27 EXPEDITION RESEARCH PROJECTS IN TUNDRA AND PERIGLACIAL REGIONS

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Tundra refers to the treeless landscape beyond the tree-line in polar regions characterised by mosses, lichens and dwarf shrub vegetation. The term "tundra" is derived from a Finnish word, and was originally used to describe areas of the Arctic north of the boreal forest or "taiga", but it is now increasingly used also to describe similar areas in the Antarctic and sub-Antarctic. In addition, the alpine zone above the tree-line in mountain areas is often termed "alpine tundra" and the transition zone or ecotone with forested regions, where there are scattered trees, is called "forest tundra" (Ives and Barry, 1974).

Tundra is characterised by a periglacial environment with a non-glacial cold climate, where freezing and thawing of the ground are a dominant influence on landscape and life. There is, however, no one-to-one agreement between periglacial envi-

Figure 27.1 *Collecting meltwater from Antarctica as part of a long-term project to model climate change (© Alun Hubbard)*

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ronmental conditions and vegetation. Most tundra is underlain by permafrost (perennially frozen ground), only the surface metre or so of which (the active layer) melts during a relatively short summer season (Harris, 1986). Extensive areas of the boreal forest in Siberia and North America are also underlain by permafrost, which may be continuous, discontinuous or sporadic, depending on the severity of the periglacial climate. Permafrost develops where the loss of heat from the ground caused by winter cooling exceeds the heat absorbed during the summer months. Where conditions are not so cold, non-permafrost periglacial environments are characterised by seasonally frozen ground. This occurs, for example, south of the permafrost limit in the Arctic. The most severe periglacial climates give rise to polar deserts, which are characterised by a much sparser and simpler vegetation than the tundra (Alexandrova, 1988).

Today, some 20 per cent of the land area of the Earth is periglacial (i.e. has a cold climate but is not necessarily adjacent to an ice sheet or glacier) and about twice this area was affected beyond the limits of the glaciers and ice sheets at the maximum of the last glaciation (French, 1996). Such regions include much of Canada, Alaska, the fringes of the Antarctic (Hansom and Gordon, 1998), and numerous islands at high latitudes in both the Northern and Southern Hemispheres. Research projects might involve aspects of the present natural landscape (possibly involving landforms and geomorphic processes, geology, microclimate, soils, plant communities, animal ecology, contemporary environmental change and human impact), or palaeoenvironmental reconstruction (the reconstruction of past conditions from sedimentary sequences or other "natural archives").

GEOMORPHOLOGICAL ASPECTS

A wide range of distinctive periglacial landforms could be investigated. These are described by French and Slaymaker (1993) and Ballantyne and Harris (1994). Some forms are rather spectacular, such as rock glaciers and pingoes, the latter being conical-shaped hills up to 50 m high which grow as a result of high water pressures in partly frozen ground. These should be distinguished from other types of frost mound, such as palsas: peat-covered mounds up to about 5 m high in areas of discontinuous permafrost, which form as a result of the growth of ice lenses as water freezes. A wide variety of sorted and non-sorted patterned ground phenomena (which result from frost processes in the active layer) may provide a larger sample size for investigation. Expedition research could focus on specific types, such as earth hummocks (thufur), sorted circles, solifluction lobes or stone stripes. Alternatively, the whole assemblage of forms could be investigated in an area, paying particular attention to their position in the landscape and/or altitudinal zones. Such forms could be mapped, measured by cross-profiles, excavated to study their internal structure, sampled with particular reference to sediment characteristics and related to site conditions. If there is the possibility of a return visit, there would also be considerable potential for monitoring movement and associated environmental conditions, which would shed further light on their origin and development, e.g. the re-survey of peg lines or the position of surface stones and the re-excavation of buried markers or flexible tubes are common approaches to monitoring mass movement on periglacial slopes.

Surprisingly little is known about most periglacial processes and their effects. Several areas of controversy are discussed in the reviews in Clark (1988). The effectiveness of both physical weathering (frost shattering) and chemical weathering under periglacial conditions provides a good example. Whether or not such processes are enhanced beneath snow patches has not been resolved and observations on where frost shattering is important or on the nature and rate of chemical weathering could make a major contribution to knowledge. Field observations and measurements should, where possible, be followed up by relevant laboratory analyses of samples collected in the field (e.g. Goudie, 1990; Gale and Hoare, 1991).

Fluvial processes are another neglected area of periglacial geomorphology. Although expeditions will rarely be in the field for the whole melt season, even a short period of monitoring can detect interesting patterns in stream discharge and sediment yield. Fluvio-periglacial landforms may possess distinctive characteristics (see, for example, McEwan and Matthews, 1998). The effects of lake and sea ice, wind action and thermokarst development (from the melting of ground ice) are other possible topics for investigation.

PALAEOENVIRONMENTAL RECONSTRUCTION

The reconstruction of past environments can add an interesting dimension to scientific research. Lowe and Walker (1997) and Roberts (1998) should be consulted for good introductions to the major geological and climatic changes of, respectively, the late Quaternary (about the last 100,000 years) and the Holocene (the last 11,500 years). Cold, frozen or waterlogged conditions, all common in tundra and periglacial regions, are particularly conducive to the preservation of evidence for palaeoenvironmental reconstruction. There are, however, possible disadvantages in the slow rates of organic production and the high potential for the disturbances of sedimentary sequences. Nevertheless, plant remains in the form of macrofossils (tree trunks, wood fragments, leaves and seeds) and microfossils (pollen) may be found in boggy areas, lakes and soils. Animal fossils, such as the bones of vertebrates, mollusc shells and insect remains, may similarly provide vital evidence. If good sections cannot be found, sedimentary sequences may be revealed by excavation or coring. Whereas excavation with spades may be possible for some drier terrestrial sites, the use of specialist coring devices is usually necessary for bogs (mires) and lake sediments, the latter also requiring rubber boats or rafts. Tree boring for dendrochronological investigations is also possible in the forest tundra zone. Many techniques are described by Berglund (1986).

BIOLOGICAL ASPECTS

One advantage to carrying out research in tundra and periglacial environments is the relative simplicity of the ecosystems. There are fewer species of plants and animals than in temperate and tropical regions. Identification of species, many of which are circumpolar in distribution, is relatively straightforward. However, it is worth considering a project on one of the lower plant groups, such as mosses and lichens, which are often neglected but which comprise the most important component of many tundra plant communities. The types of vegetation and their ecology in different parts of the world are described in some detail in the work of Walter and Breckle (1986) and Wielgolaski (1997). The range of ecological research themes that might be attempted is exemplified by the individual chapters in Sonesson (1987) and Woodin and Marquiss (1997).

There are strong environmental controls on plant distribution in both polar and alpine tundra (Körner, 1999), and the effects of environmental gradients are often clearly visible in the vegetation landscape at both large and small scales (Dahl, 1986), e.g. a distinct zonation of plant species and communities occurs around late-lying snow patches, which reflects the length of the snow-free season and other factors. There is plenty of scope in the tundra for mapping plant communities, relating their distribution to site conditions, or carrying out detailed measurements of productivity and environmental controls, such as heat, moisture, nutrients, light and wind.

Studies on the population ecology of individual species can yield important new data. Diverse adaptations to periglacial environments are reflected in plant morphology, dynamics and physiology. Different adaptations and/or slightly different environmental requirements may permit the coexistence of species within the same community. Various modes of vegetative reproduction (e.g. vivipary, bulbils and layering) are well developed in tundra species, although sexual reproduction by seed is more important in the High Arctic, on glacier forelands and in early successional stages at more favourable sites.

There is also plenty of scope for studies of the ecology of small mammals, birds and invertebrates. Some larger mammals are, of course, dangerous; others, however, such as beaver and reindeer, can be safely investigated. Remmert (1980) and Stonehouse (1989) give introductory accounts of Arctic animal ecology, and several chapters in Bliss et al. (1981) give useful insights into more specialised studies of particular groups.

SOILS

Soils of the tundra and cold regions generally have not been as intensively studied as those of temperate and tropical regions because of their limited agricultural potential. Low temperatures, deep freezing and the existence of permafrost produce unique soil properties and distinctive soil profiles. An introduction to soils in the Arctic is provided by Fitzpatrick (1997) and an introduction to the soils in a Norwegian mountain tundra area by Ellis (1980).

Figure 27.2 *A periglacial slope in the Norwegian Alpine zone (© John Matthews)*

INTERACTIONS IN THE LANDSCAPE

The integrated study of whole ecosystems (e.g. Bliss et al., 1981) or whole landscapes (e.g. Oechel, 1989) is probably beyond the scope of most expeditions. However, the idea of investigating interactions between, for example, plants and animals, plants and soils, or plants and geomorphic processes, has much to recommend it. Investigations of the last mentioned type could be described as studies in landscape ecology, geoecology or biogeomorphology. An example is provided by the interaction of vegetation and frost disturbances of various sorts (Komárková and Weilgolaski, 1999). Many more interactions and disturbances are described in the context of recently deglaciated terrain by Matthews (1992, 1999).

HUMAN ACTIVITY AND IMPACTS OF GLOBAL WARMING

Last, but not least, human activity in tundra and periglacial regions should not be ignored. Small populations have left a legacy of archaeological sites, many of which have not yet been excavated (see, for example, Jacobs and Sabo, 1979). All of the indigenous peoples of the Arctic have been greatly affected by the exploration and exploitation of Arctic resources (Sugden, 1982; Harris, 1986). Numerous sociological and economic problems have arisen for the Inuit of North America and similar groups as a result of this intrusive human impact. The unique engineering difficulties and conservation issues arising from the mining, oil and gas industries, road construction, water supply and waste disposal could, in turn, be investigated (e.g. Williams, 1979). Even the effects of expeditions have been the subject of serious study (Gellatly et al., 1986).

The effects of global warming could also be investigated because most climatic models predict that high latitudes will be most affected by the continuing increase in the concentration of greenhouse gases in the atmosphere. Continuing global warming is likely to affect both the geomorphology (e.g. Koster, 1994) and the vegetation (e.g. Chapin et al, 1992).

CONCLUSION

In conclusion, there are varied and important opportunities for scientific research in tundra and periglacial regions. Included are some of the most remote and inhospitable places on Earth. Although expedition research in these environments is often uncomfortable and sometimes dangerous, there are relatively few health hazards and there will be no shortage of excitement.

FURTHER INFORMATION

Key references

Alexandrova, V.D. (1988) *Vegetation of the Soviet Polar Deserts*. Cambridge: Cambridge University Press [Translated from Russian].

Ballantyne, C.K. and Harris, C. (1994) *The Periglaciation of Great Britain*. Cambridge: Cambridge University Press.

Bliss, L.C., Heal, O.W. and Moore, J.J. (1981) *Tundra Ecosystems: A comparative analysis*. Cambridge: Cambridge University Press.

Chapin III, F.S., Jefferies, R.L., Reynolds, J.F., Shaver, G.R. and Svoboda, J. (eds) (1992) *Arctic Ecosystems in a Changing Climate: An ecophysiological perspective*. San Diego: Academic Press.

Clark, M.J. (ed.) (1988) *Advances in Periglacial Geomorphology*. Chichester: Wiley.

Dahl, E. (1986) Zonation of Arctic and alpine tundra and fellfield ecobiomes. In: Polunin, N. (ed.), *Ecosystem Theory and Application*. Chichester: Wiley, pp. 35–62.

Ellis, S. (1980) Soil-environmental relationships in the Okstindan Mountains, north Norway. *Norsk Geografisk Tidsskrift* **34**: 167–76.

Fitzpatrick, E.A. (1997) Arctic soils and permafrost. In: Woodin, S.J. and Marquiss, M. (eds), *Ecology of Arctic Environments*. Oxford: Blackwell Science, pp. 1–39.

French, H.M (1996) *The Periglacial Environment*, 2nd edn. London: Longman.

French, H.M. and Slaymaker, O. (eds) (1993) *Canada's Cold Environments*. Montreal: McGill Queen's University Press.

Gellatly, A.F., Whalley, W.B., Gordon, J.E. and Ferguson, R.I. (1986) An observation on trampling effects in North Norway: thresholds for damage. *Norsk Geografisk Tidsskrift* **40**: 163–8.

Hansom, J.D. and Gordon, J.E. (1998) *Antarctic Environmental Resources: A geographical perspective*. Harlow: Longman.

Harris, S.A. (1986) *The Permafrost Environment*. London: Croom Helm.

Ives, J.D. and Barry, R.G (eds) (1974) *Arctic and Alpine Environments*. London: Methuen.

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Jacobs, J.D. and Sabo III, G. (1978) Environments and adaptations of the Thule culture on the Davis Strait coast of Baffin Island. *Arctic and Alpine Research* **10**: 595–615.
Komárková, V. and Wielgolaski, F.E. (1999) Stress and disturbance in cold region ecosystems. In: Walker, L.R. (ed.), *Ecosystems of Disturbed Ground*. Amsterdam: Elsevier, pp. 39–122.
Körner, C. (1999) *Alpine Plant Life*. Berlin: Springer.
Koster, E.A. (1994) *Global Warming and Periglacial Landscapes*. In: Roberts, N. (ed.), *The Changing Global Environment*. Oxford: Blackwell Science, pp. 127–47.
McEwen, L.J. and Matthews, J.A. (1998) Channel form, bed material and sediment sources in the Sprangdøla, southern Norway: evidence for a distinct periglacio-fluvial system. *Geografiska Annaler* **80**(A): 17–36.
Matthews, J.A. (1992) *The Ecology of Recently-deglaciated Terrain: A geoecological approach to glacier forelands and primary succession*. Cambridge: Cambridge University Press.
Matthews, J.A. (1999) Disturbance regimes and ecosystem response on recently-deglaciated terrain. In: Walker, L.R. (ed.), *Ecosystems of Disturbed Ground*. Amsterdam: Elsevier, pp. 17–37.
Oechel, W.C. (ed.) (1989) Ecology of an arctic watershed: landscape processes and linkages. *Holarctic Ecology* **12**(3): 227–334.
Remmert, H. (1980) *Arctic Animal Ecology*. Berlin: Springer-Verlag.
Roberts, N. (1998) *The Holocene: An environmental history*, 2nd edn. Oxford: Basil Blackwell.
Stonehouse, B. (1989) *Polar Ecology*. Glasgow: Blackie.
Sugden, D. (1982) *Arctic and Antarctic: A modern geographical synthesis*. Oxford: Basil Blackwell.
Walter, H. and Breckle, S.W. (1986) *Ecological Systems of the Geobiosphere* 3. *Temperate and polar zonobiomes of northern Eurasia*. Berlin: Springer-Verlag.
Wielgolaski, F.E. (ed.) (1997) *Polar and Alpine Tundra*. Amsterdam: Elsevier.
Williams, P.J. (1979) *Pipelines and Permafrost: Physical geography and development in the circumpolar north*. London: Longman.
Woodin, S.J. and Marquiss, M. (eds) (1997) *Ecology of Arctic Environments*. Oxford: Blackwell Science.

References for key techniques and methodology

Berglund, B.E. (1986) *Handbook of Holocene Palaeoecology and Palaeohydrology*. Chichester: Wiley.
Gale, S.J. and Hoare, P.G. (1991) *Quaternary Sediments: Petrographic methods for the study of unlithified rocks*. New York: Halsted Press.
Gardiner, V. and Dackombe, R. (1983) *Geomorphological Field Manual* London: George Allen & Unwin.
Goudie, A. (1990) *Geomorphological Techniques*, 2nd edn. London: Unwin Hyman.
Kent, M. and Coker, P.D. (1992) *Vegetation Description and Analysis: A practical approach*. New York: Wiley.
Lowe, J.J. and Walker, M.J.C. (1997) *Reconstructing Quaternary Environments*, 2nd edn. Harlow: Longman.
Moore, P.D. and Chapman, S.B. (eds) (1986) *Methods in Plant Ecology*, 2nd edition. Oxford: Blackwell Science.
Sonesson, M. (ed.)(1987) *Research in Arctic Life and Earth Sciences: Present knowledge and future perspectives*. Copenhagen: Munksgaard (Ecological Bulletins, No. 38).

Key scientific journals

Arctic
Arctic, Antarctic and Alpine Research
Boreas
Ecography (formerly *Holarctic Ecology*)
The Holocene
Permafrost and Periglacial Processes

Polar and Glaciological Abstracts
Polar Record
Polar Research

Key organisation

Scott Polar Research Institute. Website: www.spri.cam.ac.uk
This organisation has several research groups investigating a range of issues in both the environmental sciences and social sciences in the Arctic and Antarctica:

- Glaciology and Climate Change Group
- Glacimarine Environments Group
- Polar Landscape and Remote Sensing Group
- Polar Social Science and Humanities Group
- NERC Centre for Polar Observation and Modelling Group