complex of the eastern San Gabriel Mountains, on which virtually no other continuous measurements are being made.

The detection of a change in a stress anomaly of this scale associated with a relatively small (magnitude ~ 4) earthquake provides new evidence about another important question in earthquake prediction: whether near-surface rocks (< 100 m deep) are well coupled to rocks at greater depth and thus accurately reflect stress conditions at depth (*13*). Local conditions may dictate the quality of this coupling. The San Antonio dam site would not appear to be ideally coupled to deeper rocks. Fractures abound, and the geology of the site is complicated by numerous faults, from microscopic offsets to the Cucamonga thrust fault, which forms the boundary of the Transverse ranges, a few hundred meters beneath the site. Absolute stress levels in the rock, even at a depth of 20 m, would not necessarily be associated with tectonic stress fields generating earthquakes at depths of several kilometers. Yet the long-term data on changes in stress at San Antonio dam are remarkably consistent with predicted tectonic stress changes (Fig. 1), and the anomaly, particularly the existence of a preseismic portion, strongly suggests that stress changes in the focal region were being transmitted to shallow depths 15 km away (Fig. 2). Absolute stress levels or long-term changes might still be relaxed with time at such shallow depths, but short-term coupling appears to be good.

The Lytle Creek stress anomaly is superposed on more than 2 years of data from the San Antonio dam site that indicate that a long-term rise of compressive stress is occurring, especially in the north-south direction (Fig. 1). The San Antonio site is the only one displaying such a consistent change, although other sites indicate an increase in levels of horizontal shear stress. In this portion of southern California, thrust faulting along the several active frontal faults, collectively called the Sierra Madre fault system, is consistent with increased north-south compressive stresses. The San Fernando earthquake of 1971 ruptured a segment of this fault system to the west of Los Angeles, but the faults to the east did not move. Consequently, the continuing buildup of stress being measured at the San Antonio dam site, only 60 km east of Los Angeles, is a source of considerable concern.

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Siliceous Microfossils from the Lower Cambrian of Northwest Canada: Possible Source for Biogenic Chert

Abstract. *Round to oval, scalelike siliceous microstructures from cherts in Cambrian limestones of the western Yukon Territory suggest affinity with chrysophycean algae. At least six morphotypes present include porous forms with single branching processes and nonporous oval, ringlike forms. Partially dissolved specimens may indicate a contribution to contemporaneous or early diagenetic chert formation.*

The early fossil record of silica-secreting organisms is sparse, probably at least in part because both plants and animals deposit hydrated amorphous silica which is mineralogically unstable. Of the considerable variety of fossils known from rocks of Cambrian age, only some sponges have been thought to have siliceous skeletons (*1*). Radiolarians, first identified with confidence in Lower Ordovician rocks (*2*), are the earliest silica-secreting, single-celled organisms heretofore known. Marine primary cherts of Ordovician and younger age are commonly interpreted to reflect accumulations of sponge spicules, radiolaria, or other siliceous microorganisms, whether or not skeletal remains can be recognized in them. This interpretation, however, is not readily applied to Cambrian and older rocks because the existence of contemporaneous siliceous microorganisms has not been demonstrated.

Fossils reported here come from the west-central Yukon Territory in nearly flat-lying, peak-capping outcrops at 65°16′N, 140°55′W. They occur in thin-bedded, dark gray to black, finely laminated, fetid limestones and gradationally overlying massive, medium gray silicified limestones. Angular clasts that appear to be rip-ups host the fossils in the massive limestones; in the underlying beds they occur both in black chert nodules and, rarely, in the surrounding recrystallized limestone.

The transitional contact involved is that of the uppermost Tindir Group fetid limestone unit and the overlying Funnel Creek Limestone (*3*). In the Tatonduk River section to the southwest, the fetid limestone grades downward into dolomitic sandstones and shales that in turn grade downward into maroon shales and glacial mixtites of the lower Upper Tindir Group basalt and red beds unit. The Cambrian lower boundary is thought to fall within, or at the base of, the basalt and red beds (*4*). Archaeocyathids in carbonates which conformably overlie the Funnel Creek Limestone are late Early Cambrian in age, referrable to the Lenian stage of the Siberian platform. Thus the Funnel Creek Limestone and Tindir fetid limestone unit are no younger than late Early Cambrian and are more likely of middle Early Cambrian age.

The siliceous microfossils occur with a wide variety of organic-walled algal microfossils (*5*). These are particularly abundant and well preserved in siliceous nodules in the fetid limestone but rare and generally degraded in the surrounding recrystallized material. In the Funnel Creek Limestone, organic-walled cells are less common, although similar and well preserved.

Because the siliceous fossils are very delicate, they have been examined only in thin section under ordinary light microscopy. Their indigenous nature is confirmed by the facts that they do not occupy fractures, they commonly lie oblique within the rock slice, they are typically not in focus at the top or bottom of the slice, and nearby algal cells lie in planes both above and below the siliceous fossils. These fossils tend to occur in closely spaced groupings, a few of which are cut by calcite-filled fractures.

In these cases the groups are clearly seen to be divided and dislocated by the fractures.

All of the siliceous microfossils are variations of thin, rounded to oval, slightly concavo-convex plates. In most instances, plates of only one type are found in a single grouping, but a dominant plate type may be intimately associated with one or two additional morphotypes. At least six morphologies appear to be represented, three or more of each type occurring in the fetid limestone and in the massive carbonates. The fossils commonly occur in groupings in which 11 or more individual plates are observable. One particularly striking type in the fetid limestone (Fig. 1A) has plates closely nested in a more or less oval arrangement. In this type the nearly circular plates range from 26 to 40 μm in diameter and are evenly porous in a hexagonal pattern. A specimen 26 μm in diameter lying normal to the plane of the thin section exhibits 14 pores, each 2 μm in diameter. The plates are 1 μm thick and gently tapered toward the smoothly rounded periphery. Short, slender projections perpendicular to the plane of the plate and arising near the periphery have been observed on some plates of this type (Fig. 1B). One of the groups includes a second, oval, nonporous type of plate 27 to 29 μm in maximum diameter, less than 1 μm thick, and closely nested. These are coated with smooth, brown material, presumably an iron compound, not present on the porous plates with which they are clearly associated. A third plate type occurring in the fetid limestone has the same general morphology as the porous plates but is smaller, 18 to 22 μm in diameter and 0.8 to 0.9 μm thick, and bears single distinctive spinelike processes arising from the center on one side (Fig. 1C). The processes are about 7 μm long and arise between pores. They are slightly expanded just above the base and taper toward the tip where they branch at nearly right angles into three to six tapered extensions up to 4 μm long. All branches have sharply pointed tips, and so probably no breakage has occurred. Very smooth, nonporous, saucer-shaped plates (Fig. 1I), which occur in clumps containing only this type, apparently represent an additional morphotype in the Tindir limestone. These are 15 to 29 μm in diameter and less than 1 μm thick, with very smooth margins and no apparent radial structure.

Fossils from the Funnel Creek Limestone appear primarily as oval, saucer, or ringlike structures of varied size. These occur as isolated individuals or in clumps where plates of more than one size or type may be present (Fig. 1E). The observed overall size range of the ringlike fossils is 10 to 52 μm in width and 16 to 83 μm in length, but these figures cannot be taken as wholly accurate because most specimens lie at low to moderate angles to a given focal plane. Complete gradation of sizes has not been

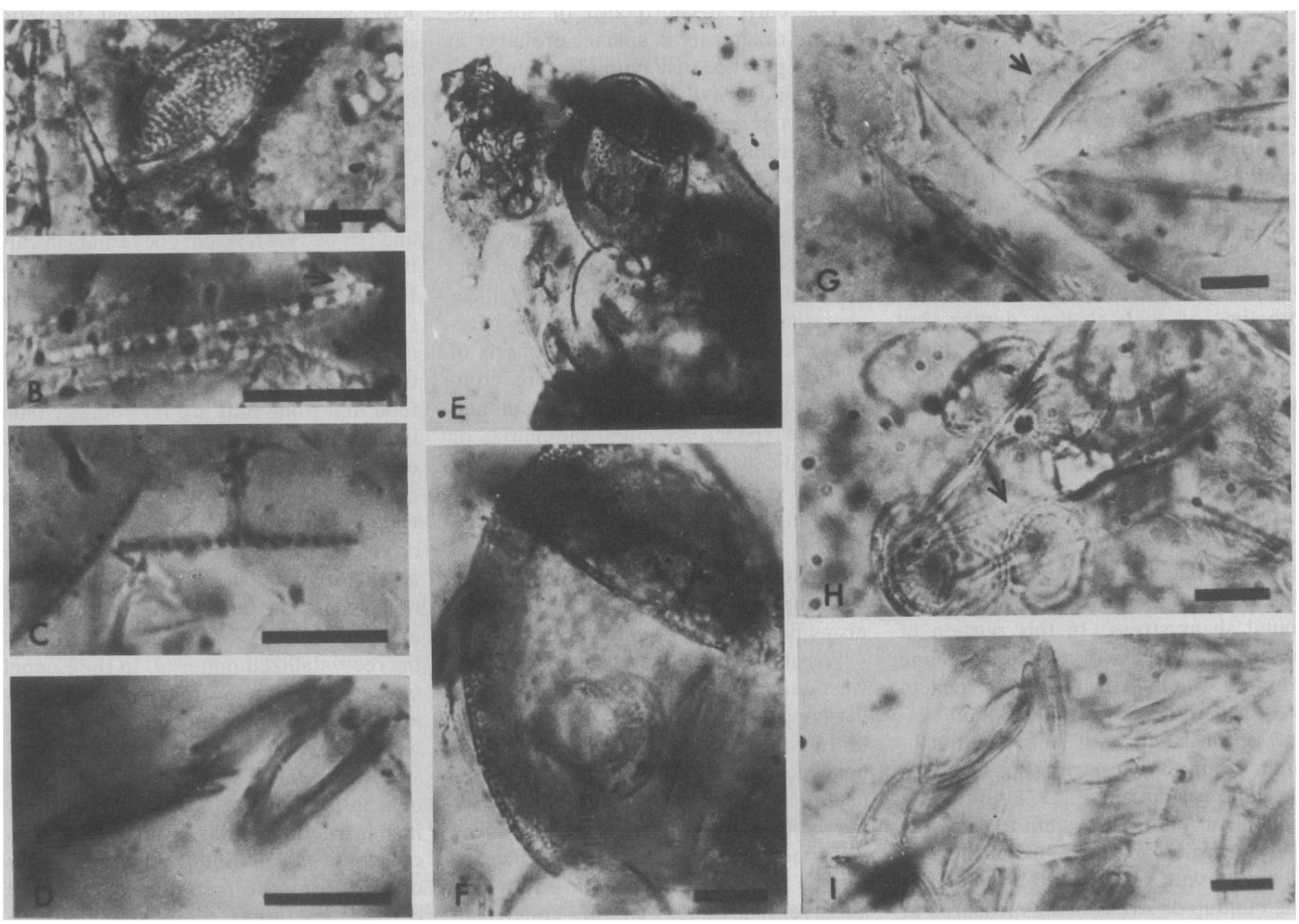

Fig. 1 (A) Cluster of porous siliceous scales seen in cross section. Close nesting of individual scales may reflect the original arrangement in an oval, saclike organism. (B) Porous scale with short processes near the periphery (arrow). (C) Porous scale with central branching process. (D) Small oval scales of the group in (E), shown in cross section. (E) Cluster including several oval morphotypes. Thin rings in discrete group at the upper left do not occur elsewhere in the cluster. One large oval lies partly around another to the upper right. (F) Part of the cluster shown in (E). Small ovals lie underneath the large one, which appears to have a minutely beaded rim. (G) Nonporous scales, occurring in the group shown in (H), with one extremely thin, inflated surface (arrow). (H) Cluster of ovals similar to those in (E) but including rare, thin porous structures (arrow). (I) Nonporous saucer-like scales that occur in clusters containing only this morphotype. Scale bar for (A) and (E), 25 μm; all others, 10 μm.

observed in these fossils. Smaller specimens, ranging from about 10 to 15 μm in least diameter, are the most abundant, but all observed occur with one to several of the larger ovals, of about 45 to 52 μm in least diameter. The flattened ringlike appearance of these fossils is deceptive. Both the larger and smaller ovals are distinctly invaginated around the periphery. When seen in profile, the smaller ovals reveal deeply recessed peripheral surfaces, are about 3 μm high, and have one oval surface about 2 μm larger in diameter than the other (Fig. 1D). The larger ovals are much less deeply invaginated around the periphery, are about 7 μm high, and have one surface 8 to 10 μm larger in diameter than the other. Pores have not been observed in these plates, but one large, isolated specimen exhibits very thin, faint, radially arranged brownish lines about 11 μm apart at the inner rim that extend to the outer margin. A number of ovals appear to have minutely beaded margins (Fig. 1F).

One of the groupings of these fossils contains particularly pale, glassy individuals. In addition to the ovals, it includes numerous slightly curving structures 32 to 67 μm long that appear single-layered and have faintly recurved ends (Fig. 1G). Although extremely difficult to see, these appear to expand along one side, at maximum expansion resembling a rimmed hemisphere with a slightly convex peripheral surface and straight to obliquely truncated top. Pores are observable in the central parts of two apparently different plates in the grouping; in these the pores are 0.2 μm in diameter and spaced 1 to 1.2 μm apart in specimens 32 and 53 μm long (Fig. 1H). The clump shown in Fig. 1E contains a different oval morphotype. This occurs as a discrete, although apparently associated, closely packed grouping of rings about 6 μm wide and 10 μm long with "walls" less than 0.5 μm thick.

Several groups of organisms, particularly coccoliths, diatoms, and some other mineral-depositing algae, can be suggested for comparison with one or more of the morphotypes described. Fundamental questions in recognition of affinity are the composition and size of the fossils and their organization and mode of formation in the organisms represented. Coccoliths are similar in general morphology, and perhaps mode of formation, to the ringlike oval fossils. However, coccoliths are composed of calcium carbonate and range from 1 to 15 μm in greatest dimension, clearly smaller than many of the fossils, and coccolithophores typically do not form distinctly different types and sizes of plates on one individual. Diatoms, which are siliceous and range from less than 10 to over 100 μm in greatest dimension, include slightly concavo-convex, round, perforate forms similar to those in the fetid limestone, but diatoms lack the distinctive processes present in one of these fossils, and none of the fossils show evidence of formation in overlapping pairs as is the normal mode for diatoms.

The group most promising for comparison on morphologic grounds is clearly the chrysophycean algae in which covering siliceous scales occur in wide variety in modern representatives. Although chrysophyceans of which I am aware commonly have scales less than 10 μm in size, many have oval scales reminiscent of the Funnel Creek Limestone fossils in particular, and some species form several types and sizes of scales, on single individuals, that can be compared to the variation in morphotypes in the clumps of fossils. *Ochromonas* and *Mallomonas*, both common in the modern marine plankton, exemplify several chrysophycean genera that might be considered. Lacy-looking structures, referred to as diademiformic scales in *Ochromonas* by Takahashi (*6*), could be comparable to the cluster of thin rings mentioned above in association with one of the Funnel Creek oval fossils. The specimens shown in Fig. 1G are clearly reminiscent, at least in gross aspect, to domed oval scales in *Mallomonas* in which the upper surface appears truncated. Perforate structures generally similar to the Tindir fossils occur in several chrysophycean genera including *Paraphysomonas*. Although these are not reported to have processes comparable to those in the fossils, many chrysophycean scales do bear spines.

I will not attempt here to further pursue specific modern analogs because the great time gap and poor fossil record intervening between these fossils and modern genera make such comparison of dubious validity. The fossils may well represent more than one suprageneric modern group or one or more early stocks for which no modern representatives can be recognized.

The remaining question of the original composition of the fossils must also be addressed. Examination in polarized light confirms that each plate is composed of a single crystal of an anisotropic mineral with moderate to low relief. Although the refractive index could not be precisely measured, it is close to that of adjacent quartz grains and much less than that of adjacent carbonate grains. Birefringence is maximum first-order gray, whereas it is fourth order in the carbonates. Secondary replacement of carbonate by silica is considered unlikely, because there is no evidence of the mosaic structure commonly seen in silica-replaced biogenic carbonate.

Although many specimens are very well preserved, obviously intact, and with measurable thickness, degradation expressed as extreme thinness and partial dissolution is marked in other specimens. Thus, whatever the closest phyletic affinity for these fossils may be, their occurrence in Lower Cambrian rocks establishes an early Phanerozoic appearance of mineralized microorganisms that may have affected the level of biologically fixed silica in contemporary seas.

Although the currently known chrysophycean fossil record extends back only to Mesozoic time (*7*), Loeblich (*8*) has suggested that the family represents an important ancestral stock, having only chlorophyll a, that probably arose in the late pre-Cambrian and gave rise to the foraminifera by Late Cambrian time, the dinophyceans by Silurian time, the haptophyceans by Pennsylvanian time, and the diatoms by middle Mesozoic time. If the fossils reported here are indeed chrysophyceans, the existence of this possible stem group is established on paleontologic grounds almost as early as previously predicted on nonpaleontologic grounds. Indeed, the variety in plate types and associations present in the fossils reported here suggests that even earlier representatives of the lineage could be found.

Note added in proof: After this report was accepted, dissolution of one rock sample with concentrated hydrogen chloride and hydrogen fluoride, to release the co-occurring organic-walled microfossils, yielded a few brownish scales of types seen in thin section. These scales must be at least in part composed of an organic compound.

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