Correspondence

The Editor,
Journal of Glaciology

SIR,

Comments on "Glaciers in Picos de Europa, Cordillera Cantábrica, northwest Spain" by González Suárez and Alonso

González Suárez and Alonso (1994) reported the discovery of glaciers and glacial ice in some protected places at the bottoms of high walls in the Picos de Europa mountains. They described the presence of this glacial ice particularly at the bottom of the summit of the Picos de Europa, Torrecerredo (2648 m), in the glacio-karst closed depression of Jou Negro. In this letter, we wish to call attention to the fact that the existence of these glaciers had been known and was discussed long before González Suárez and Alonso encountered them in their research. In addition, we wish to describe research we have conducted over the last 3 years which contradicts some of the scientific descriptions of these glaciers offered by González Suárez and Alonso.

PREVIOUS RESEARCH ON GLACIER EXISTENCE IN PICOS DE EUROPA

Since the middle of the 19th century, several authors, such as Prado (1860) and, from his references to them, Saint Saud and Labrouche (1893) and Penck (1897) established the existence of glaciers in Picos de Europa. Indeed, these authors explicitly mentioned Jou Negro glacier. A few years later, Obermaier (1914) published a rigorous study about glacier land forms and the Quaternary expanse of glaciers in Picos de Europa. From his research, he concluded that these authors had confused small snowpatches with glaciers. He recognized the existence in summer of "... small snowpatches in some well protected sites of heat action. It is not possible to give them glacier denomination because they are located in deep hollows in completely dead condition". Until now, this opinion has been held by various authors, who have done research on the Picos de Europa Massif. The Spanish glacier catalogue made by the Instituto Español de Glaciología, later revised, extended and published by Martínez de Pisón and Arenillas Parra (1988), does not consider these accumulations as glaciers. Also, the Iberian Peninsula glacier catalogue, co-ordinated by Serrat (1980), expressed the same opinion. Moreover, it is worth noting that these catalogues do not include Pyrenean perennial snowpatches similar to the Picos de Europa snowpatches located in the Monte Perdido Massif.

Two explanations for this contradictory historical record can be offered. First, the glaciers reported in 1860 may have disappeared by the turn of the century. Secondly, the original report of the glaciers may have been erroneous. Prado's description of "glaciar del Llambrión" is so ambiguous that it is quite possible that he had made an erroneous identification.

THE JOU NEGRO SNOWPATCH AND ITS BORDERS

At the present time, the Jou Negro snowpatch morphology is concave throughout the summer, adjusting perfectly to the northern Torrecerredo slope and the bottom of the Jou Negro depression. There is a moraine ridge underlying the bottom of the Jou Negro perennial snowpatch, which has a characteristic moraine-glacier morphology (Fig. 1). It has a well-defined edge and has a steep slope towards the inside of the snowpatch, particularly on the lateral margins. We agree with González Suárez and Alonso's interpretation of the inherited glacier-morainic ridge. It is not being formed at the present time but was built completely during the Little Ice Age. At present, debris accumulation is not forming a protalus rampart at the base of the snowpatch, because wall debris does not terminate there; this debris lies in the snowpatch hollow whose central level is not as high as its borders.

González Suárez and Alonso showed that the Jou Negro glacial ice revealed itself accidentally as a result of very considerable ablation in recent years. However, in the aerial photograph, taken in September 1969 by Diputación de Oviedo, it is possible to see dark-coloured ice similar to what they described but only in the central part of the snowpatch.

We have checked the existence of ice in a part of the surface between the northern walls of Torrecerredo and the well-defined moraine ridge. In July, this small surface between the walls and the morainic arc, about 14 300 m^2 in area and 2235 m in mean altitude, is fully covered by firn but, in August and September, before the first snowfalls, the snowpatch is fragmented by long steep-faced debris mounds about 6 m high. Meltwaters have created a channel between the largest debris mounds; both channel margins show up to a few metres thickness of ice beneath debris (Fig. 2). Also, there are different ice bodies beneath the debris mounds.

DISCUSSION

The Jou Negro ice has no layers which reveal a sedimentary structure and no surface structures showing ice movement such as *crevasses* or *rimayas* resulting from flow and not generated by differences in the thermal expansion between rock and firn or ice joints. It is possible that some of this could be fossil ice, inherited from the Little Ice Age, but this is immobile ice; because of this, it is difficult to call it a glacier. Furthermore, the ice is still being formed at present. There are two possible reasons why this is so: either meltwaters refreeze after their infiltration when they come into contact with a seasonal ice front and fossil ice, or its origin is the transformation of

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Fig. 1. The Jou Negro hollow with a morainic ridge in the foreground. Note the debris mounds in the snowpatch. (Photograph taken on 5 September 1994.)

the residual snow or firn when it remains trapped beneath debris derived from the walls. In any case, there are high-mountain periglacial processes leading to perennial and spatially sporadic ice formation which are connected with very special conditions of exposure, preservation and melting of snowpatches at this altitude.

Fig. 2. Sketch from the Jou Negro hollow. 1. Morainic ridge from the Little Ice Age. 2, 3, 4, 5, 6 and 7. Debris mounds with ice bodies. 8. Meltwater channel in the debris accumulation over ice. 9. Firn.

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CONCLUSION

There are no true glaciers in the Picos de Europa Massif but perennial snowpatches with firn where the presence of small fossil ice bodies is possible. In the Jou Negro depression, one of these snowpatches contains periglacial ice and, also, there could be ice inherited from the Little Ice Age. However, these are examples of dead, not moving, ice and they serve to establish the presence of sporadic permafrost in the Picos de Europa periglacial belt.

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Sir,

Glacial-ice fragments in Antarctic sea ice

Sea ice, as the result of freezing of sea water, can have various textures determined by the prevailing thermal and hydrodynamic conditions during ice formation and subsequent growth (Weeks and Ackley, 1982; Eicken and Lange, 1989). In the Antarctic, flooding of surface snow also often leads to snow-ice formation, giving rise to a meteoric component in the sea ice (Lange and others, 1990; Eicken and others, 1994), which has a granular texture with grains of several millimeters up to some centimeters in size. Snow-ice is believed to form up to 4% of the total sea-ice volume in the Weddell Sea (Eicken and others, 1994) and perhaps more than twice as much in the Ross, Amundsen and Bellingshausen Seas (Jeffries and others, 1994).

Here, we report a novel finding of glacial-ice fragments (up to several centimeters in diameter) in a sea-ice core obtained in the Bellingshausen Sea north of Alexander Island, Antarctica. To our knowledge, glacial ice has not previously been described as an important component of sea ice, although in this core it amounted to 20% of the core volume. The features of the core, including texture, salinity and $\delta^{18}O$ measurements, are reported and the relevance of glacial ice fragments as a component of the sea ice in this region of the Antarctic is discussed.

GENERAL ICE-CORE PROPERTIES

Ice coring was part of a larger sea-ice program during an expedition of RV *Polarstern* to the Bellingshausen and Amundsen Seas in the late austral summer of 1994 (Fig. 1; Miller and Grobe, 1995). The ice core was obtained on 29 January 1994 during an ice station at 68°40.2′ S, 72°37.3′ W, approximately 11 nautical miles (n.m.) south of the sea-ice edge and 20 n.m. from the coast. The ice concentration was 10/10 and the ice floes were mostly 10–100 m in diameter with piled-up brash in between. There was hardly any evidence of ice deformation (see Haas and Viehoff (1994) for a detailed description of ice conditions). The floe sampled was approximately 30 m × 40 m in size and had a mean ice thickness of 3.1 ± 1.1 m, covered with 0.51 ± 0.13 m of snow. A thickness profile

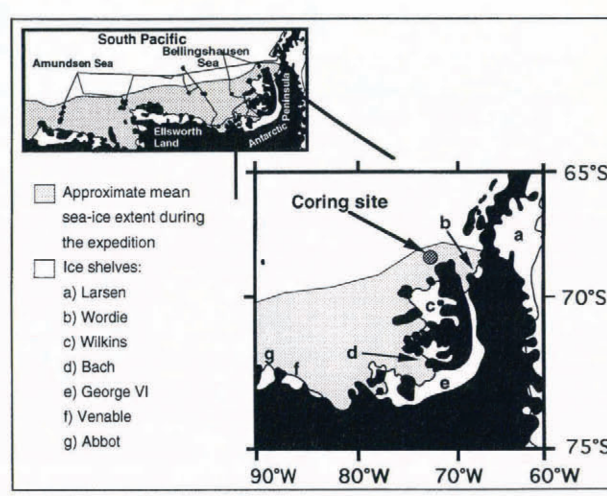

Fig. 1. Map of the cruise track. The site where the glacial-ice fragments were found is marked by an arrow. All other coring sites during the expedition are indicated by black circles.

derived from drilling (Fig. 2) revealed that, although the surface was rather flat, the underside of the ice was highly irregular. During drilling, many gaps or voids several centimeters thick were penetrated. These were mainly in the uppermost ice and may be characteristic of summer sea ice in this region (Jeffries and others, 1994). Some

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