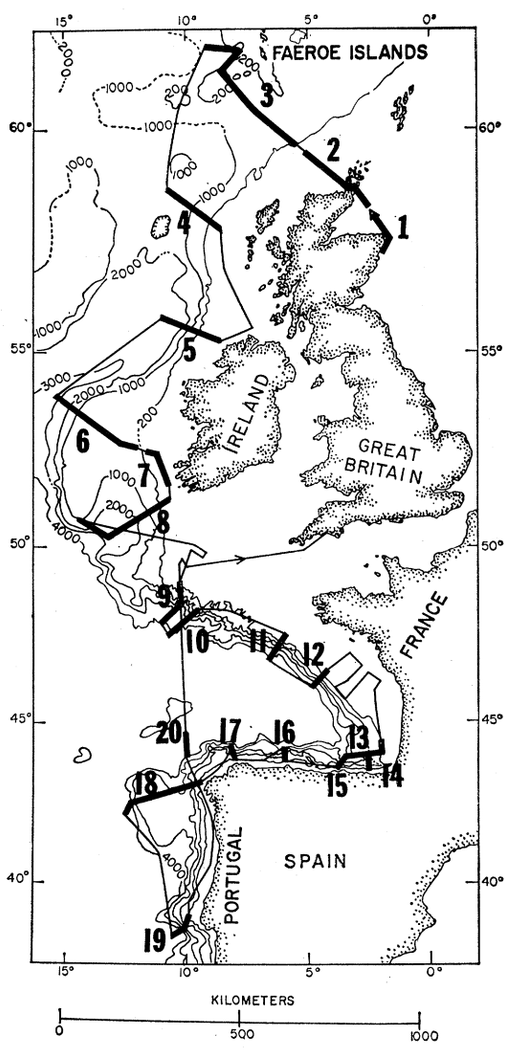
Continental Margin of Western Europe: Slope Progradation and Erosion

Abstract. *Reflection profiling of the continental margin off western Europe shows seaward-dipping continental-slope deposits that have been dissected by submarine canyons west of the English Channel. These records refute previous interpretation of structural benches of older, nearly horizontal strata outcropping on the slope face.*

The geological structure of the continental slope off western Europe—particularly the slope at the western end of the English Channel trough—has long been a subject of interest and speculation. Interfaces recognized at the few seismic-refraction stations south of England on the outer continental shelf and at a single station on the continental slope (*1*) have been correlated and projected oceanward in two extreme ways. They were thought to indicate either beds lying parallel with the present continental slope, or beds outcropping there and giving rise to structural benches—as was suggested for the eastern margin of the United States (*2*). Samples of rock indicated that a Tertiary succession outcropped on the upper part of the continental slope (*3*), but detailed study of the morphology revealed no relation between relief and rock age (*4*), although the importance of submarine canyons was indicated.

In view of the uncertainty about the geological structure west of the English Channel, and the almost complete lack of information about that to the north and south, a reconnaissance survey was undertaken with the combined 60,000-joule reflection-profiling systems of the Scripps Institution of Oceanography and the U.S. Navy Electronics Laboratory aboard the National Institute of Oceanography's R.R.S. *Discovery*. Eighteen of the profiler traverses (Fig. 1) extend across the outer part of the continental shelf, the continental slope, and the upper part of the continental rise. On the continental shelf, outcrops of older rock also were sought with side-scanning echo-ranging equipment. The reflection profiles in the vicinity of the Faeroe Islands have been described (*5*) and detailed interpretation of the remaining profiles is in progress.

Parts of the continental shelf and most of the continental slope from the Faeroes to southern Ireland are underlain by a thin veneer of sediments unconformably overlying older folded rocks, which are at least in part sedimentary. The continental margin off



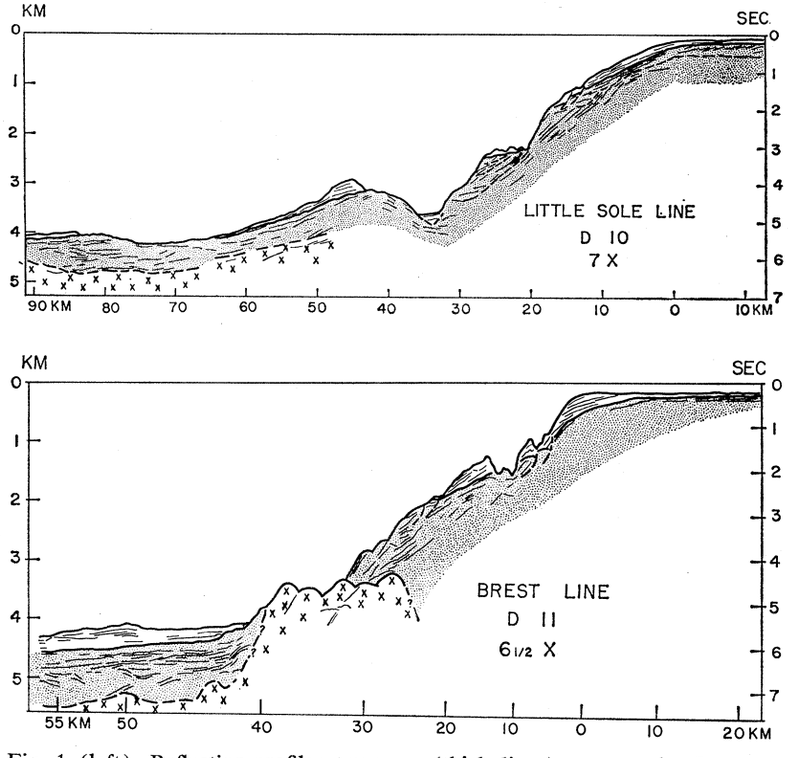


Fig. 1 (left). Reflection-profiler traverses (thick lines) run on the European continental margin. Fig. 2 (top right). Line drawing of reflection-profiler traverse 10. Vertical scales are two-way travel time (seconds) and water depth (kilometers); horizontal scale varies with ship's speed; vertical exaggeration is an average value. The shaded stratigraphic sequence is interpreted as tertiary sedimenatry rock (3 and 4) and × pattern indicates probable basement rock. Profile crossed the axis of a submarine canyon at kilometer 35; note erosional remnant of younger sediment at kilometer 45 to 65 and slumps on the shoaler flank of canyon. Fig. 3 (bottom right). Line drawing of reflection-profiler traverse 11; scales, × and shaded sections as in Fig 2. Note outcrop of possible basement rock near foot of slope and erosional remnants of younger slope sediments cut by submarine canyons and modified by slumping.

most of Spain and Portugal has little accumulation of sediment; the sedimentary rocks of the narrow continental terrace are folded and faulted, and the continental slope is steep and of tectonic or faulted origin. A basement high, or a possible structural bench of basement rock, may occur at the foot of the slope off France; there the upper slope is an undissected thick section of slope sediments.

The reflection profiles west of the English Channel trough show that the bedding of the uppermost kilometer of Tertiary rock (*3*) is parallel with the general surface of the continental slope (Figs. 2 and 3); thus, successive southwesterly dipping beds have been deposited on the continental slope, building it seaward. Lines 11 (Figs. 1 and 3) and 12 (Fig. 1) also have suggestions of outcrop of older basement rocks near the foot of the continental slope west of Brittany. Submarine canyons apparently were subsequently incised in the Tertiary rock, and slumping from the walls of the canyons was caused by oversteepening. This structural form resembles that found recently off parts of the eastern United States (*6*) and many other parts of the world.

J. R. CURRAY
D. G. MOORE
Scripps Institution of Oceanography, La Jolla, and *U.S. Navy Electronics Laboratory, San Diego, California*
R. H. BELDERSON
A. H. STRIDE
National Institute of Oceanography, Wormley, Godalming, Surrey, England

References and Notes

1. E. C. Bullard and T. F. Gaskell, *Proc. Roy. Soc. London Ser. A* **177**, 476 (1941); M. N. Hill and A. S. Laughton, *ibid.* **222**, 348 (1954); A. A. Day, M. N. Hill, A. S. Laughton, J. C. Swallow, *Quart. J. Geol. Soc. London* **112**, 15 (1956); A. A. Day, *Deep-Sea Res.* **5**, 249 (1959); D. T. Donovan, *The Geology of British Seas* (Univ. of Hull, 1963).
2. B. C. Heezen, M. Tharp, M. Ewing, *Geol. Soc. Amer. Spec. Paper 65* (1959).
3. D. Curry, E. Martini, A. J. Smith, W. F. Whittard, *Phil. Trans. Roy. Soc. London Ser. B* **245**, 267 (1962).
4. M. L. Hadley, *Deep-Sea Res.* **11**, 767 (1964).
5. A. H. Stride, R. H. Belderson, J. R. Curray, D. G. Moore, *ibid.*, in press.
6. D. G. Moore and J. R. Curray, *Bull. Amer. Ass. Petrol. Geol.* **47**, 2051 (1963); later unpublished data.
7. Work aided by ONR and NSF. Contribution from Scripps Institution of Oceanography and U.S. Navy Electronics Laboratory.

19 July 1966

Muscle Postjunctional Membrane: Changes in Chemosensitivity Produced by Calcium

Abstract. *Increases in the extracellular concentration of calcium ions above 1.8 millimoles per liter caused a reversible decrease in the sensitivity of the muscle postjunctional membrane to carbamylcholine. A quantitative study of the inhibitory effect of calcium ions on membrane depolarization produced by carbamylcholine indicates that calcium ions compete with carbamylcholine for some common binding sites on the postjunctional membrane. Calcium ions (20 millimoles per liter) caused a neuromuscular block wherein prolonged endplate potentials were produced after nerve stimulation. Calcium ions applied ionophoretically to the postjunctional membrane decreased the amplitude and prolonged the time course of the transient depolarization produced by ionophoretically applied carbamylcholine.*

Calcium has a considerable influence on neuromuscular transmission, and its important role in facilitating the release of acetylcholine from presynaptic terminals is well known. However, many investigators who have studied the effects of Ca^{2+} at the neuromuscular junction have tended to minimize the action of this ion on the postjunctional membrane (PJM). Such a position is generally based on the work of del Castillo and Stark (*1*), who concluded that Ca^{2+} has no significant effect on the depolarization of the PJM caused by the application of acetylcholine in bulk. In our view, the action of Ca^{2+} on the PJM is appreciable. Our reasons for reemphasizing the postjunctional effects of Ca^{2+} are as follows: (i) work from our laboratory (*2*) has shown that Ca^{2+} has an important influence on the "desensitization" of the PJM which develops during sustained application of quaternary ammonium agents such as carbamylcholine (Carb); (ii) the amplitude of miniature endplate potentials is significantly reduced when the concentration of Ca^{2+} is raised to 7.2 m*M* (*3*); (iii) increased concentrations of extracellular Ca^{2+} decrease the conductance of the PJM during neuromuscular transmission (*4*); and (iv) the techniques used by del Castillo and Stark, although the best available at the time, do not give results as definitive as can now be achieved.

We studied (in vitro) the effect of changes in extracellular concentrations of Ca^{2+} on sensitivity of the postjunctional membrane of frog sartorius muscle to Carb. (Carb is an analogue of acetylcholine; it can depolarize the PJM, but is resistant to hydrolysis by acetylcholinesterase.) By means of intracellular recordings at the neuromuscular junction, the sensitivity of the PJM was determined by measuring the maximum reduction in membrane potential achieved during microperfusion of the junction with carbamylcholine in various concentrations (*5*).

Maximum membrane depolarization was attained after 10 to 20 seconds of perfusion with Carb. Where Carb was applied in such high concentration that the fiber gave a mechanical response, an additional set of experiments was conducted in which Carb was applied in bulk and 2 minutes later, when the muscle movements had ceased, postjunctional membrane potentials were determined during the following 3 minutes. The maximum values of depolarization thereby obtained agreed reasonably well with those obtained when intracellular recordings were made continuously during Carb perfusion.

The Ringer solution we used was buffered with 1.0 m*M* tris (hydroxymethyl) aminomethane (Tris) to prevent precipitation of Ca^{2+}. The *p*H of each bathing solution was adjusted to 7.0 to 7.3 by the addition of HCl. Control experiments indicate to us that Tris itself has no detectable effect on neuromuscular transmission. When the concentration of Ca^{2+} in the bathing solution was changed from 1.8 m*M* (control) to a new value, the preparation was allowed to equilibrate at the new concentration of Ca^{2+} for 1 hour before any tests with Carb were run.

The resting potential and the minimum value of the membrane potential produced by application of Carb ($3.2 \times 10^{-5} M$) are given for muscles equilibrated with various concentrations of extracellular Ca^{2+} (Fig. 1). The depolarizing action of Carb is considered to be measured by the term ΔV which represents the difference between the