tween a drastic change in solar activity and the subsequent change in $C^{14}$ activity. Of the 30 instances between 527 B.C. and A.D. 1964 in which the sunspot-auroral index showed a large increase or decrease, 14 had sufficient $C^{14}$ measurements to allow an approximate estimate of the lag period. Since $C^{14}$ data were not available from every year, or even from every decade, this estimate represents a maximum value for the mean atmospheric $C^{14}$ residence time. The length of the 14 observed lag periods varied from 2 to 39 years, with a mean of 15.1 years. This value falls within the estimated exchange period noted above and suggests that the use of $C^{14}$ as a climatic or solar index should not be applied with an accuracy of less than around two decades.

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## Blake Outer Ridge: Development by Gravity Tectonics

Abstract. *A continuous seismic profile across the Blake Outer Ridge reveals clear evidence of a structural origin for the ridge. A ridge core separates distinctive regions of structure east and west of the crest and does not support a theory of depositional origin. The presence of horizon A continuously beneath the ridge rules out faulting or folding involving basement rocks. Gravity tectonics are suggested as the mechanism for formation of the ridge after the deposition of the sediments above horizon A.*

The Blake Outer Ridge is a low feature on the sea floor that forms the eastern boundary of the Blake-Bahama Basin which it separates from the Hatteras Abyssal Plain (Fig. 1; *1*). The ridge has two distinct portions: a relatively sharp, crested, southeastward-trending, northern portion that ends against the Blake Plateau; and a broad, rolling, southern portion that trends southwestward toward the Bahamas (*2*). The two portions are separated by a saddle near 28°30′N and may not be related to each other structurally or genetically, although this possibility seems unlikely.

The northern ridge rises 1000 m above the Blake-Bahama Basin and 1500 m above the abyssal plain to the east, with very gentle gradients (less than 0.5° to 2.5° along the eastern side of the crest). Comparison with other sea-floor topography emphasizes the gentleness of the gradients: normal continental-slope gradients average 5° to 6° (*3*), being as steep as 20°; 25° gradients are common on seamounts and volcanic islands (*4*). Very steep gradients exceeding 45° are known on the Blake Escarpment (*1*) and along the eastern edge of the Bahamian platform (*5*). Gradients of the same magnitude as those of the ridge occur only on the continental rise

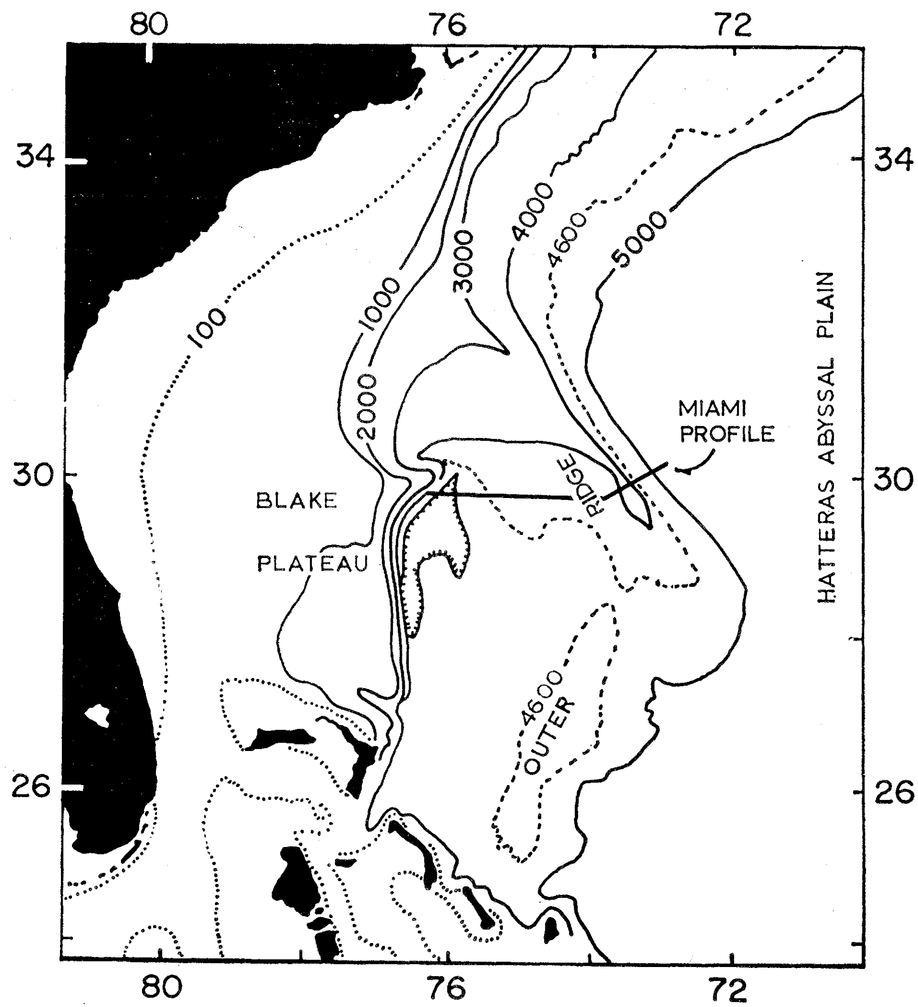


Fig. 1. Blake Plateau, Blake-Bahama Basin, and Blake Outer Ridge (after *2*), with track of profile 9a; contours in meters.

(see *6*) and on the continental slope off the Mississippi River delta; Shepard (*3*) suggests that the latter reflect modification by salt domes of the slope and of the pattern of deposition of sediment.

Figure 2a is a tracing of a seismic-reflection profile across the ridge (*7*). Horizon A, recently identified as a Cretaceous abyssal-plain surface (*8*), is continuous beneath the ridge and the basin, extending under the Hatteras Abyssal Plain to the Bermuda Rise. Bedrock is about 0.5 second below and parallel to horizon A. Two layers are present above horizon A: layer *y* which forms the ridge, and the overlying layer *x* which is about 1 km thick. Layer *y* pinches-out several miles east of the ridge, and *x* comes to rest directly on horizon A. Aside from the major reflecting horizons, little internal structure is seen in this profile because of the wide spacing of the shots and the high speed of the ship over the line (*9*). On the basis of this work, the appearance of the ridge as a broad mound of transparent sediment resting on horizon A has led to the suggestion that the ridge has been formed by differential deposition of sediments on horizon A (*2, 10–12*) by southward-flowing, deep, geostrophic currents (*12, 13*). Although apparent southward transport of sediment has been studied on the continental shelf north of this area (*13*) and near-bottom waters have shown a high content of silt (*11*), this hypothesis does not seem to explain satisfactorily formation of the ridge.

In order to examine the internal structure of the ridge in greater detail, a seismic-reflection profile was shot normal to the crest of the ridge near 30°N during cruise P-6610 of R.V. *Pillsbury* (*14*). This profile (Fig. 2b; *3*) does not support a depositional origin for the ridge, suggesting rather a structural origin. Major sedimentary layers can be identified (*x* and *y* in Fig. 2a). The internal structure in layer *x* is particularly clear; the layer is at least 1 km thick near the basin, and shows a series of very regular and coherent horizontal reflecting layers for more than 100 km west of the ridge crest, with very gentle folds. The folds, even and regular throughout the horizons penetrated (up to 0.4 second), suggest an upward-tilting movement on this side of the ridge. Layer *x* rises and thins toward the ridge; it abuts against layer *y*, which forms the core of the ridge.

Seaward of the ridge the structure of layer *x* is entirely different. The sea floor has greater inclination (2.5°) for the first 20 km and then assumes a more gentle gradient. This portion of the slope is underlaid by confused reflectors that slope slightly upward toward the crest, being truncated by the upper surface of layer *y* and by the crest of the ridge. In this region the surface of layer *y* is about 0.85 second below and parallel to the sea floor (Fig. 3). Near the core of the ridge this surface becomes difficult to trace. The possibility that the jumbled material in the wedge is from layer *y* would explain the absence of reflections from layer *y* near the crest.

The internal structure evident in the ridge seems to preclude a purely depositional origin for the ridge. Deposition of sediment from currents flowing parallel to the ridge should result in evenly layered beds continuous across the crest of the ridge. Deposition seems incapable of creating the abrupt boundary, with the truncation and folding of the sediments, that occurs near the crest, or the jumbled wedge of sediment forming the eastern face of the ridge.

If the ridge is not the result of differential deposition on a horizontal surface, some mechanism must be sought for its elevation subsequent to the deposition of layers *x* and *y*. The presence of horizon A, continuous and horizontal, beneath the area from the basin to the Bermuda Rise requires that the region has not undergone deep crustal deformation since the deposition of this layer during the Cretaceous. Thus the ridge cannot be ascribed to either faulting or folding involving the basement rocks; nor can it be related to the structure of Cape Fear Arch or an associated island arc, as has been suggested (*3, 15*).

The possibility that the ridge origi-

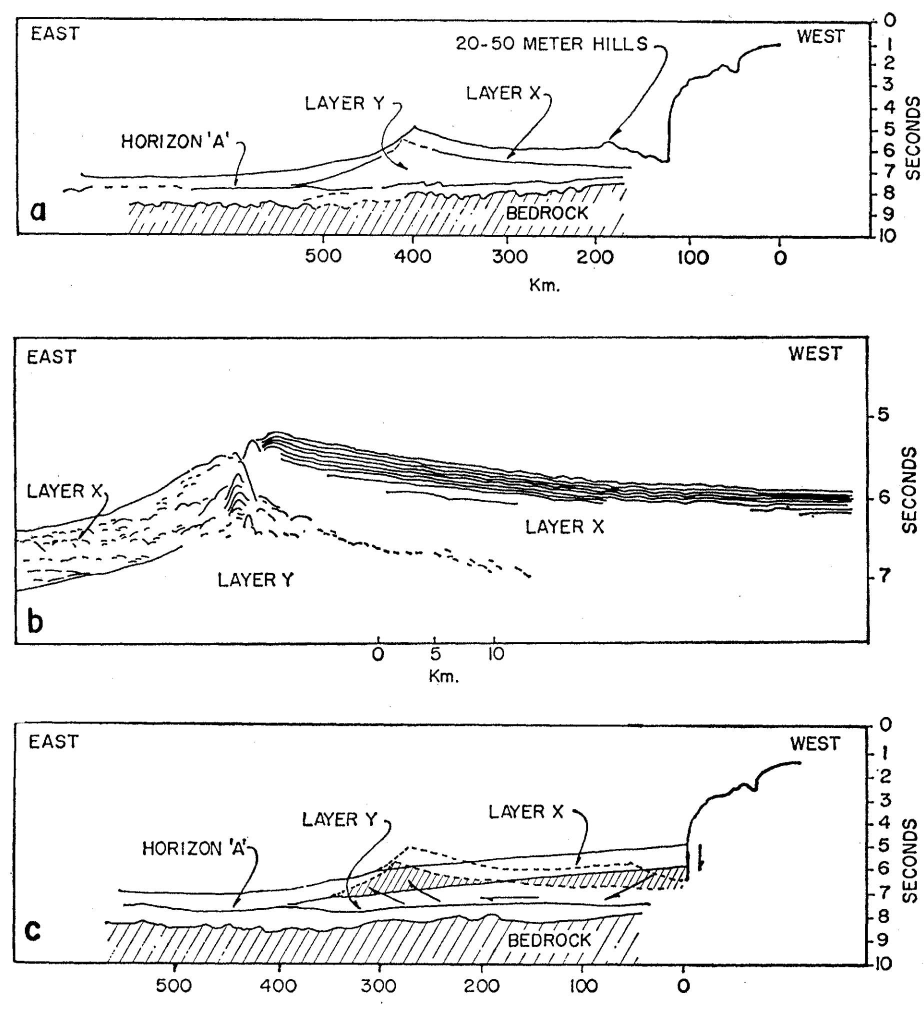


Fig. 2. (a) Seismic profile across Blake-Bahama Basin and Outer Ridge (after *9*). (b) Tracing of profile 9a. (c) Proposed process of development of Outer Ridge by diapirism and gravity tectonics. Solid lines, original depositional form; dashed lines, present structure. Arrows indicate flow in layer *y* and motion on Blake Escarpment.

nated as one or more submarine volcanoes is not precluded by the presence of horizon A beneath it, since volcanoes fed by narrow fissures from deep magma chambers could rest in nonisostatic equilibrium atop horizon A, and the fissures would not necessarily be seen on a reflection record.

However, there are several objections to such an origin. Gradients on shield volcanoes on the sea floor average 15° to 20° (*4*) rather than the 0.5° to 2.5° shown by the Outer Ridge gradient. Furthermore, a single volcano, having a base as large as the ridge does, would be as large as one of the Hawaiian Islands and roughly symmetric in shape. A series of aligned volcanoes would have a sharp relief that is entirely missing from the ridge (see Fig. 4 for comparison of the longitudinal profile of the ridge with that of a portion of Aves Ridge, a volcanic ridge in the Caribbean). Magnetic data from the ridge (*16*) show no anomaly that might suggest a basaltic core. Finally, the acoustic properties of lava beds would most likely prevent recording of reflections from horizon A if it were overlaid by a volcanic ridge.

A mechanism that merits serious consideration as an explanation of the origin of the Outer Ridge is gravity tectonics. Diapiric intrusion and extrusion, together with gravity sliding, are common in the continental crust (*17*) and have been recognized on the sea floor to a limited extent (*4, 18, 19*). Salt domes, the most common type of diapiric structures, are generally circular, but, when horizontal and vertical stresses are not uniform, more-linear shapes such as salt walls and salt anticlines are common (*20*).

On a much larger scale, the *argille scagliose* in the Apennines has acted as the plastic layer in regional and local gravity tectonics. This shale formation was laid down in a sedimentary basin between Corsica and Elba, but it is now found on both sides of the Apuane Alps and northeastward across the Apennine watershed (*17*). It has reached its present position by being pressed out of the original basin by lateral or vertical stresses and by gravity flow to the northeast. This movement may have been aided by gravity sliding across a series of successively developing ridges (*21*), or it may have been due entirely to squeezing, flow, and diapiric intrusion (*17*). Displacement of the formation from its original basin has been over 200 km, a distance of the same order of magnitude as distances entailed in formation of the Outer Ridge.

The Sigsbee Knolls in the Gulf of Mexico have been tentatively identified as salt domes (*19*), and salt domes are recognized as controlling the topography of the continental slope off the Mississippi River delta (*4*). Diapirism has also been proposed for the origin of abyssal hills (*18*), with the pre-Cretaceous red shales postulated by Hamilton (*22*) forming the plastic layer. Gravity sliding has been proposed (*23*) to explain the origin of hills along the lower continental rise off eastern North America.

If one applies internal flow and diapirism to the Outer Ridge, layer *y* must be the plastic layer and all movement must occur above horizon A. Layer *y* pinches-out a short distance beyond the ridge (Fig. 2a) and probably had little greater extent before formation of the ridge (Fig. 2c). Above it, layer *x* extends as a wedge across the Hatteras Abyssal Plain to pinch-out on the Bermuda Rise. Layer *x* thickens toward the west, but immediately below the Blake Escarpment the layering has been compressed and distorted by movement on the scarp.

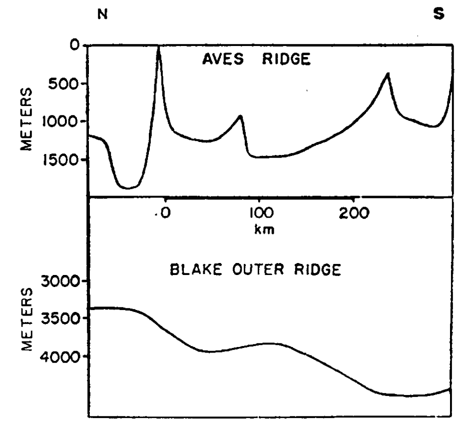


Fig. 4. Longitudinal profiles of Outer Ridge and Aves Ridge.

Figure 2c illustrates the proposed development of the ridge. Solid lines depict the situation prior to formation of the ridge, and the dashed lines show the present structure. Layer *y* was mobilized by overburden pressure of layer *x* (about 1 km thick) and by movement on the Blake Escarpment. This movement was important in initiating flow in layer *y*, and also formed a block to any westward flow by compressing the sediments near the scarp. Arrows in the figure show the direction of movement in layer *y* and also the motion on the scarp. The amount of material displaced and the area it has filled to form the ridge are shown by hatching.

The linear form of the ridge developed because of the wedge shape of the sediment layers, which thicken to the west and resulted in greater vertical stresses there. The gentle folds in layer *x* west of the ridge show that the movement in layer *y* was basically outward and upward, forming the ridge and causing the greatest disturbance just east of the crest and immediately beneath it. At the crest of the ridge, layer *y* has apparently broken through layer *x* to form the jumbled wedge to the east (Fig. 3); similar breakthroughs occur in asymmetric salt domes (*24*).

About 100 km west of the ridge, the surfaces of layers *x* and *y* are crumpled in a series of folds; this is a distinctive region of 20- to 50-m hills on the sea floor (*2*). These features probably result from gravity sliding of layer *x* back toward the basin since formation of the ridge. Local diapirism does not appear to be involved, be-

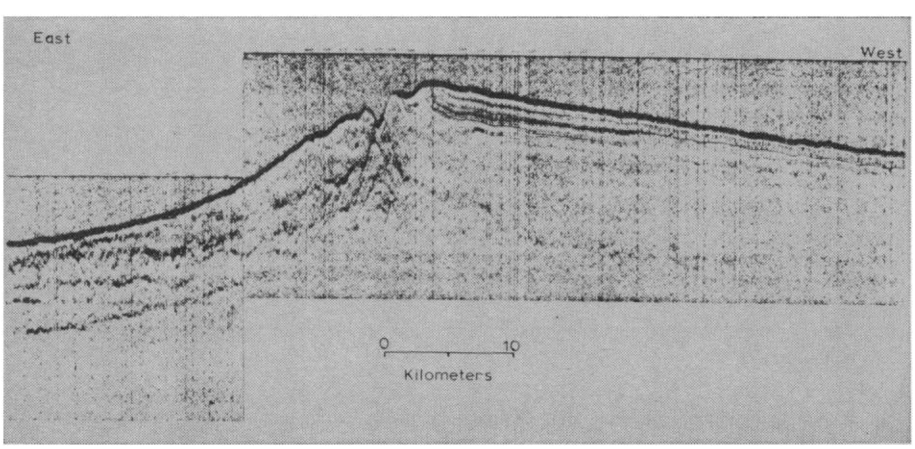


Fig. 3. Portion of the original record, crossing the crest of Outer Ridge; 2-second sweep.

cause layer $x$ does not thin over the rise and is not faulted.

Application of gravity tectonics to the formation of the Outer Ridge gives the most satisfactory explanation of its development. The presence of horizon A denies any deeper tectonic development, and the internal structure of the ridge precludes simple differential deposition of sediment to form the ridge. On the sea floor, large areas are covered by unconsolidated and semiconsolidated sediments. Slump features on the continental margins and the activity of turbidity currents show that these materials are quite plastic and may become highly mobilized under appropriate circumstances. These conditions should be eminently suited to the development of local and regional topography by gravity tectonics aided by changing patterns of sedimentation through geologic time, which would result in imbalance of vertical stresses in different areas. With gravity tectonics playing a large role in the development of structural land forms on the continents, it would be unusual if similar processes were not important on the sea floor.

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## Superconductivity at 20 Degrees Kelvin

We have found a superconductor with a transition temperature at 20°K. The substance is a solid solution between $Nb_3Al$ and $Nb_3Ge$.

During the past decade no substantial increase in superconducting transition temperature has been achieved. For the last 13 years, ever since the discovery of $Nb_3Sn$ in 1954 (*1*), the limit of all superconducting transition temperatures has remained in the vicinity of 18°K. All attempts, through the formation of mixed phases with $Nb_3Sn$ or other compounds crystallizing in the same $\beta$-W structure, to raise the transition temperatures over the values of both of its end points have been unsuccessful. The first attempt to do so was made by Hardy and Hulm (*2*) right after their discovery of the superconductivity of $V_3Si$ at 17°K. Many other efforts have been made since. However, the number of negative results are so great we shall not list them. An excellent compilation can be found in Roberts' article on superconducting compounds (*3*).

The increase of superconducting transition temperature to 20°K was accomplished through the formation of a solid solution between $Nb_3Al$ and $Nb_3Ge$, crystallizing in the $\beta$-W structure.

In the $\beta$-W structure, $Nb_3Sn$ and

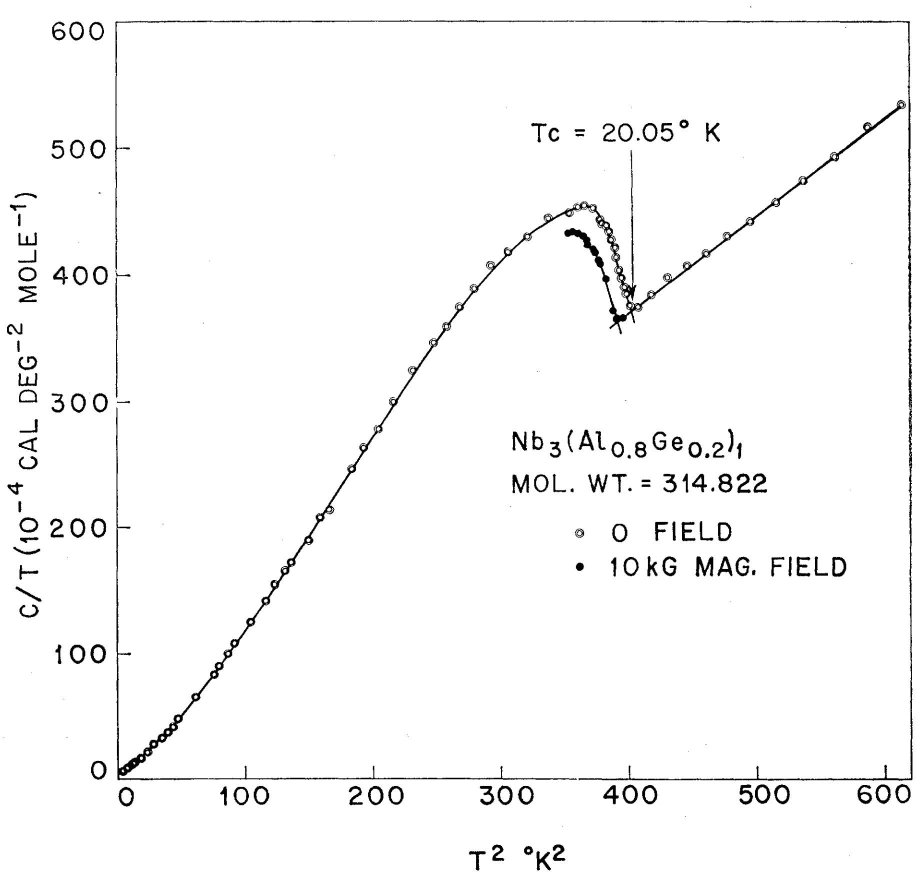


Fig. 1. Specific heat of $Nb_3Al_{0.8}Ge_{0.2}$ without magnetic field and with 10 kG.