alpha particles in cellulose nitrate is 80 ± 20 percent. This result is independent of the polarity of the electric field.

In the experiment reported here the electric field was applied roughly parallel to the path of the ionizing particles. One would not expect this field to change the net charge in an ion column created by passage of the alpha particle. Hence, the mechanism for the ion explosion spike would not be enhanced. The fact that track formation is enhanced supports the hypothesis that additional processes are important in the formation of etchable tracks, at least in cellulose nitrate.

By studying the nature of the track enhancement as a function of the strength of the electric field, and also as a function of the angle between the field and the particle forming the track, one should be able to gain a better understanding of the relative importance of the different mechanisms involved in the formation of etchable tracks. Possible applications of track enhancement through the use of an electric field are numerous. For example, it may be possible to construct a detector which would have the same spatial resolution as photographic films, but which could be "triggered" by the application of an electric field when an appropriate signal is received, much as spark chambers are operated.

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6. We thank Professors J. G. Brennan, T. E. Carew, R. W. Deutsch, F. L. Talbott, and Father E. M. Carreira for their cooperation. Supported in part by ONR contract N00014-67-A-0377-00021. F.J.K. is a NSF predoctoral trainee.

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Alaskan Upper Miocene Marine Glacial Deposits and the Turborotalia pachyderma Datum Plane

Abstract. *In southeastern Alaska the first marine evidence of widespread glaciation occurs in Miocene sections near the base of the Yakataga Formation. An associated temperature decrease of about 10°C is indicated by the influx of an upper Miocene cold-water planktonic foraminifer,* Turborotalia pachyderma, *an event that occurred about 13 million years ago.*

One of the most dramatic developments of the past one or two decades is the discovery of several kinds of evidence supporting major middle and later Tertiary polar glaciation—long before the onset of the classic Quaternary glaciations (*1*). Of utmost importance is the need to gather additional kinds of evidence concerning pre-Quaternary glaciations and to define precisely their times of occurrence. Evidences of marked pre-Quaternary climatic cooling have been noted in the middle Pliocene of Italy (*2*) and in the circum-Pacific area (*3*). An earlier cooling cycle has now been defined in the upper Miocene in Italy (*4*) and in other temperate areas (*3*).

In southeastern Alaska we have discovered a transition from warm- to cold-water planktonic foraminiferans near the boundary between the Poul Creek and the superjacent Yakataga Formations (Fig. 1). Further, the appearance of the cold-water planktonic fauna, *Turborotalia pachyderma* (Ehrenberg), defines the datum which Bandy and Ingle proposed as the boundary between the middle and upper Miocene of temperate and cooler-water areas (*5*) about 13 or 14 million years ago. In California this datum falls at the base of the Mohnian Stage; in Italy it is reported to fall at or near the base of the Tortonian (*6*); in New Zealand it would fall near the base of the Tongaporutuan (*7*). At this time *T. pachyderma* evolved from its immediate ancestor *T. continuosa* (Blow), according to Jenkins (*8*) and to our studies. Rare specimens of *T. continuosa* occur in the upper Poul Creek Formation at Cape Yakataga and at other locations.

Late Tertiary glaciation in Alaska, as represented by marine tillites of the Yakatage Formation, described by Miller (*9*), has been known for many years. Subsequent study has shown that the age of the Yakataga Formation spans much of the Miocene-Pliocene and has further defined the occurrences of the marine tillites (*10*). These marine tillites of the Yakataga Formation are evidently quite widespread; they extend more than 300 km along the southeastern coast of Alaska, centering at Kulthieth Mountain and Cape Yakataga (Fig. 1). Denton and Armstrong (*11*) have now obtained radiometric dates of volcanic rocks interbedded with nonmarine tillites from the north flank of the Wrangell Mountains of southeastern Alaska. They show that glacial deposits were being deposited there at least as early as about 10 million years ago. Further, some of the tillites they report fall within the interval between 8.8 and 2.7 million years ago. The latter may reflect the middle Pliocene cold interval recognized in temperate areas (*2, 3*).

A rather complete section of Tertiary rocks is exposed in the Yakataga district (*9, 10*), including the two principal Tertiary marine formations of concern here, the Poul Creek and Yakataga Formations (Fig. 1). The Poul Creek Formation, 1875 m thick, is Oligocene-Miocene, and is made up of marine sediments (shales and sandstones) with temperate or subtropical faunas. The superjacent Yakataga Formation, as much as 4574 m thick, is Miocene-Pliocene and is made up of many kinds of marine clastics including important marine tillites. It contains mostly cool- or cold-water molluscan faunas.

At the type section of the Yakataga Formation at Kulthieth Mountain (Fig. 1), the left-coiling *Turborotalia pachyderma* cold-water planktonic fauna (Fig. 2) appears abruptly about 50 m above the base of the exposed section; at nearby Cape Yakataga, the Poul Creek contact with the Yakataga Formation is exposed, and *T. pachyderma* first occurs there about 30 m above the contact. In both sections, thin conglomerates or glacial marine deposits make their appearance more or less in the same position and give

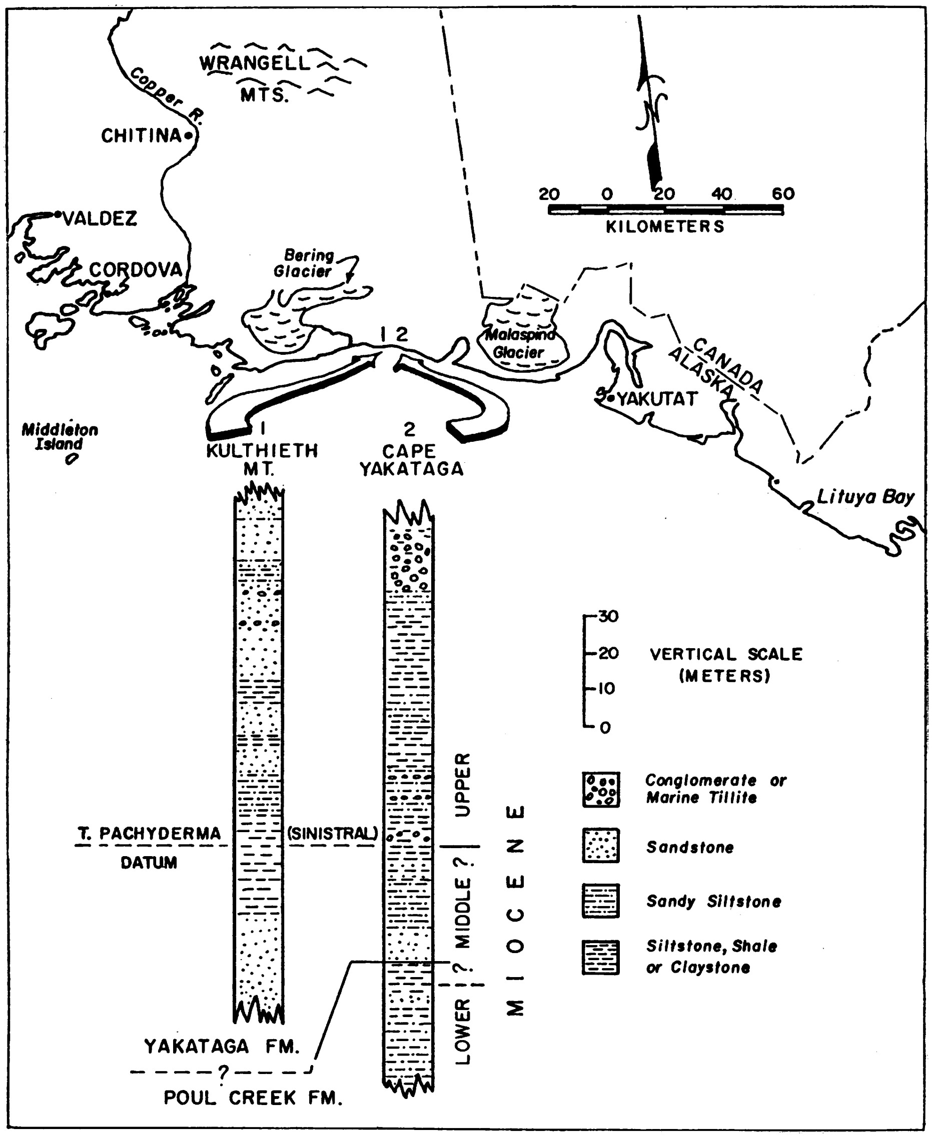

Fig. 1. Location of Yakataga, southeastern Alaska, and generalized columnar section of the Tertiary section.

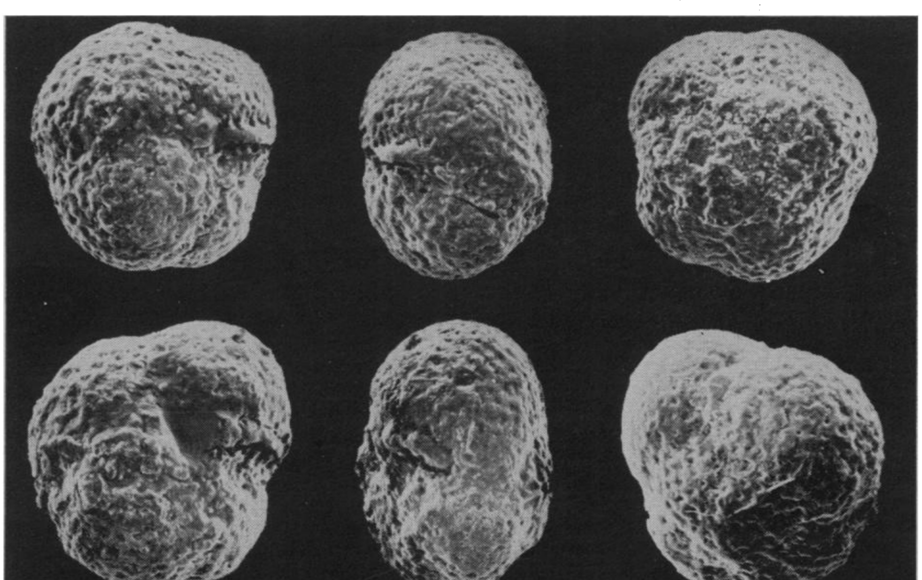

Fig. 2. *Turborotalia pachyderma* (Ehrenberg) from the type Yakataga Formation, Kulthieth Mountain section. Sample is from about 30 m above the base of the exposed section.

way about 100 m above to thick beds of marine tillites. Conversely, a warm-water *Globoquadrina* planktonic fauna occurs in the underlying upper Poul Creek Formation about 200 m below the contact. In other sections (to the east at Poul Creek and Oil Creek and to the west at Kayak Island) a *Praeorbulina* planktonic fauna of the middle Miocene occurs in the upper part of the Poul Creek Formation; this is slightly younger than the upper Poul Creek correlations in earlier works. Any discrepancy of correlation is probably due either to a lack of continuous faunas in the section or to a time-transgressive relationship of the contact between the two formations as they are traced from east to west.

Elements of the warm-water *Globoquadrina* planktonic fauna of the Poul Creek Formation are like those of warm-water faunas of the Miocene in many tropical areas (*12*), whereas the left-coiling *T. pachyderma* cold-water fauna is like that which today is mostly restricted to polar waters with surface temperatures during the summer of about 2°C. (*3*). This is not to say that the Poul Creek Formation exhibits a typical tropical fauna; it contains a sparse representation of tropical and warm-temperate species. Considering average summer surface temperatures, it is likely that a cooling of from 10° to perhaps 15°C occurred with the development of the *T. pachyderma* populations as inferred from distributional patterns of modern planktonic groups. This degree of cooling is considerably greater than the temperature drop of about 7°C suggested by Wolfe and Leopold (*13*).

Referring to the benthic foraminiferal populations, Rau (*14*) interpreted the uppermost Poul Creek fauna as having lived in warm, shallow water. Conversely, it is noteworthy that an abyssal to lower bathyal *Melonis pompilioides* (Fichtel and Moll) fauna (*15*), occurs lower in the section in the Poul Creek Formation along with other deep-water forms such as *Martinottiella communis* (d'Orbigny), *Cyclammina cancellata* Brady, and others. Specimens of *Sphaeroidina variabilis* Reuss occur in the Poul Creek Formation and attain diameters greater than 0.7 mm. By contrast, the Yakataga Formation contains an upper bathyal fauna near the base including *Uvigerina juncea* Cushman and Todd and more finely perforate forms of *Melonis*. Farther upsection in the Yakataga Formation are shallow-water faunas of the neritic zone, dominated by forms such as *Cribroelphidium*, *Elphidiella*, and others. Thus, in southeastern Alaska there was a deep-water marine basin or series of basins in which the Poul Creek deposition occurred. Basin-filling predominated beginning in the early and middle Miocene and was followed by rapid sedimentation and the introduction of marine glacial deposits intermittently during the later Miocene and the Pliocene. These gave way to the mostly nonmarine tillites of the classic Quaternary as represented in modern exposures.

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Topological Inconsistency of Continental Drift on the Present-Sized Earth

Abstract. *Certain continents have in the past moved with respect to each other in a manner clearly implied by sea-floor spreading and other data. However, the resulting collective motion of all the continents was apparently not topologically possible on the present-sized earth. An expanding earth might resolve this difficulty.*

The old hypothesis (*1, 2*) that the present continents split off from one supercontinent and moved to their present positions is now supported by an enormous array of evidence (*3*). This evidence is derived from measurements of geological structure and age (*4, 5*), from paleomagnetism, from the geometrical fit, and, perhaps most convincing of all, from the evidence of previous history as recorded in the magnetic age and fracture zone patterns associated with ocean-floor spreading (*6, 7*).

The latest reconstruction of South America, Africa, Europe, Greenland, and North America by Bullard *et al.* (*8*) is similar to that given by Baker (*2*, p. 14) in 1911 and is almost universally accepted. A reconstruction of Africa, Antarctica, Australia, India, and Mozambique has recently been given by Hurley (*5*) on the basis of geological data. This is similar to past reconstructions and also seems implied by the evidence from the magnetic and fracture zone patterns for the floor of the Indian Ocean. An approximate combination of these reconstructions is shown in Fig. 1. This figure is not an exact reconstruction of the former positions of the continents, but it does show the approximate relative positions of the continental masses before they split apart from Africa, as suggested by Hurley (*5*) and Bullard *et al.* (*8*) and much other data.

The hypothesis that the present continents were once part of a single continental mass is still somewhat controversial. However, the other conjecture that there were two original continental masses with the southern continents grouped around the South Pole and the northern continents grouped around the North Pole with a large ocean floor intervening seems to be contradicted by the presently accepted reconstruction of North America, South America, Africa, Europe, and Greenland, at least in the time period in question, which is from the present to approximately 150 million years ago.

Although the theory that the continents split apart and subsequently moved is widely accepted, the questions of why and how are still being argued. One group (the majority) believes that a thermally driven slow convective flow in the mantle of the earth split the crust of the original supercontinent and carried the fragments apart as a new ocean floor welled up from the interior. A minority group believes that continental separation was caused by an expansion of the interior of the earth (*9*). According to this view, which apparently goes back at least to Hilgenberg (*10*) and Halm (*11*), the expansion of the earth's interior split the original earth's crust and, as the earth expanded, the ocean floors were formed in the voids between the continents. Some of the expansionists have suggested that this radical expansion took place because of a gradual decrease in the gravitation constant, such as Dirac (*12*) had suggested for completely different reasons. In addition to the advocates of continental drift and large expansion of the earth, there are others who have proposed a combination of the two processes. All of these positions have been expounded at length, and there are arguments for and against every explanation.

The purpose of this report is specific. On the basis of very widely accepted interpretations of ocean-floor spreading and continental separation, a topological argument is developed. This argument appears to show that the separation and movement of the continents in the last 150 million years cannot be explained by continental drift on the surface of the present-sized earth.

The essence of this argument can be understood by reference to Fig. 2. This figure is an equidistant projection of the earth's surface with the origin of the projection in the central Pacific on the