Mackay, J. R. 1958. The Anderson River map-area, N.W.T. *Canada. Department of Mines and Technical Surveys. Geographical Branch, Memoir* 5.
Smith, D. I. 1961. Operation Hazen. The geomorphology of the Lake Hazen region, N.W.T. *McGill University, Montreal, Geography Department. Miscellaneous Papers* No. 2.
Stephenson, P. J. 1961. Patterned ground in Antarctica. *Journal of Glaciology*, Vol. 3, No. 30, p. 1163–64. [Letter.]

SIR, *Quaternary glaciations in southern Victoria Land, Antarctica*

Following the glaciological work of the Victoria University of Wellington Antarctic Expeditions (1958-59 and 1959-60) in the Wright and Victoria Valleys area of southern Victoria Land, Antarctica (Bull and others, 1962), more detailed observations on the late glacial history of the eastern half of the Wright Valley were made in 1959-60 and 1960-61 by Dr. R. L. Nichols of Tufts University (Nichols, 1961).

In general these later observations confirm the earlier ones. In the lower levels of the eastern part of the Wright Valley, Nichols has distinguished three stages in the extent of the glacier flowing westward from the area at present occupied by the Wilson Piedmont Glacier. The oldest of these stages (Nichols's *Pecten Glaciation*) is represented by the outwash gravels and sediments which occur south-east of Bull Pass, about 18 km. west of the present terminus of the Lower Wright Glacier (see Bull and others, 1962, fig. 8). The next youngest stage, Nichols's *Loop Glaciation* is represented by the prominent terminal moraine 11 km. west of the Lower Wright Glacier and by associated lateral moraines extending eastwards from this point. His most recent stage, the *Trilogy Glaciation*, is represented by terminal, lateral and ground moraines in the area near the Clark and Lower Wright Glaciers. The most recent of these moraines, extending 2 or 3 km. from the present snouts of these glaciers, are still ice-cored.

Nichols's *Loop Glaciation* corresponds to our *Third Glaciation* in the eastern part of the valley. We did not map the recent moraines near the Clark and Lower Wright Glaciers and have not marked them as being a separate glaciation on our map because the moraine ridges which establish this *Trilogy Glaciation* are much less pronounced than the features used to distinguish other glaciations in the valley. However, in the text we mention that moraines of our *Fourth* (Nichols's *Trilogy*) *Glaciation* and more recent moraines occur near the Lower Wright Glacier.

The only significant difference in interpretation occurs with the stratified gravels near Bull Pass. Nichols associates them with a separate (*Pecten*) glaciation; we regarded them as outwash from the *Loop* cr *Third Glaciation*. The difference arises from the age attributed to the moraines which in places overlie the gravels. These were deposited by glaciers flowing from Bull Pass on the north and by the unnamed hanging glaciers on the south side of Wright Valley. Although these are marked as *Third Glaciation* on our generalized map we have regarded them (on the basis of degree of weathering) as being somewhat younger than the main deposits of Nichols's *Loop Glaciation*. Nichols regards these overlying moraines as contemporaneous with the main *Loop Glaciation* deposits, so that the gravels must be associated with an older glaciation. Nichols's interpretation may be strengthened by the presence of the formless deposits occurring on the sides of the valley between the *Loop Glaciation* terminal moraine and Bull Pass. Nichols has regarded these as lateral moraines associated with the *Pecten Glaciation*, while we considered them as being an earlier part of the *Third Glaciation*, considerably modified by the action of the lakes which later occupied the part of the valley west of the main terminal moraine of the *Loop* or *Third Glaciation*.

Further information on this problem may result from the work in the valley carried out in this last austral summer.

A more significant problem is the presence of the pectens which Nichols found in the stratified gravels in the centre of the Wright Valley, nearly 40 km. from the present coastline.

All of the glaciations referred to above post-date the last continuous glacier which flowed from the inland ice plateau through the valley to the McMurdo Sound area. After the disruption of the continuous glacier, small increases in the flow of plateau ice over the rock threshold at the head of the valley have caused local advances of the Upper Wright Glacier, as reported earlier. The relationship between these stages in the western end of the valley and those in the eastern end is not yet firmly established, but it is apparent that at the time the pectens were deposited the flow of ice eastwards from the plateau was not much greater than at present, while the glacier flowing westwards in the eastern part of the valley was relatively much more extensive than now.

It must be emphasized that the differences in the regime of the glaciers at the two ends of the valley are extreme. The supply of ice to the Clark Glacier and to the Wilson Piedmont Glacier and its extension, the Lower Wright Glacier, is at present from *névé* fields in the eastern parts of the Asgaard, Olympus and St. Johns Ranges, and by accumulation on the glaciers themselves, so that the extent of these glaciers is determined by the local balance between accumulation and ablation. On the other hand the extent of the glacier in the western end of the valley is controlled almost entirely by the elevation of the inland ice and therefore on the mean accumulation over a considerable area of the inland ice.

The change in the relative extent of the eastward- and westward-flowing glaciers could have been caused in a number of ways. It is possible that the snow accumulation near the coast was much greater than at present while that on the inland ice plateau remained unchanged. Alternatively a prolonged period with a decrease in summer temperatures without change in the accumulation, would greatly extend the Clark and Lower Wright Glaciers without affecting the extent of the Upper Wright Glacier, where the ablation is at present negligible.

However, this only explains the relative sizes of the glaciers and does not account for the pectens. The subglacial topography of the Lower Wright and Wilson Piedmont Glaciers is not well known, but on one traverse up the mid-line of the Lower Wright Glacier and across the Wilson Piedmont Glacier to the coast near Marble Point (Bull and others, 1962, fig. 1) the bedrock rises to about 600 m. above present sea-level (Bull, 1960). This renders difficult any explanation of the transport of the pectens from the sea in terms of local glacier variations.

Hollin (1962) has shown that the extent of the grounded ice mass of Antarctica is determined almost entirely by the position of sea-level. A decrease in the sea-level of 150 m. would result in the seaward extension of the continental ice by about 100 km. and an increase in the ice thickness at the present edge of the continent of about 1,200 m. However, near the centre of the ice sheet (for example, inland from the western end of the Wright Valley) the increase in thickness would be very much smaller, 50 m. in a calculation made with one particular set of simplifying assumptions and about 200 m. in Hollin's calculation. The second effect of such a decrease in sea-level would be the grounding of ice in the area at present occupied by the Ross Ice Shelf. Once the ice was grounded, the area would accumulate the ice flowing from western Antarctica and from the southern parts of eastern Antarctica until its surface attained a nearly parabolic profile. With a drop in sea-level of 150 m. the northern limit of the grounded ice in the Ross Sea area would be at about lat. 76° 30′ S. and the elevation of the surface east of the Wright Valley would be about 1,200 m. In such circumstances the transport of pectens from an area previously occupied by sea into the Wright Valley would have been possible, while the extent of the glaciers flowing eastwards from the inland ice plateau was not greatly different from now.

The pectens have been dated by Nichols, using a radiocarbon method, at more than 35,000 years B.P. It is probably unwise to place too much reliance on this single evaluation in establishing an Antarctic glacial chronology. The date given for the pecten's age is a few thousand years older than the greatest depression of sea-level in the Würm Glaciation, given by Fairbridge (1961) as occurring between 17,000 and 30,000 years B.P. Fairbridge gives a value of about 100 m. for the maximum depression of sea-level, but Ewing and others (1960) consider that the depression was probably 150 m. This and related points are further discussed by Hollin (1962).

I am grateful to Dr. Nichols and Mr. Hollin for valuable discussions on various aspects of the history of the ice-free valleys and to Mr. Webb for critically reading the manuscript. I thank Mr. Hollin also for letting me read his paper before publication. This note has been written while I am engaged on National Science Foundation grant G-20473 (Ohio State University Research Foundation Project 1396).

Institute of Polar Studies,
Ohio State University,
Columbus 10, Ohio, U.S.A.
C. BULL
22 February 1962

REFERENCES

Bull, C. 1960. Gravity observations in the Wright Valley area, Victoria Land, Antarctica. *New Zealand Journal of Geology and Geophysics*, Vol. 3, No. 4, p. 543–52.

Bull, C., *and others*. 1962. Quaternary glaciations in southern Victoria Land, Antarctica, by C. Bull, B. C. McKelvey and P. N. Webb. *Journal of Glaciology*, Vol. 4, No. 31, p. 63–78.

Ewing, M., *and others*. 1960. Revised estimate of Pleistocene ice volume and sea-level lowering, by M. Ewing, W. L. Donn and W. Farrand. *Bulletin of the Geological Society of America*, Vol. 71, No. 12, Pt. 2, p. 1861.

Fairbridge, R. W. 1961. Eustatic changes in sea-level. *Physics and Chemistry of the Earth*, Vol. 4, p. 99–185.

Hollin, J. T. 1962. On the glacial history of Antarctica. *Journal of Glaciology*, Vol. 4, No. 32, p. 173–95.

Nichols, R. L. 1961. Multiple glaciation in the Wright Valley, McMurdo Sound, Antarctica. *Abstracts of symposium papers, tenth Pacific Science Congress of the Pacific Science Association, Honolulu, 1961*, p. 317.

https://doi.org/10.3189/S0022143000027490 Published online by Cambridge University Press