kinds of traps in the boron. The experiment is thus analogous to the production of a 'glow curve' in the examination of a luminescent material.

Some of the boron used in these investigations was prepared in this laboratory by an electron beam zone melting process and the remainder purchased as zone-refined material prepared by the Eagle-Picher Research Laboratories, Miami, Oklahoma.

Electrical connexion to the boron was through baked-on silver paste contacts which were substantially ohmic.

The observations described differ from, but may be related to, the 'magnetic pulse' and 'colour memory' effects studied at the U.S. Army Signal Research and Development Laboratory, Fort Monmouth, New Jersey[1].

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[1] Gaulé, G. K., Breslin, J. T., Pastore, J. R., and Shuttleworth, R. A., *Boron*, edit. by Kohn, J. A., Nye, W. F., and Gaulé, G. K., 159 (Plenum Press, Inc., New York, 1960); and private communication to P. H. R. Scholefield of this laboratory.

GEOLOGY

Age of the Orogeny and Granites in South-West England

Mr. Butcher's valuable contribution[1] to this puzzling problem raises a number of points which I would like to answer.

First, there is no evidence that the deformation of the pre-Permian rocks of south-west England was delayed until Stephanian or post-Stephanian times. On the other hand, there is some evidence[2] that metamorphosed, schalstein and spilite areas (and perhaps even the Delabole Slates) were being eroded somewhere south of Wales in Pennant Series (that is, Morganian) times. Hints of early Morganian instability occur in the Bristol Coalfield and in the south-eastern portion of the South Wales Coalfield. Dr. Kelling has recently been studying Pennant rocks in South Wales and is finding that over considerable southern and central areas of that coalfield a mainly southerly source (not too far away either) and a parent mass of rocks like those of Devon and Cornwall are indicated.

Secondly, similarity of fold system[3] does not necessarily prove contemporaneity of deformation. The folded and thrust south-west England sediments (the age of which has not been proved beyond about the Modiolaris Zone) are separated from the Somerset area by the powerful Cannington Park thrust-belt (which could have brought into juxtaposition rocks deformed at different times of the Carboniferous).

Thirdly, no one has ever suggested that the granites were being eroded during Pennant Sandstone (or even later Carboniferous) times. I agree with Mr. Butcher that these granites, when intruded, would be deeply buried. I also agree that "at the present level of erosion, the youngest sediments so far recognized by fossils are referable to the Upper Gastrioceras Zone[1]". There could still, however, have been an appreciable thickness of later Ammanian (for example, Similis-Pulchra Zone) deposits above this "present level of erosion" when the granites were intruded. In other coalfields of England and Wales, the thickness of the Ammanian succession above the Amman Marine Band is at least equal to (and in some cases almost double) that of the underlying Coal Measures. This thickness in the Somerset Coalfield (the one nearest Devon) is about 2,000 ft. If the south-west England area was experiencing a renewal of thick greywacke-type deposition in later Ammanian times, then that higher succession could have attained a thickness of many thousands of feet. Prentice (ref. 4, p. 408) has suggested that quite thick greywackes could have been deposited in a relatively short space of time. The granites could then have been intruded during early Morganian times and yet be buried under a considerable thickness of earlier Coal Measure rocks.

I would (with caution) suggest another possibility to account for the depth of burial in Morganian times of the granites. Great thrusts occur in the Armorican fold belt of Cornwall and south Devon. Such thrusts may have carried masses of Devonian, or older, rocks (removed by later erosion) well north over areas of deformed Culm. There could then have been thrust-masses of pre-Carboniferous rocks on top of the Culm, (*a*) when the granites were being intruded and (*b*) when the Pennant Series was being deposited farther north. Such an interpretation might even explain the presence of Devonian limestone pebbles (of southern aspect) in the New Red Sandstone near North Tawton, Devonshire[5]. The high percentage of Devonian fragments in the Permo-Triassic breccias of south-west England[6] might also be explained in this way.

Lastly, while derived Dartmoor granite is unknown in these breccias, a considerable percentage includes porphyries which could have been connected with the granite intrusions[6].

I therefore maintain that the case for a very late Carboniferous orogeny in south-west England, and also for a Permian granitic injection, has not been proved. On the contrary, available evidence supports an earlier (probably early Morganian) age for the main deformation of the Devonian and Culm rocks of Devon and Cornwall. The granite intrusions probably accompanied this deformation.

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[1] Butcher, N. E., *Nature*, **190**, 253 (1961).
[2] Heard, A., *Geol. Mag.*, **59**, 83 (1922).
[3] Kulp, J. L., Long, L. E., Giffin, C. E., Mills, A. A., Lambert, R. St. J., Giletti, B. J., and Webster, R. K., *Nature*, **185**, 495 (1960).
[4] Prentice, J. E., *Quart. J. Geol. Soc. Lond.*, **116**, 397 (1960).
[5] Hutchins, P. F., *Geol. Mag.*, **95**, 119 (1958).
[6] Wells, A. K., and Kirkaldy, J. F., *Outline of Historical Geology* (London, 1958).

I feel that the evidence cited by Mr. T. R. Owen does not necessarily support an Upper Westphalian (Morganian) age for the orogeny and granites. An intra-Westphalian orogeny could only be satisfactorily demonstrated by the discovery of younger unconformable Carboniferous sediments, as, for example, in northern Spain[1]. Such post-orogenic sediments are not known in Devon and Cornwall. However, our knowledge of this region is still very meagre, and it may be that they will yet be found. Meanwhile, it seems to me preferable on the present evidence to correlate the main orogeny in Devon and Cornwall with that in adjacent regions to the north. In this, I agree with Kulp *et al.*[2] and Lambert and Mills[3]; but also with Mr. Owen that the case has not been proved.