were evident than at Oslo, but for most of Antarctica the isolated coastal exposures and ice-covered interior seem a crucial impediment to further understanding. Radar ice-thickness measurements are revealing something of sub-ice morphology and, in those rare cases where allied geophysical data are available, seem capable of generating some small, speculative understanding of the interior. There is no doubt, however, that the geology of most of Antarctica, East and West, and its important glacial history, will remain obscure without an expensive and time-consuming programme of survey-controlled, regional sub-ice drilling.

Perhaps the liveliest part of the symposium, in contrast, was a two-day section on the geodynamics of the Scotia Arc. Considerable progress has been made since 1970, particularly in understanding southern South America's evolution and strengthening its connection with South Georgia. A Cainozoic age for almost all the Scotia Sea is now established, but the earlier history of the region remains uncertain. A crucial unknown, the positions of the Antarctic Peninsula and South America at the Gondwanaland margin, should emerge shortly; magnetic anomaly-based Gondwanaland reconstructions at Madison were conflicting, but obviously convergent, and the growth of marine geophysical interest in the Weddell Sea should complete the puzzle.

Under the influence of geodynamics, some Scotia Arc studies are oriented towards the processes involved in formation. The area is particularly well-endowed with back-arc basins, and a geochemical data base for these and other active margin igneous processes as broad as any in the world is now available.

Mineral resources, presently occupying the attention of Antarctic Treaty signatories were considered in only six out of about 150 papers. This dearth does not reflect wilful ignorance (the academic ostrich!), nor in the informal opinion of the meeting does it hide a much greater actual knowledge. Simply, reconnaissance mapping is complete and any resource detectable by such means is known; none is economic to extract at present, and such more detailed, follow-up surveys as have been carried out have proved no more fruitful. Offshore petroleum prospects were not discussed at Madison but this case is essentially similar, although there has been less reconnaissance.

The main goal of Southern Ocean marine geology (a topic hardly considered at Oslo) is an understanding of the interdependence of climate, circulation, sedimentation and Antarctic glaciation in a ocean basin of changing shape and with the most vigorous oceanic current system in the world. At Madison, papers based mainly on Deep Sea Drilling data and the Eltanin piston core collection attempted partial analyses of some of these relationships over time intervals varying from 1,000 years to 150 Ma. Individual papers were interesting but the pervading impression was of a huge field largely unexplored, with the gaps between contributions at least as important.

The four disparate fields considered above, with very few exceptions, contain all that is of wider interest in Antarctic earth science at present. They are at very different stages of development, from youth to old age, and their futures too are likely to diverge. Marine geology should prosper independently, with the driving force of the Southern Ocean's importance to world climate and primary productivity, and the basic unity of circum-Antarctic circulation as a constraint on the multi-disciplinary approach. One looks, perhaps, for an injection of numerical modelling, to link through the huge range of periodicities being examined and to direct further sampling.

The future of Antarctic geology is less certain. Some aspects, such as Scotia Arc studies, may continue to develop and, as the emphasis in geology changes, remain as fertile ground for the study of processes. For much of Antarctica, however, a similar transition from unmapped wilderness to geological laboratory may not be possible; without sub-ice drilling too little of the context may ever be learnt. The value of Antarctica to global geology will then decline. Economic geology has reached a similar impasse. Workable deposits within and around Antarctica must exist and, given the increasing world pressure on known resources, continued interest is inevitable. There are no easy, short-term prospects, however, so the opportunity is still there for a balanced, disinterested political decision on the course of further exploration and exploitation. □

Have gunk, will travel

from Peter J. Smith

A *nuée ardente* is a rapidly flowing, turbulent and often incandescent cloud of gas and ash originating in an explosive volcanic eruption. The first one to come to the attention of scientists, but surely not the first ever to be seen, was that from Mt Pelée (Martinique), which in 1902 overwhelmed the town of St Pierre, killing all but two of the inhabitants. This still remains the most famous of all, although many others, including much larger ones, have been observed since, not least from Mt Pelée itself.

But observation is one thing and scientific investigation is another; by their very nature *nuées ardentes* in action (as opposed to the deposits they leave behind) are not particularly amenable to the latter. The pioneer in this field was Frank Perret, who studied hundreds of *nuées ardentes* at close quarters after the eruption of Mt Pelée in 1929, captured their visual beauty in a remarkable series of photographs, and almost ended as a victim of one. Today, however, some aspects of glowing clouds may be studied from the relative safety of an aeroplane, which is how Moore and Melson (*Bull. Volcan.* **33**, 100; 1969) observed the 1968 eruption of Mt Mayon (Philippines) and how Stith *et al.* (*Geophys. Res. Lett.* **4**, 259; 1977) approached the eruption of St Augustine Volcano (Alaska) in 1976.

One of the most conspicuous characteristics of a *nuée ardente* is, of course, its speed, which reference books usually give as "perhaps 100 kilometres an hour" or something equally vague but which Stith and his colleagues have now determined much more accurately using aerial photography. Thus the *nuée ardente* produced by St Augustine Volcano on 8 February 1976 began moving down the initial 1 : 3 slope with a speed of 180 km per hour, slowed to 75.6 km per hour down the subsequent 1 : 7 gradient, then to 46.8 km per hour (1 : 12) and finally to 21.6 km per hour (1 : 28) before entering the sea 6 km from the volcanic cone. The average speed was 54.0 km per hour, which means that the 6 km was covered in less than 6.7 minutes.

The chief reason for such astonishing speeds is the 'fluidisation' of the volcanic particles brought about by the release of gases, a process which greatly reduces the frictional resistance of the mass as it moves under gravity. The dangers are obvious. A *nuée ardente* travels not only rapidly but with very little noise. A community in its path may be overcome without ever knowing what happened. □

Peter J. Smith is a Reader in the Department of Earth Sciences at the Open University.