Scars (the rocks which lie along the shore), to examine the petrifactions which Pontoppidan talks of in his Natural History of Norway, as to be found in Steensund, in Sulen-Öerne, at the beginning of the 61° of north latitude. I went on shore at different places; and although I carefully examined every place around, I found not a trace of petrifaction.* On the contrary, I found that the part of the continent separated from it by the Sound, and the island of Indre- or Østre-Sulen, consisted of a solid conglomerate,† composed of boulders, from the size of a pea to that of a man's head. These boulders consisted chiefly of gneiss, quartz and clayslate, which were involved and bound together in a mass so solid that it was difficult to find out what the binding medium was, as the interstices between the large stones were completely filled up with small boulders. On closer examination, at particular spots, I found that this binding medium was chlorite and hard clay.

On this rock there seemed to me proofs of the powerful operation of ice. I found that the precipices on the side of the mountain next the Sound were several feet (*sic*) in height, and perfectly perpendicular; and though they were composed, as I have mentioned, of boulders cemented together, they were perfectly even and smooth. If these precipices had been the effect of rents, attended with successive masses tumbling down, then the boulders adjoining the rent must have been found adhering sometimes to the one and sometimes to the other of the separated masses (those which have fallen into the sea are no more to be seen); and, in that case, the boulder left in one mass must have left a mark of itself in the corresponding one. This, however, was by no means the case, as the rock which remained was perfectly smooth, and had the appearance as if these boulders had been cut across by a sharp knife. I can explain this phenomenon in no other way than by supposing that large masses of ice pressing through the Sound have cut these precipices lying parallel to the direction of the Sound.

I could give other proofs of the conclusion I have sought here to establish, but, to persons capable of judging of the matter, I consider these as sufficient."

* Professor Rathke, who had formerly been at the same place, and found none, recommended to me to make this examination.

† The translation is at fault here. It should read ". . . . I found that both the mainland and the island of Indre- or Østre-Sulen, which are separated by the Sound, consisted of . . ."—*Ed.*

(*Communicated by Professor Kaare Strøm, Oslo*)

# THE INTERNATIONAL DEVELOPMENT OF SNOW SURVEYING

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Snow surveying was initiated in north-western America forty years ago and has proved of the greatest value to farmers for estimating run-off for irrigation and to engineers for flood prevention. The methods of surveying have been gradually improved and many works have appeared dealing with this aspect of the matter. Snow survey systems have been extended from western North America westward to Australia and eastward to New England, Quebec, Newfoundland, Norway, Sweden, Switzerland, India and westward again to Argentina and Chile in South America. The systems in Australia, New England and Newfoundland have been quantitative. Nearly all the others are based on seasonal percentage or correlation. International snow surveys were first established in 1921 by the United States and Canada in the basins of the St. Mary and Milk Rivers in Montana, Alberta and Saskatchewan. Free access was granted across the national boundary and snow surveys and forecasts were shared.

In 1947 an international snow survey system was organized by India and Nepal in the Himalaya, particularly for the management of reservoirs under construction or planned on the Kosi and Tista

Rivers in eastern India. The low latitude of the eastern Himalaya results in a high snow line of 16,000 feet (4876 m.) and an early snow melt season. However, the presence of trails to Tibet through Sikkim made possible the use of snow courses in the Tista basin to indicate the seasonal run-off in the larger but almost inaccessible Kosi basin in Nepal. But the separation of Pakistan from India has hindered this plan while making almost inevitable an ultimate co-operation of the three countries to establish a snow survey system covering the entire Himalaya. This will include the Tista, Kosi, Ganges feeders and the Punjab rivers which now flow mainly into Pakistan. The monsoon, which begins only in May or June, supplements the snow melt run-off, but on the mountain slopes it falls mainly below 8000 feet (2438 m.). Glacier melt appears to affect the run-off only slightly, although the glacial area in some basins is 12 per cent of the total area of its basin.

The southern Andes of South America are a remarkable laboratory for problems of snow surveying. The Argentine-Chile international mountain boundary of 2400 miles (3862 km.) contains the highest peaks in the Americas. It is bare and arid and windswept in the north, but forested and wet and glacier-capped in the south. This section also possesses spacious mountain lakes, in number and beauty like those of Switzerland. In the north where a "little California" exists at the eastern base of the Andes, 90 per cent of the winter precipitation falls on the west or Pacific slope and 90 per cent of the summer precipitation falls on the east. Sites for snow courses are few. Although streams are far apart, there is sufficient harmony between neighbouring streams to use forecasting over wide areas. This is particularly true in using Chilean streams to forecast the Argentinian streams on the opposite side of the crest. At one point the Andes slope is so steep on the west that the winter storms from the Pacific provide rain in Chile and snow of similar percentages on the mountain divide, so that the winter stream flow in Chile can be used as an index of the next summer's snow melt flow in Argentine. As in India, glaciers were thought to furnish the essential flow of the streams and control the agricultural economy of the country. But the presence of pitted glaciers in the north and snow-covered glaciers in the south was conclusive evidence that seasonal snow provided the annual flow of the streams and at best the glaciers could become active only later in the season after their snow cover had first melted. The Santa Cruz Basin of Southern Patagonia formed an exception, being obviously glacier fed, but only up to one-third of its total flow.

The lack of noticeable influence of glaciers on run-off in the Pacific north-west of the United States has been shown by H. P. Boardman in our report on snow surveying in the Himalaya. The southern Andes are an exceptional area for international snow surveys and exchange of water and power. Although the boundary generally follows the divide, in some cases it necessarily bisects the area between the snow crest and the run-off or drainage crest of the range. Furthermore, the mountains are so impassable in places that snow survey parties must make detours across the national boundary.

In Tierra del Fuego the rivers and Lago Cami lie on both sides of the boundary, with snow sources on one side and outlet on the other. Chile has abundant water and Argentina has large arid areas. Chile can thus provide supplemental power and possibly water in exchange for reservoirs and power plants. In any case, the seasonal snow-surveys and forecasts should be the joint function of the two countries.

The Alps, in which lie the sources of the Rhine and the Rhône, afford Switzerland the opportunity of international co-operation along these rivers. Need has already risen in Holland at the mouth of the Rhine for seasonal forecasts of the snow melt flow of this river in order to regulate more efficiently the storage reservoir in the Zuyder Zee area recently reclaimed from the sea. Because of the close harmony found to exist between the feeders of the Swiss Rhine and the Rhine at Bâle and also with the Rhône at Geneva, a snow survey even at the source of the Rhine above the Lake of Constance (Boden See) should be accurate within 15 per cent for all of these streams during four years out of five with a maximum error of 35 per cent in twenty-one years.

The area involved is 100 by 150 miles (160 by 240 km.), but the snow cover probably represents the downstream flow. The only discordant factor on the lower Rhine might be the Main. The Danube, however, has other minor sources downstream. Switzerland has already inaugurated a broad system of snow surveys to supplement its earlier system in the basin of the Lake of Zürich. Like the Andes, the Alps by their altitude prolong their snow melt season from four months, usual in North America, to five months, and by controlling lakes add yet another month to the run-off cycle. Thus the April–July period is expanded to April–September, but the longer period corresponds in seasonal percentage closely to the shorter period on which the above harmony in stream flow is based. In its snow research and water sources Switzerland is the hydrologic service center of Europe.

International snow surveys traversing the Scandinavian peninsula would provide a picture of drifting snow in Norway and Sweden and a broader basis for forecasts of stream flow. Southern Sweden, however, projects below Norway into a belt of earlier melting. Snow surveys are practised in both countries and the late run-off of glaciers is being utilized to prolong the period of dependable power. A national snow survey system has been planned in the Pyrenees to forecast water power supplies on the River Ebro of Spain for occasional dry winters. Systematic forecasting has also been projected for the mountains of Iran, a snow-fed country strikingly like Nevada, where snow surveying was first developed. The distant snow-clad peaks and the filaments of green descending from them through the desert to a broad oasis reveal from the air the intimate relationship between snow cover and vegetation. At present the success or failure of the coming summer is forecast by looking at the snow.

*MS. received July* 1949

# CORRESPONDENCE

The Editor,
*The Journal of Glaciology*

SIR,

## *Bismuth and Ice*

At the Joint meeting of the Society with the British Rheologists and the Institute of Metals, Dr. C. H. Desch suggested the investigation of bismuth for its analogies with ice. The enclosed leaflet, a reprint of the *Bulletin de la Société Vaudoises des Sciences Naturelles* dated 17 April 1907, shows that this problem did not escape my attention many years ago.

But the experiment was not easy owing to the difficulty of maintaining the metal exactly at the right temperature—267° C., which is a few degrees below its melting point. Another difficulty was its brittleness and the fact that only very small quantities of the metal were available. As you will see I used small rods of bismuth 1 cm. in diameter and placed on them an iron wire 0·3 mm. in diameter, weighted with a weight of nearly 3 kg., giving a pressure of 100 atmospheres. The rods were completely cut through but no regelation of the incision took place. The iron wire was, in places, covered with melting bismuth and traces of local melting were visible during the experiment.

It would be interesting to repeat this experiment with larger quantities of the metal and under temperatures better controlled than was possible for me at the time.

## *The Growth of the Glacier Grain*

Since Hugi over a century ago demonstrated the grain structure of the glacier no definite answer has been given to one fundamental question: has the growth of the crystal in its course from the peaks to the valley been assisted or retarded by the movement of the glacier?

Emden showed in 1880 that the crystals in ice could grow even in the complete absence of movement provided only that the temperature fluctuated around the zero point, which, of course, is the case, too, in the moving glacier.

I should like to take this opportunity of saving from oblivion certain observations I made as early as 1897 at the Montanvers section of the Mer de Glace and which I communicated to the