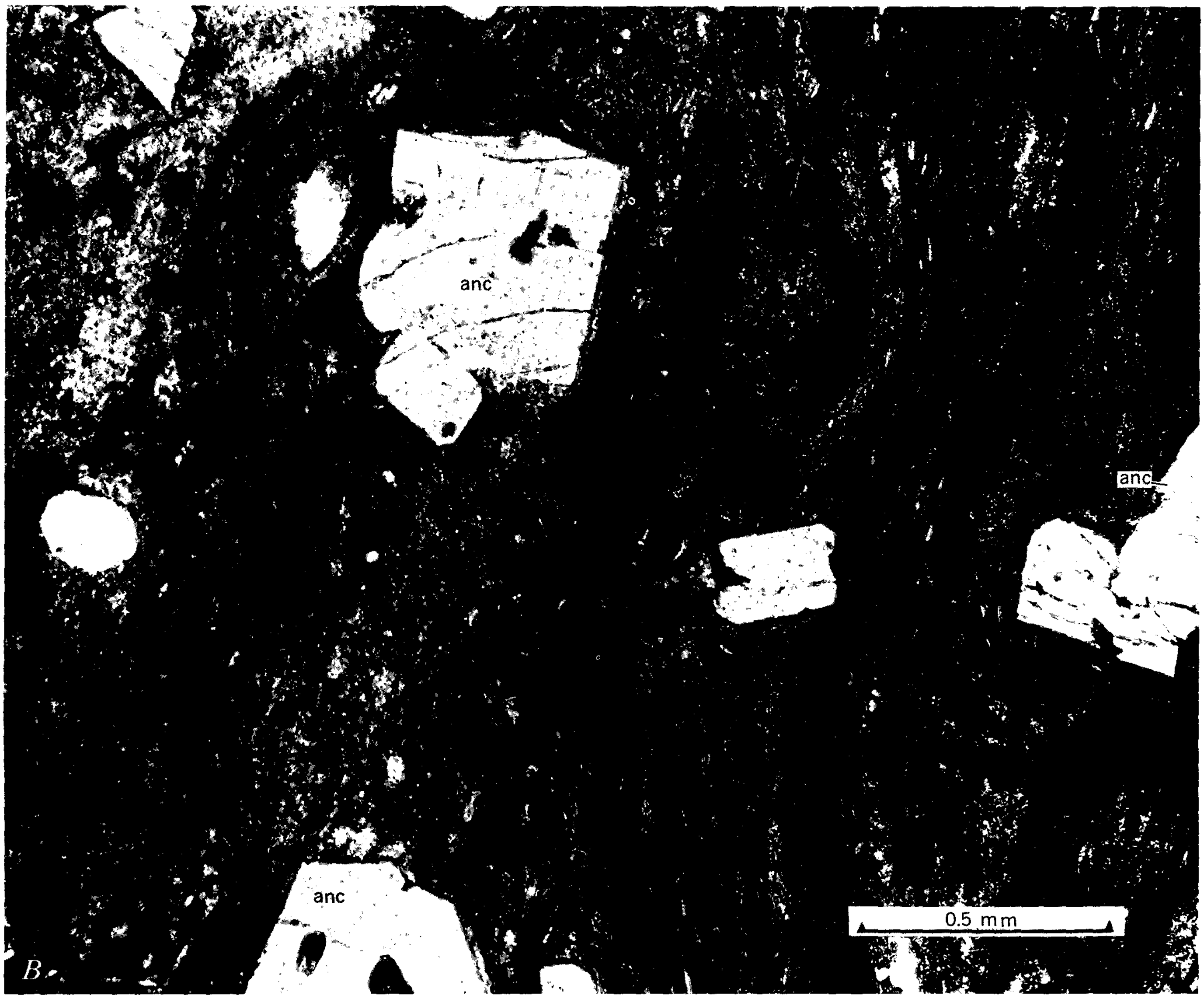
Analyses of two samples of these sodium-rich rocks are presented in table 200.1. Sample 1 was collected from a large intrusive at the west base of Hart Mountain and sample 2 from a brecciated flow on the east flank of the mountain. The alkali content of these rocks, totaling about 10.5 percent, is higher than normal for rhyolite, and the ratio of Na_2O to K_2O is approximately 6 to 5. In both rocks analyzed the content of Al_2O_3, CaO, and MgO is noticeably low. Both samples are characterized by a slight molar excess of $Al_2O_3 + Fe_2O_3$ over $Na_2O + K_2O$. Standard minerals of the norm, which for both specimens includes quartz, orthoclase, albite, acmite, and diopside, also are presented in table 200.1. Even though the groundmass of both samples is too fine grained to permit accurate and complete modal analyses, an approximate modal analysis has been made of sample 1 (table 200.1) using a standard point count method (Chayes, 1949).

The sodium-rich rocks of Hart Mountain contain many phenocrysts of alkali feldspar ($2V(-)=47° \pm 2°$), fewer phenocrysts of a pleochroic green diopsidic pyroxene (variable $2V(+)=65° \pm 5°$; $n_\beta \approx 1.77$) with slightly darker green reaction rims, and scattered rare phenocrysts of quartz and oxyhornblende in a fine-grained groundmass. The groundmass consists of anhedral grains of quartz and alkali feldspar, small prisms and shreds of acmite ($n_\alpha \approx 1.76$; $n_\gamma \approx 1.80$; $X \wedge c = 0° - 5°$), a pleochroic blue amphibole (riebeckite?, $n_\beta \approx 1.69$; $X \wedge c = 4°$), a pleochroic brown mineral ($n_\beta \approx 1.76$; $Z \wedge c \approx 43°$)



B

FIGURE 200.1.—Photomicrographs of thin sections of soda rhyolite intrusive, *A*, and flow-banded and autobrecciated flow, *B*. Phenocrysts of anorthoclase (anc) and diopsidic pyroxene (py) in fine-grained groundmass of quartz and alkali feldspar (light colored minerals) and acmite, riebeckite?, aenigmatite-rhönite?, and magnetite (dark colored minerals).

TABLE 200.1.—*Rapid rock analyses (in weight percent), calculated norms, and an approximate mode of two samples of soda rhyolite from Hart Mountain, Lake County, Oreg.*

[Analysts: P. L. D. Elmore, I. H. Barlow, S. D. Botts, Gillison Chloe, U.S. Geological Survey]

Sample / Field number	1 GWW-3-60	2 GWW-4-60
SiO_2	68.6	69.4
Al_2O_3	13.5	13.2
Fe_2O_3	3.1	3.2
FeO	1.8	1.8
MgO	.03	.05
CaO	.52	.30
Na_2O	5.8	5.8
K_2O	4.7	4.6
H_2O	1.0	1.0
TiO_2	.37	.35
P_2O_5	.03	.05
MnO	.17	.18
Total	99.6	99.9
CO_2	<.05	<.05
Norm[1]		
Quartz	16.6	18.2
Orthoclase	27.8	27.2
Albite	43.0	42.0
Acmite	5.5	6.5
Diopside	2.2	1.2
Hypersthene	1.1	1.7
Magnetite	1.6	1.4
Ilmenite	.8	.8
Total	98.6	99.0

Approximate mode[2]

Phenocrysts[3]		35.2
Anorthoclase	32.0	
Diopsidic pyroxene	3.0	
Oxyhornblende	.2	
Magnetite		2.0
Groundmass		62.4
Quartz and alkali feldspar	48.0	
Riebeckite?, acmite, and aenigmatite-rhönite?	14.0	
Orange-brown alteration mineral	.4	

[1] Calculated by C.I.P.W. system.
[2] Based on a 350-point traverse in each of three thin sections, sample 1. Color index 20.
[3] A few crystals of quartz present in some sections.

probably transitional in the rhönite-aenigmatite series, magnetite, and an unidentified orange-brown alteration mineral.

The alkali feldspar phenocrysts commonly are faintly zoned and exhibit either fine grid-twinning or poorly developed simple twinning. A cryptoperthitic intergrowth of the albite and orthoclase components in this alkali feldspar is suggested by the complex diffraction pattern obtained from the phenocrysts (fig. 200.2*A*). To simplify the diffraction pattern and allow an estimate of composition, the phenocrysts were heated in a muffle furnace for 6 hours at 1,000°C to homogenize the albite-orthoclase components into one feldspar. A diffraction pattern of the homogenized feldspar (fig. 200.2*B*) is similar to the pattern (fig. 200.2*C*) given for a high temperature synthetic alkali feldspar whose composition is $Ab_{71}Or_{29}$ (Donnay and Donnay, 1952, fig. 4). The normative feldspar shows about $Ab_{60}Or_{40}$ which suggests that this compositional estimate is the right order of magnitude. The moderately large axial angle (47°±2°) of the natural feldspar is comparable to those given by Tuttle (1952, table 1) and by Carmichael (1960, table 3, spec. 3112F) for anorthoclase of compositions ranging from about $Ab_{76}Or_{23}$ to $Ab_{63}Or_{36}$. An X-ray diffraction pattern of the light fraction (sp gr <2.88+) of the groundmass suggests that the groundmass feldspar also is anorthoclase.

Some mineralogic differences exist between the sodium-rich rocks exposed on Hart Mountain and those southeast of Crane Mountain. Sanadine, as phenocrysts, is an important constituent of the rocks near Crane Mountain. Also, quartz (as phenocrysts and crystal fragments), oxyhornblende, and aenigmatite or rhönite are more abundant, whereas diopsidic pyroxene and acmite are rare or lacking.

According to the classification of Rittman (1952), these volcanic rocks chemically are soda rhyolite, close to his alkali rhyolite. They have many chemical and mineralogical characteristics in common with varieties of pantellerite (Washington, 1913), but contain slightly less $Na_2O + K_2O$, less $Fe_2O_3 + FeO + TiO_2$, and more Al_2O_3 than those on the island of Pantelleria.

The geologic occurrence of these rocks as intrusive and flow units within large andesitic and basaltic volcanic piles suggests that they are late volcanic differentiates. As yet, no data are available as to the characteristics of the parent magma or the type of pre-Tertiary bedrock intruded; consequently, there is no evidence either for or against sodium enrichment of the magma by contamination.

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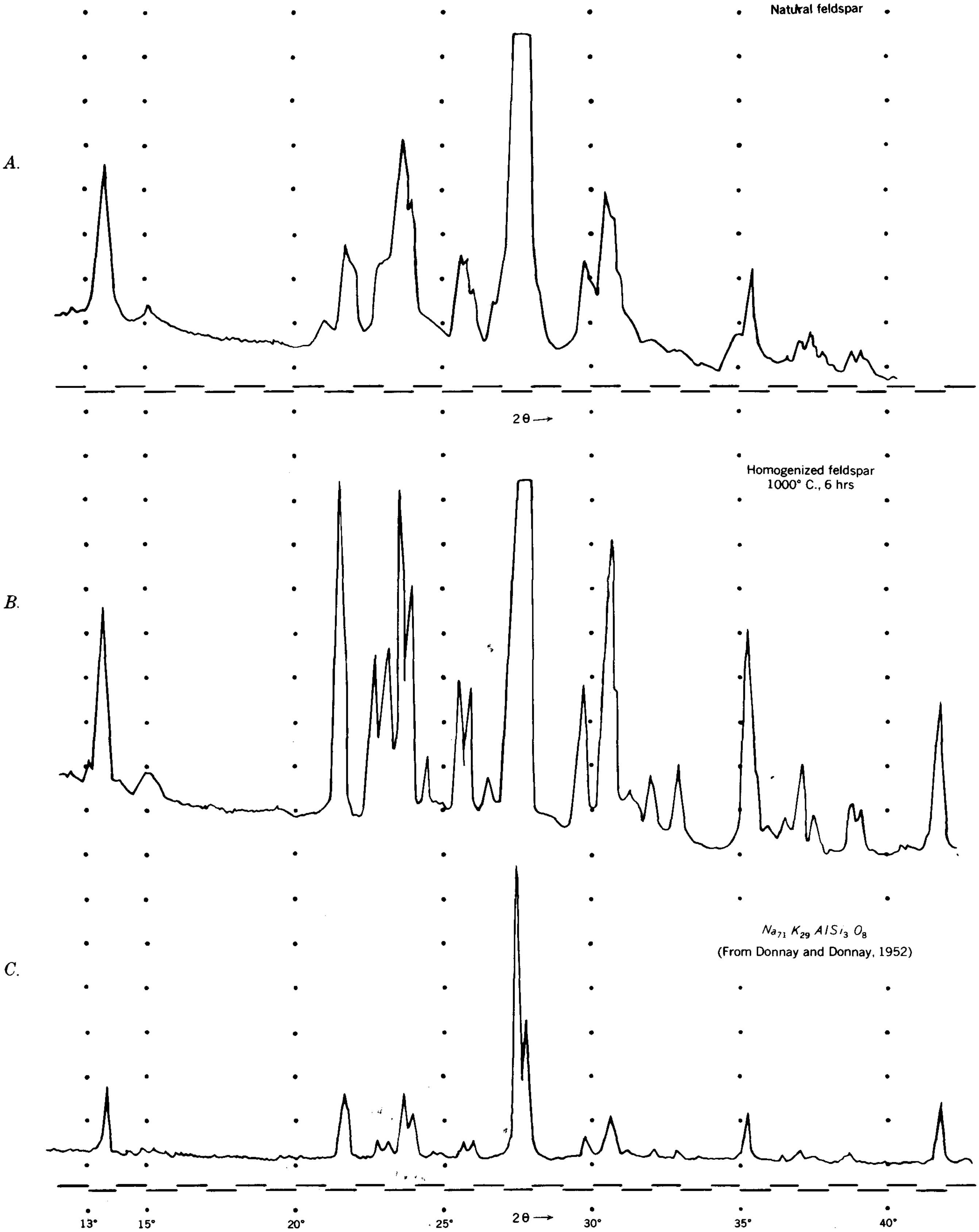

FIGURE 200.2.—Powder diffraction patterns. *A*, Unmodified natural feldspar phenocrysts; *B*, homogenized feldspar phenocrysts; and *C*, high-temperature synthetic alkali feldspar.

201. PREHNITE-PUMPELLYITE METAGRAYWACKE FACIES OF UPPER TRIASSIC ROCKS, ALDRICH MOUNTAINS, OREGON

By C. Ervin Brown, Washington, D.C.

In east-central Oregon a thick sequence of Upper Triassic rocks, briefly described by Thayer and Brown (1960), contain authigenic mineral assemblages characteristic of the prehnite-pumpellyite metagraywacke facies and the laumontite stage of the zeolite facies of Coombs (1960). The lithology and authigenic alteration are similar to those of a sequence of rocks in Southland, New Zealand, in which the lower grade mineral facies were first recognized (Coombs, 1954).

The rocks in Oregon, which make up most of the Aldrich Mountains, have a composite thickness of 40,000 to 50,000 feet and comprise conglomerate, graywacke, shale, siltstone, tuffaceous graywacke, andesitic tuff, rhyolitic vitric tuff, and basaltic lava. These are unconformably overlain by as much as 14,000 feet of similar Jurassic rocks present south of this area (Lupher, 1941).

Intraformational unconformities, differences in trends of folds, and faults that cut only the older rocks of the sequence show that deformation recurred during deposition. Eastward thickening of younger units in the sequence indicates successive eastward shifts of the basin of deposition. Absence of foliation suggests that the strongly folded sedimentary rocks were only partly indurated and possibly well lubricated by connate water during folding and deep burial.

Many of the rock types contain large amounts of authigenic chlorite, albite, and quartz, and also minor quantities of sphene, epidote, and rutile that possibly are not authigenic. Authigenic pumpellyite, prehnite, and laumontite occur chiefly in volcanic rocks or rocks rich in volcanic debris.

Albite is the most abundant detrital plagioclase throughout the stratigraphic section. Although some fragments are obviously from albitic rocks, I believe most of them were albitized in places. Albite also forms fine-grained mosaics of twinned laths intergrown with quartz that replace the matrix of tuffaceous graywackes and tuffs. In one specimen of bedded vitric tuff, the shard structure is well preserved despite complete recrystallization of the glass to a felt of intergrown albite laths and quartz. Albitic plagioclase too fine for microscopic identification also has been indicated in devitrified tuffs by X-ray diffraction.

Authigenic quartz likewise occurs throughout the stratigraphic section, both intergrown with albite as a devitrification product and as cryptocrystalline clots associated with laumontite. Greenstones near the base of the section contain secondary quartz; and pillow basalts about 4 miles southwest of Canyon City are veined by quartz, pumpellyite, and calcite. Fine-grained quartz veinlets are numerous in siliceous mudstone and chert in the lower part of the sequence.

Chlorite is most abundant as an alteration product of basic volcanic fragments in graywackes and basaltic lithic tuffs. It forms much of the yellowish-green cryptocrystalline matrix in graywacke, tuff, and greenstone. In places chlorite forms flaky spherulitic aggregates, some of which show an anomalous blue interference color.

Prehnite occurs most commonly as wispy patches in tuffaceous rocks, but also forms idioblastic prisms as much as 0.5 mm long in mudstone and siltstone and veins in shattered rock near early faults. The wispy patches are as much as 10 mm in diameter and weather to light-gray spots.

Pumpellyite has been found mainly in basaltic lavas in the lower part of the stratigraphic section and in the pillow lavas southwest of Canyon City. It occurs with chlorite in amygdules and also forms veinlets with calcite and quartz. Pumpellyite also occurs in coarse lithic tuffs.

Authigenic laumontite occurs as spots in siltstones of Jurassic age south of the Aldrich Mountains and almost completely replaces some rhyolitic or dacitic vitric tuffs of Triassic age. Laumontitized tuff is present in 2-inch layers in the upper part of the section and in beds as much as 10 feet thick in the lower part. Irregular optically continuous patches as much as 5 mm across generally include several hundred relict shard forms. Laumontite has replaced interstitial material in dacitic volcanic breccia and in a conglomerate near the base of the section.

Celadonite occurs as thin green bands, mainly in tuffaceous rocks that constitute most of the peaks of the Aldrich Mountains. In thin section this mineral is seen as irregular blue-green pleochroic blebs localized in layers. Celadonite is also present in greenstones near the base of the sequence and in finely cross-bedded tuffaceous siltstones near its top.

Epidote, sphene, and rutile are found throughout

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