THE CAIRNGORMS AS A PROPOSED SITE FOR THE EVALUATION OF BIOSENSING EQUIPMENT AND ASTROBIOLOGICAL INSTRUMENTATION. S .J. M. Phillips[1], J. Parnell[1], [1]Dept. of Geology & Petroleum Geology, University of Aberdeen, Aberdeen AB24 3UE, U.K., (s.j.phillips@abdn.ac.uk).

Cairngorms as a Unique Extreme Environment: The Cairngorms is a sub-arctic site with a mixture of continental and oceanic climates. The area hosts a wide diversity of habitats, from native woodlands and open moorland through scrub and sub-arctic habitats [1].

The Cairngorms provides a good initial evaluation site for biosensing equipment and astrobiological instrumentation due to the variety and extremes of weather, ecology and terrain that can be easily accessed within a 3800 sq km area.

Location and Zonation of the Cairngorms: The Cairngorms are located in the east central Highlands of Scotland (Fig.1).

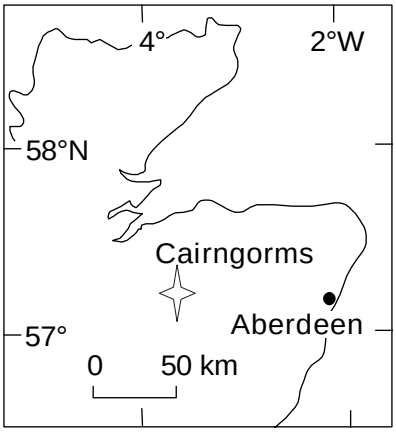

Fig. 1. Map of the Cairngorms, NE Scotland.

The area can be broadly divided into 3 distinct zones; the mountain and plateau zone, the forest and moorland zone and the valley zone [1].

Physical Geography and Ecology: The physical geography is dominated by vast high plateaus and deep incising glens. The area hosts four of Scotland's five highest mountains and fifty-two summits are over 900 m. There is a vast area of land over 600 m, which is classified as the montane zone and is the largest area of arctic mountain landscape in the UK [1].

Vegetation in the Cairngorms can be subdivided into two distinct zones, based on altitude. The lowland zone consists of heaths and moors with human influence in the form of agriculture. The highland zone consists of heather, lichen, scrub and alpine plants.

Surface Terrain: The nature of the surface provides numerous settings and situations to test rovers and automatic robotic instruments that need to move across difficult terrain and negotiate obstacles. The flanks of the high plateau of Ben Macdui are exposed and consist of large angular to sub angular boulders over 1 m in diameter which provide a potential test site for rovers. In the lower glens, bogs and marches exist, providing a challenging environment for the testing of equipment that needs to be stable in rapidly changing surface conditions.

Climate of the Cairngorms: Weather conditions can vary dramatically with the seasons and altitude, with major changes occurring within a time scale of 2-3 hours. This provides a range of media that can be used to validate, develop and improve sampling techniques.

Rainfall over the Cairngorms region is spatially and volumetrically variable. Over 2250 mm/yr of rain falls on the summits to less than 900 mm/yr in Spey and Dee Valleys [1]. This could be sampled to assess the detection range and limits of equipment for measuring soluble organic compounds.

Temperature variations are pronounced, due to the landlocked nature of the Cairngorms, than a coastal region, with higher altitudes experiencing maritime temperatures and lower altitudes experiencing more continental regimes. At lower altitudes, in the valleys, the temperatures from December through to February range from -5ºC to 7ºC. During the summer months of June through to August the temperatures can range between 9 and 27ºC [1]. The remaining months can be anywhere between these extremes. Temperatures lower than -27ºC have been recorded in Grantown, due to temperature inversions resulting in cold air pockets producing extreme, low temperatures. At higher altitudes, on the summit plateaus, the temperature can vary to a greater degree due to the altitude, with diurnal and annual variations being larger. A temperature gradient drop of 2.2ºC/300 m from the summit of Ben Macdui to Braemar between April and June has been recorded as a result of the chilling effect of lying snow and no prevailing winds resulting in air frosts [1]. The range of temperatures are useful when testing if equipment and can operate in extremes of temperature. The durability and fatigue of materials can also be tested in these extremes.

Wind speed and direction varies throughout the area, the dominant prevailing wind is from the south-west, ranging between 177-275 km/hr on the summit plateaus [1]. This high speed could be used as an excellent way to test the aerodynamics of biosensing equipment or to test the stability and maneuverability of rovers.

Snow can fall year round, with snow lying for 90 days/yr at the top of Coire Cas chairlift to over 50 days/yr at Achnagoichan, with the summits receiving over 100 days/yr of snowfall. Snow cover remains for approximately 60 days/yr on low ground and 200 days/yr on higher summits [1]. Snow cover, depth and water equivalents have been measured in the in the Allt a' Mharcaidh catchment in the western Cairngorms [2]. The peak measured water equivalent held in the catchment snow pack ranged from around 50 mm in mild winters to 200 mm in more severe ones. Deepest accumulations occurred on north and east facing slopes above 700 m [2]. This large, reliable yearly accumulation of snow can used as an analogue environment for the testing of biosensing equipment in terms of operation and as a media to sample and analyse. The largest accumulations of snow occur in sheltered, shallow corries with depths of up to 20-30 m on the north-east aspect of Ben Macdui. In Garbh Choire Mor, Braeriach, the snow lies all year round and is the only perennial cover in the UK, with all other snowfall being semi-permanent. Avalanches on the Great Slab of Coire an Lochain occur frequently [1]. This would be a good test area to assess how well equipment would remain intact and operational during a high impact event and if the instrument would continue transmit data.

An alpine snow melt regime exists during the spring, producing large flooding events. Chemical compounds, metals and organics concentrated in the lying snow change the water chemistry of the catchment. Preferential elution of Cl and SO4 have been recorded and observed to be characteristic of each melt season. The most acidic stream flows were observed during peak snow melt (pH < 5.5) with the highest levels of inorganic aluminum being recorded [2], which would allow the testing of sensor sensitivity.

Air Quality: Studies on the summit of Cairngorm reveal that pollution influences the chemistry of the precipitation. Salt concentrations in rime ice measured over a four year period indicated increased entrapment of pollutants, or a more polluted air mass, when it prevailed from a southerly or easterly direction [3]. Frequent, heavily contaminated "black" snow falls, occurring over the Cairngorms, from large source regions, have been recorded and analysed. Black carbon has been detected, possibly originating from Eastern Europe, Russia and Baltic regions [4]. The effect of the polluted air mass therefore affects the nature of the water in the catchment with the entrapped pollutants in the snow entering into burns and lochs [5]. This should be considered when testing biosensing equipment.

Organic Compounds in Ice and Snow: Analysis of ice and snow samples from the Cairngorms provides information on the surface chemistry. Organic compounds extracted from snow, ice and trapped particulates using solvent extraction and subsequent GC-MS analysis reveal the extent of biological material contained within the snow. Analysis of the melt water, shown in Fig. 2, illustrates the limited range of soluble compounds, with the particulate matter containing larger amounts non-soluble organic compounds. From a biosensing perspective this indicates that large volumes of melt water would need to be collected and concentrated in order to detect the higher end organic compounds that are difficult to detect or are only found in small concentrations in melt water.

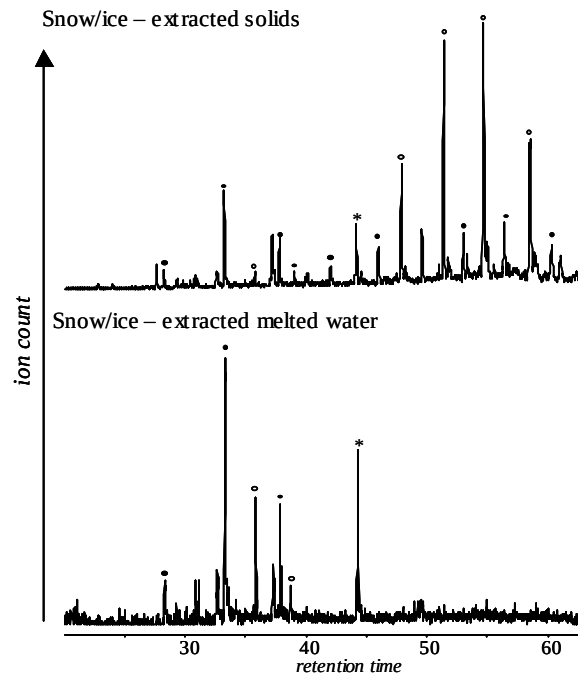

Fig. 2. GC-MS trace showing distribution of fatty acids (●) and alcohols (○) in extracts of melted snow and particulate matter.

The varied nature of the Cairngorms makes a good test area for biosensing equipment. The wide variety of media to sample, snow, melt water and rain allows for the development and innovation of sampling techniques. The extremes of temperature, wind and terrain allow for the testing of operational limits of astrobiological tools and the development of more sophisticated analytical tools.

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