Phanerozoic-Cryptozoic and Related Transitions: New Evidence

Abstract. *The fossil* Pteridinium, *a distinctive component of a worldwide early metazoan (Ediacaran) assemblage, is provisionally recorded from probable early Cambrian strata in eastern California. In context with other evidence, this finding implies a Cambrian age for the Ediacaran fauna and approximate coincidence of limits between Phanerozoic-Cryptozoic, Paleozoic-Precambrian, and Cambrian-Precambrian.*

Recent study of markings of biologic origin in rocks near the base of the Paleozoic in the White-Inyo Mountains of eastern California reveals similarities between one of these markings and the problematical genus *Pteridinium* (*1*), which occurs at the base of the Nama System in South West Africa. The Nama fauna has been correlated with the Ediacaran fauna of South Australia (*2*) on the basis of their mutual inclusion of *Pteridinium* and also another problematical organism, *Rangea*, both provisionally assigned to the Pennatulacea (*3*). From other fossils at Ediacara this correlation has been extended to strata in the Charnwood Forest of England (*4*) and in northern Russia and Siberia (*5*).

Thus the elements of worldwide correlation of a very early Metazoan fauna are suggested. The immediate problem is the relation of this fauna to other early metazoan faunas; and that is quite uncertain, except for the fact that the type Ediacaran fossils occur several hundred feet below a Lower Cambrian archaeocyathid assemblage in a different stratigraphic unit. This bears ultimately on the question of metazoan origins and on the vexing question of where and how to define a boundary between the major divisions of geologic time known as Paleozoic and Precambrian.

This discussion is further complicated by the historical evolution of the term Precambrian. For many years the Cambrian was considered to mark the base of the decipherable historical record, and rocks older than this were thought to represent a subordinate part of earth history not susceptible to world-wide subdivision, hence known only as pre-Cambrian. The use of the term Precambrian as a single word with a capital P was only recently introduced to dignify its present treatment as a major formal grouping of the rock succession and geologic time, and not merely something that wasn't Cambrian.

Increasingly in recent years some geologists and paleontologists have entertained the notion of recognizing a boundary between the Paleozoic and Precambrian eras that would take into consideration factors epitomized by the use of the terms Phanerozoic and Cryptozoic. The relatively late appearance of the metazoan grade of evolution probably marks and is related to some great episode in earth and atmospheric history that offers operationally practical and philosophically satisfying grounds for the division of geologic time into two major if unequal parts (*6*).

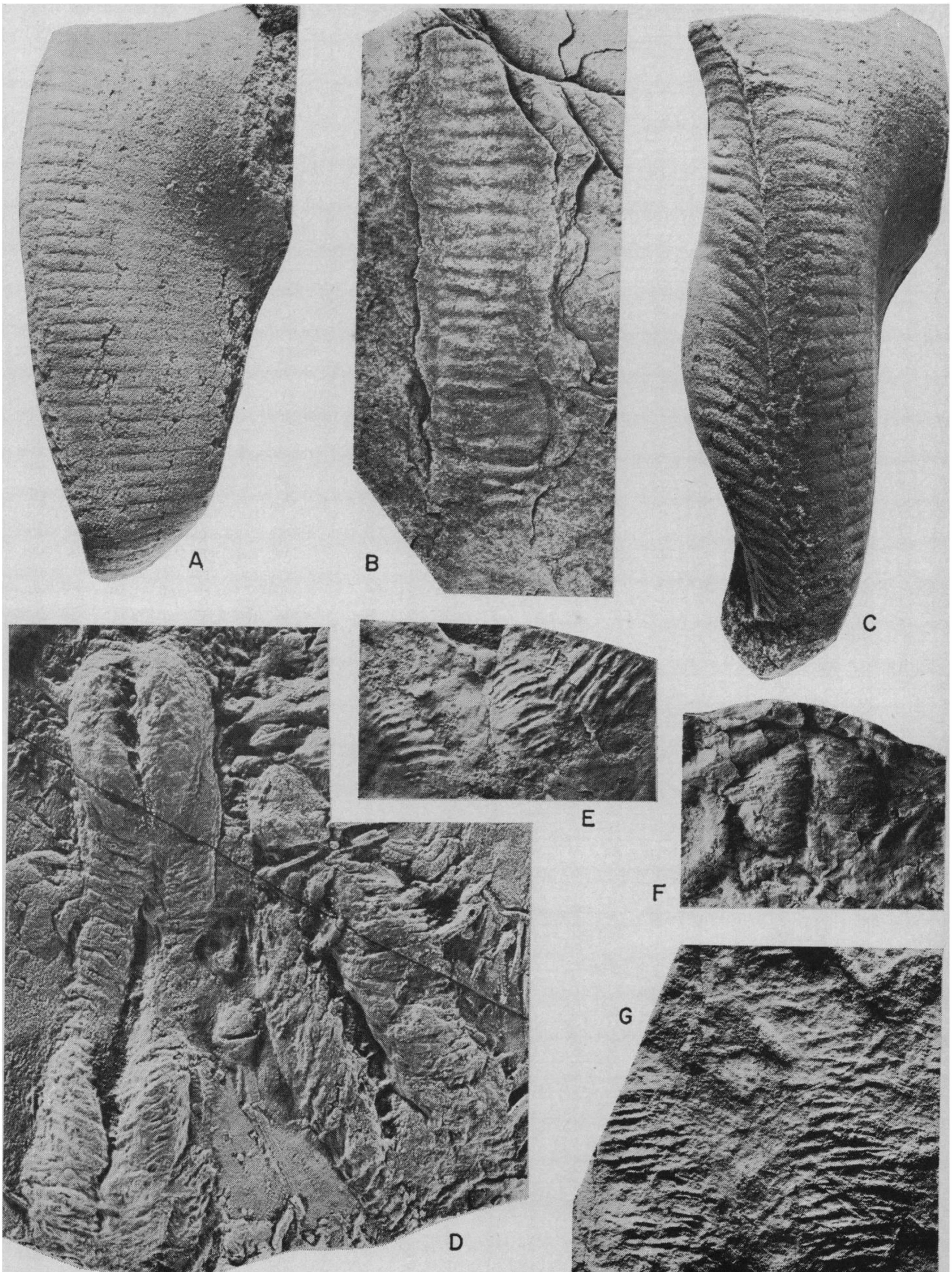
Under such a concept the era boundary between Precambrian and Paleozoic becomes independent of the Cambrian, and one thinks of the possibility of pre-Cambrian rocks of Paleozoic age. Precambrian then signifies pre-Paleozoic, and the time may come when this awkward term (Precambrian) will disappear from our language altogether. In fact, it must disappear to resolve the absurdities inherent in trying to discuss the very legitimate question of pre-Cambrian rocks of post-Precambrian age, as well as the awkward but now widely used reference to post-Precambrian in other connections. Meanwhile we can continue to talk about the problem as some have done in terms of Phanerozoic and Cryptozoic eons (perhaps eventually with more felicitous eon terms for still more ancient rocks with no animal life at all or without life).

The object that precipitates these and other reflections (Fig. 1B) is an unimpressive but nevertheless distinctive imprint which can hardly be of nonvital origin and which compares among fossils known to us only with *Pteridinium* (Fig. 1A, C), for which we have ample reference material collected by Cloud in 1965 and also loaned to him for study by P. S. Swart of the State Museum of South West Africa at Windhoek. Were there any question about the age of the California specimen (Fig. 2), one might hypothesize that it was the imprint of an annulately ribbed, orthoconic cephalopod or sipuncle, but it occurs far below the position in the geologic sequence where such fossils are known. As can be seen by comparing Fig. 1B with known *Pteridinium* to right and left, they compare closely in their slat-like ribbing, dimensions, and spacing of ribs. Nothing else is yet known at this general stratigraphic level which the California fossil resembles even faintly, and it seems likely that it is in fact a *Pteridinium* or closely related form. This fossil was found by a University of California student in the middle member of the Deep Spring Formation (locality 6, Fig. 3B) slightly more than 2000 feet below the lowest occurrence of the early Cambrium trilobite *Fallotaspis*, about 3000 feet below a zone (locality 2, Fig. 3A) containing relatively abundant *Fallotaspis* and *Daguinaspis* (*7*), and 350 feet below a zone of trace fossils including representatives of the arthropod sitzmark *Rusophycus* and crawl-track *Cruziana* (localities 1, 3, Fig. 3A; locality 7, Fig. 3B). These relations are shown in Fig. 2, and Fig. 3 shows the location and local geologic relationship.

If the reader accepts the probable presence of *Pteridinium* in California, its relation to other organisms in the same section becomes of great interest.

First let us consider the presumably arthropodan sitz-mark to crawl-track sequence *Rusophycus-Cruziana* from the beds 350 feet above *Pteridinium*. Both forms are shown to be attributable to a single organism by certain

Fig. 1. (A, C) *Pteridinium simplex* Gürich 1930, emend. Richter 1955. Kuibis Quartzite, base of Nama System, Aar, between Kuibis and Aus, southeastern South West Africa. Locality P.I. 16 of State Museum of South West Africa. (B) Compare *Pteridinium*. Close to middle of Deep Spring Formation, NE¼, NW¼, SE¼, sec. 16, T7S, R35E, Blanco Mountain Quadrangle, California. Locality 6 of Fig. 3. (D) *Rusophycus* (upper left) and *Cruziana* (continuous below *Rusophycus* at left and also on right). Obviously the two names apply to the same organism (and *Rusophycus* has priority), but it is convenient to use both names here. Tapeats Sandstone, Middle Cambrian, Chuar Valley, Grand Canyon, Arizona. U.S. National Museum No. 66148. (E, G) Arthropod (? trilobite) scratchings of *Cruziana*-type from base of upper member of Deep Spring Formation, Lower Cambrian, center E½, NE¼, SW¼, sec 18, T6S, R35E, Blanco Mountain Quadrangle, California. Locality 1 of Fig. 3. For comparison with Fig. 1D and also with *Cruziana* and other scratchings attributed to trilobites by Walcott (*10*, plates 37 to 40). (F) *Rusophycus* from base of upper member of Deep Spring Formation, Lower Cambrian. Same locality as E and G. (All illustrations are approximately natural size.)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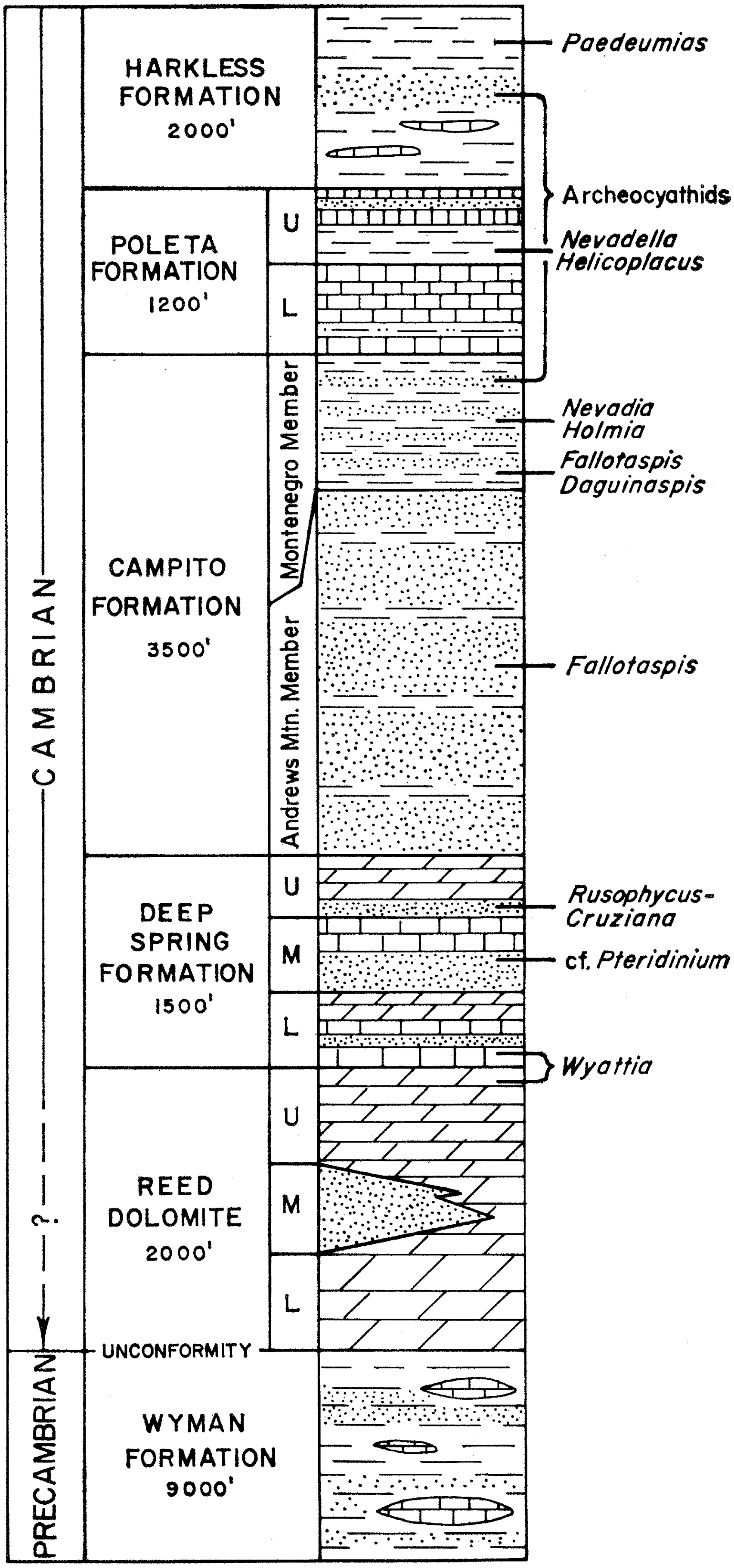

Fig. 2. Stratigraphic column for White-Inyo Mountains, California, showing positions of *Pteridinium (?), Rusophycus-Cruziana*, and *Wyattia* and their relation to other Lower Cambrian forms. Modified from Nelson (*8*).

middle Cambrian forms (*10*, plates 39 and 40), and this organism is known from published illustrations and extensive collections studied to have been more prone to a sedentary life in the Cambrian and to moving about in younger rocks. *Rusophycus-Cruziana* also has distinctive forms that vary with age, as did their makers. As to affinities, trilobites have been reported (*11*) in place in such markings, although illustrations of the association are unknown, and *Rusophycus-Cruziana* is widely considered to be a trilobite sitz-mark and crawl-track association. The paired scratches that make it up clearly indicate that the maker had chelate appendages, was certainly an arthropod, and may well have been a trilobite. The most closely reasoned case for this interpretation is that given by Walcott (*10*, especially the figures and explanations for plates 37 to 40), who attributes such markings to trilobites without reservation. Be that as it may, a survey of publications and collections at hand shows strong similarity between *Rusophycus-Cruziana* in the Deep Spring Formation (Fig. 1, E–G) and known Cambrian forms (for example, Fig. 1D). On these grounds we take the level of the Deep Spring collections of these forms (locality 7, Fig. 3B; localities 1, 3, Fig. 3A) to be within the Cambrian in the strict sense, just as much as if shell-bearing trilobites had been found at the same place. This opinion has also been expressed by Brian Daily (*12*) of South Australia, a student of the Ediacaran fossils and sequence (*13*), following his study of the same and other specimens from Nelson's collections.

Next we may turn to the occurrence reported in the Reed Dolomite (*14*) of the calyptoptomatid "mollusc" (*15*) *Wyattia*, which compares with representatives of the family Globorilidae. Examination of the type locality indicates that the *Wyattia*-bearing beds are within the basal Deep Spring Formation rather than uppermost Reed Dolomite as reported (*14*). This locality (5, Fig. 3B) is about 600 feet stratigraphically below the possible *Pteridinium* from the Deep Spring beds, and, as globorilids have previously been reported only from rocks of Middle Cambrian age, may be taken as at least strongly suggestive of a Cambrian age. *Wyattia*-like forms occur also in the upper part of the Reed Dolomite (locality 4, Fig. 3A), supporting conclusion 1 below.

What conclusions can we draw from all this? We suggest the following:

1) In the southwestern Great Basin, the Phanerozoic-Cryptozoic boundary is at least as low as the upper beds of the Reed Formation and is here provisionally placed at the boundary between the Reed and Wyman formations. There is, to be sure, as yet no positive evidence for the Precambrian age of the Wyman formation, but it has always been considered Precambrian and occurs unconformably below the Reed. Better evidence pro or con should be sought, but until it is found we provisionally accept the conventional age designation.

2) The bottom of the Cambrian in the usual sense, based on *Rusophycus-Cruziana*, is in our judgment at least as low as upper Deep Spring and probably below Deep Spring.

3) Evidence from this region suggests, although it does not prove, near coincidence between Phanerozoic-Cryptozoic, Paleozoic-Precambrian, and Cambrian-Precambrian boundaries.

4) The very early metazoan fauna represented by elements of the Ediacaran of South Australia, the Nama beds of South West Africa, and occurrences in England and the U.S.S.R. may also be present in the middle Deep Spring beds of the southwestern Great Basin. If so, these strata are referable not only to the Phanerozoic, but, logically, also to the Paleozoic and probably to the Cambrian.

5) The only reasonable alternative is to recognize at the base of the Phanerozoic Eon (and Paleozoic Era) an Ediacaran Period as proposed by the Termiers (*16*). In favor of this is the possibility that there was an interval of "pre-skeletal" evolution during which most but not all metazoans were planktonic and shell-less. In the eastern California sequence, however, this would represent, according to provisional placement of the Phanerozoic-Cryptozoic boundary, only a relatively thin and historically uneventful sequence of beds—perhaps 1800 feet to *Wyattia* or 3000 feet to the lowest yet known *Rusophycus-Cruziana*.

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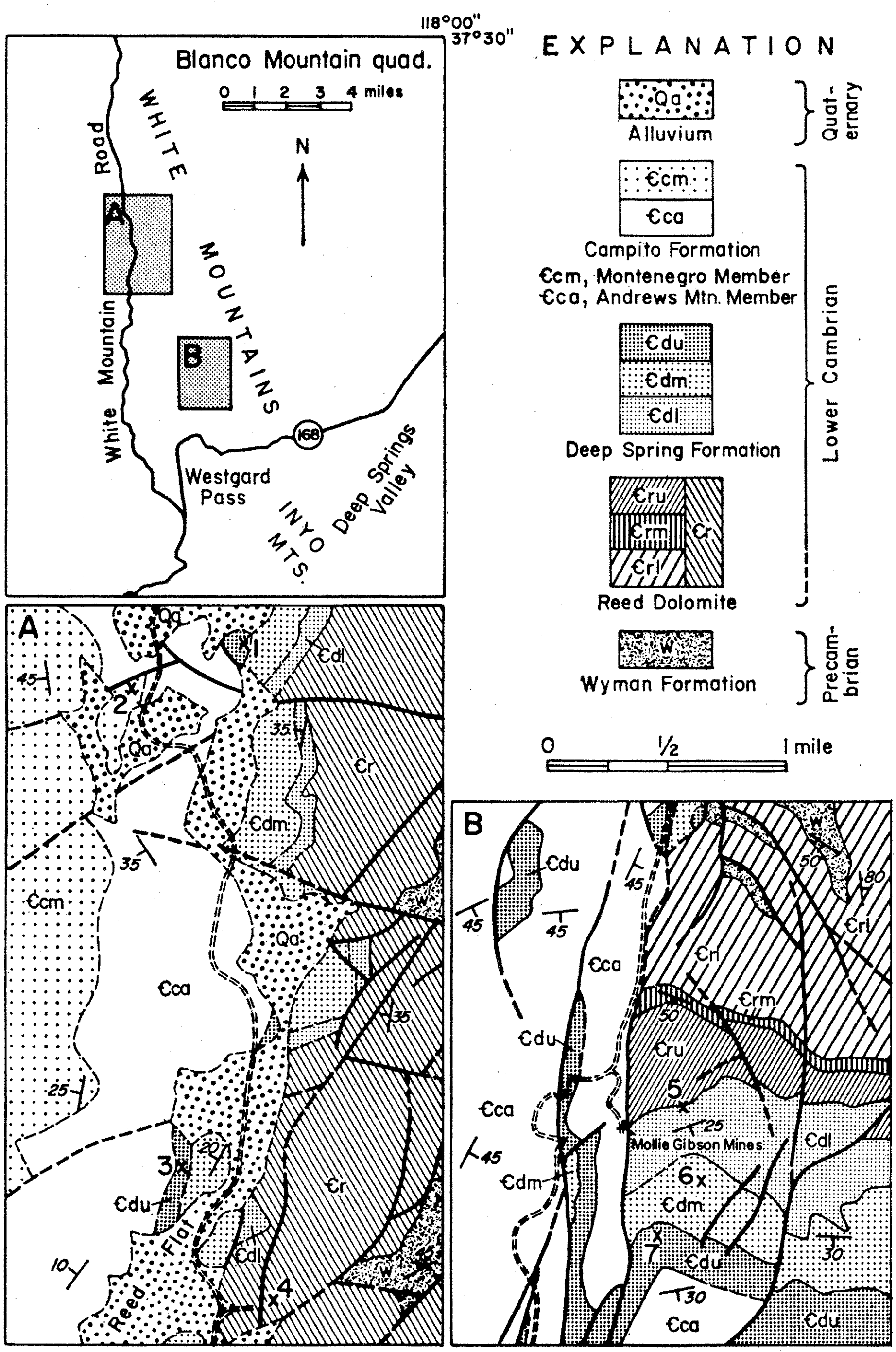

Fig. 3. Index map and geologic maps showing geologic occurrence of localities (*x*, 1-7) in White-Inyo Mountains. Geologic maps from Nelson (*9*).

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17. This paper grew directly from studies in preparation for a symposium in "Paleontological implications of the Precambrian-Early Cambrian faunas of southeastern California," organized for the 1966 Annual Meetings of the Geological Society of America by A. R. Palmer. It has roots in NSF grant GP-1807, which enabled Cloud to obtain the critical reference materials, and the support by the U.S. Geological Survey of Nelson's areal studies in the White-Inyo Mountains.

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Glaciation about 3,000,000 Years Ago in the Sierra Nevada

Abstract. *Major glaciation in the Sierra Nevada of California resulted in the deposition of till which underlies latite 2.7 × 10^6 years old and overlies andesite 3.1 × 10^6 years old. This till, herein called the Deadman Pass till, is the oldest Pleistocene glacial deposit that has been found in temperate latitudes.*

In the Devils Postpile Quadrangle in Mono and Madera counties, California, along the main drainage divide of the Sierra Nevada between Agnew Pass and Minaret Summit, small patches of till have been mapped (*1*). These till bodies were believed to represent deposits of glaciers that spilled eastward from the Minaret ice field through isolated lower passes along the divide. More detailed study indicates that most of the mapped outcrops of till are actually part of a single extensive till sheet underlying the volcanic rocks that cap the summit of the ridge crest (Fig. 1). The till overlies an andesite flow that has been dated by the potassium-argon method at 3.1 × 10^6 years (*2*), as well as metasedimentary and granitic rocks of Paleozoic and Mesozoic age. The Two Teats quartz latite, which directly overlies the till, and in places actually incorporates it, has been dated by the same method at 3.0 × 10^6 years (*2*); this finding suggests that the till is 3.0 to 3.1 × 10^6 years old.

The till at Deadman Pass, and that exposed beneath the Two Teats quartz latite in the vicinity of Deadman Pass, are composed primarily of boulders up to 1.3 m in diameter. These are angular to subrounded, and consist of 40 percent metamorphic rocks, 30 percent granitic rocks, and 30 percent volcanic and unidentified rocks. The granitic and metamorphic rocks were derived mainly from the Ritter Range and adjacent headwaters of the Middle Fork of the San Joaquin River, whereas the bulk of the volcanic rocks were derived locally. The matrix of the till generally contains 2 to 5 percent fine volcanic ash and pumice, but in one locale the till grades laterally into a lahar with 30 to 50 percent volcanic ash matrix. The boulders in the till are quite fresh, and at a few places striae and polished surfaces are recognizable.

At Deadman Pass the till contains a few angular boulders of a variety of Two Teats quartz latite. This is similar to that found near the summit of Two Teats, 5 km northwest, along the ridge crest. Since the Two Teats quartz latite sample dated by Dalrymple (*2*) was collected from the area of the summit of Two Teats, I collected another sample of the quartz latite from the ridge crest 1 km northwest of Deadman Pass for further radiometric dating. The sample locality is approximately 40 m stratigraphically above a till sheet 40 m thick containing some material that could only have been derived from the Ritter Range, 10 km west across a canyon that is now 760 m deep. Separate dates were determined by G. H. Curtis at the University of California in Berkeley on both plagioclase (KA 1956) and biotite (KA 1955) from this sample (Table 1). These two age determinations indicate ages of 2.70 × 10^6 and 2.74 × 10^6 years for this sample of the Two Teats quartz latite.

The Two Teats quartz latite was first described by Erwin (*3*), who thought it consisted of two distinct flow units. He differentiated a light colored unit and a darker glassy unit which he thought was contemporaneous with the Mammoth Mountain quartz latite, outcropping 4 km south of the southernmost exposures of the Two Teats rock. Since then, the Mammoth Mountain rock has been dated at 370,000 years and thus differentiated from the Two Teats unit (*2*), even though the two are lithologically almost identical.

Probably the Two Teats quartz latite, as most recently mapped (*1*), is actually a composite of flows and domes that erupted intermittently from two or more vents along, and east of, the present drainage divide between 3.1 and at least 2.7 × 10^6 years ago. The darker flow unit, dated at about 2.7 × 10^6 years, appears to have originated from a fissure in the lighter quartz latite on the south side of Two Teats mountain, and flowed southeastward over a till sheet deposited on the gently dipping surface of the Tertiary andesite flow. Since the quartz latite is now restricted to ridge crests, it is possible that the region has under-

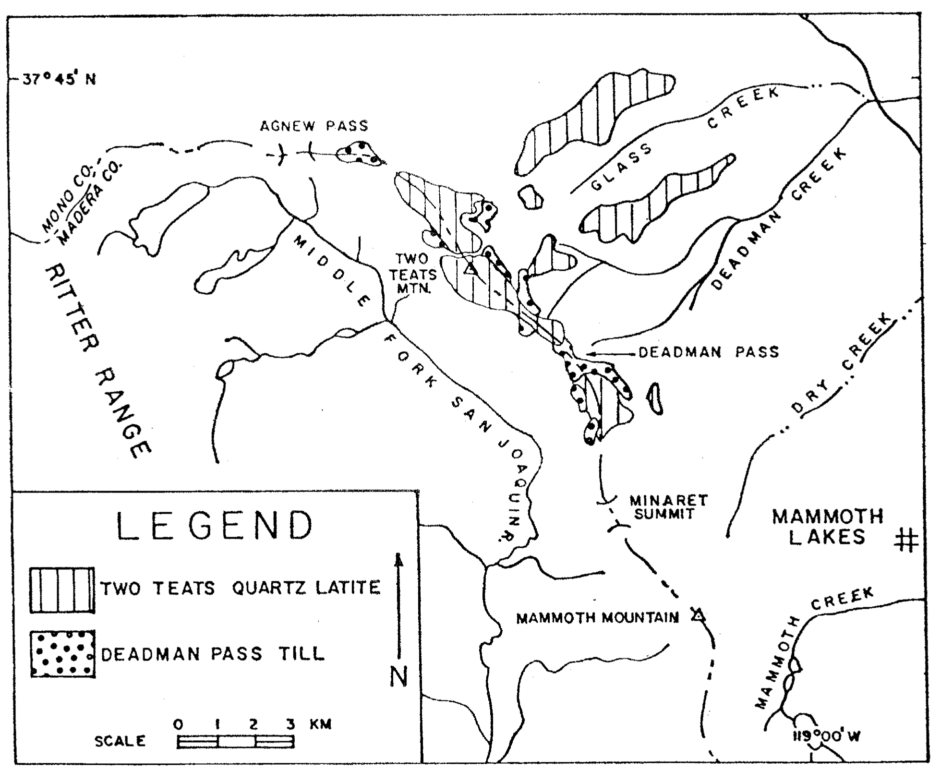

Fig. 1. Map of the Mammoth Lakes area, California, showing distribution of the outcrops of the Deadman Pass till and the overlying Two Teats quartz latite.