Paleomagnetic laboratory, University of Iceland

Historical (to 1968; see L. Kristjansson: Terra Nova 5, 6-12, 1993).

The potential of the paleomagnetic method for geological research in Iceland was first demonstrated in the early 1950's by the work of Jan Hospers, a Dutch Ph.D. student in Cambridge, U.K. His research was followed up by prof. Trausti Einarsson of the University of Iceland, working with Thorbjörn Sigurgeirsson who was at the time Director of the National Research Council. Sigurgeirsson who became professor at the University in 1958, designed equipment for making accurate remanence measurements on hand samples. With this equipment and an alternating field (AF) demagnetizer, pioneering research on the paleomagnetism of the lava pile in Iceland was done in the late 1950's. Among its notable early results were the demonstration of the suitability of the AF method to remove viscous magnetization from basalts, and the discovery of intermediate directions at boundaries between polarity zones in the lava pile. In 1964, Sigurgeirsson installed an astatic magnetometer and improved AF-demagnetizer. These were used e.g. for some measurements on core samples from a large U.K.-Icelandic expedition in 1964-65.

In 1957, Sigurgeirsson set up a geomagnetic observatory at Leirvogur near Reykjavik which has been in continuous operation since then.

Left: A typical sampling locality for paleomagnetic studies in the older parts of Iceland. Mt. Tradarhyrna above Bolungavik village, NW-Iceland, with approx. 50 lava flows of 15 Ma age (Geophys. J. Int. 155, 2003)
Right: Skalamaelifell, one of several hills in the Reykjanes peninsula of SW-Iceland where transitional remanence directions presumably from the 40-ka Laschamp reversal occur.

Developments 1968-80.

Leo Kristjansson was employed in paleomagnetic research and magnetic surveys at the University of Iceland in 1968-69 and from 1971. An extensive paleomagnetic research effort on Icelandic rocks (totalling some 2400 lava flows in several regional surveys) was begun in 1972 by N.D. Watkins of the University of Rhode Island in collaboration with I. McDougall of the Australian National University, L. Kristjansson, and other Icelandic scientists. Watkins also collaborated with G.P.L. Walker of Imperial College on completing other projects in East Iceland. Most of the measurements were made at the U.R.I. through 1978, but after the untimely death of Dr. Watkins from cancer in 1977, the paleomagnetic measurements from the major surveys were concluded, processed and written up by L. Kristjansson with the other collaborators. A Foster spinner magnetometer, presented to the University by Dr. Watkins in 1975, was in service for a few years.

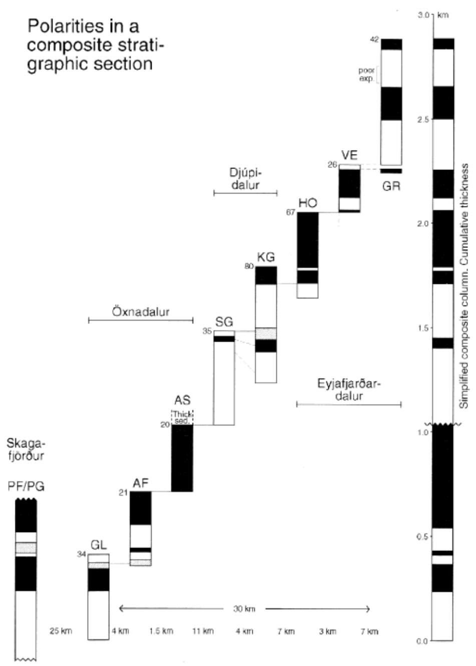
Using a proton magnetometer and other instruments designed by himself, Sigurgeirsson carried out an aeromagnetic survey over most of Iceland at 3 km spacing in

1968-80. Kristjansson surveyed parts of the insular shelf by ship in 1972-75. Magnetic anomalies observed may reach 2000 nT or more in amplitude. Various rock types in Iceland were sampled and measured in order to aid in the interpretation of the surveys; the average remanence intensity in Neogene basalt lavas is around 4 A/m but values up to an order of magnitude greater occur sporadically, e.g. in pillows in the younger formations.

<u>Developments 1980-2005</u>.

In order to maximize the scientific return on the available resources, research at the University of Iceland paleomagnetic laboratory has concentrated on simple measurements of remanence directions in a large number of basalt lava flows. Mostly, these efforts have had direct connections to stratigraphic mapping of various parts of the 0- 15 Ma lava pile. Only a few minor studies have been made on e.g. sediments, intrusives, or altered rocks.

Thermal demagnetizations, microscope work, paleointensity measurements, and rock-magnetism projects including susceptibility anisotropy have not been carried out here to any significant extent. Such studies tend to be time-consuming and require expensive equipment; the results are often ambiguous and of limited relevance to specific geological or geomagnetic problems.



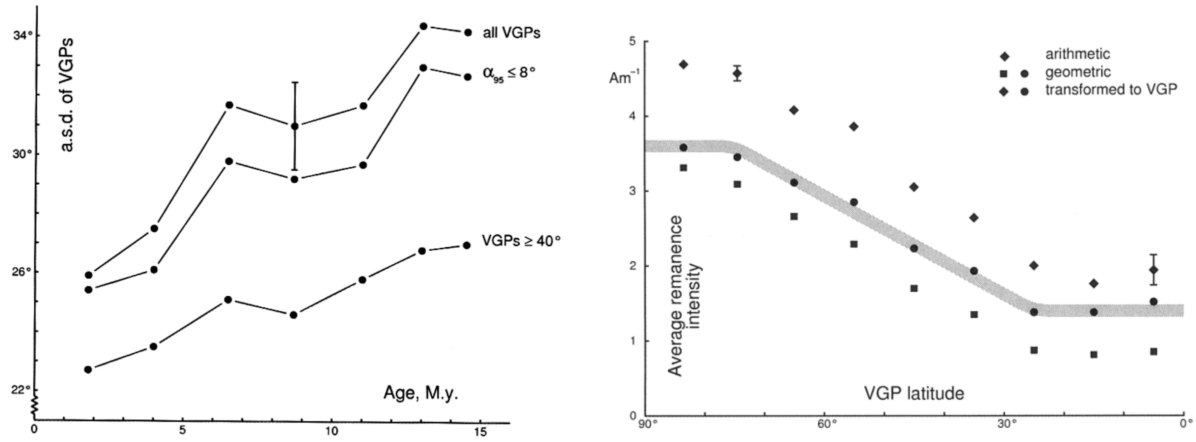
Left: A stratigraphic section of 2.9 km thickness in Eyjafjördur, N- Iceland. It is estimated to cover the time interval 9-5 Ma ago. 320 lavas were measured. (Int. J. Earth Sci. 93, 2004)
Right: L. Kristjansson collecting samples in Talknafjördur fjord, NW-Iceland 2005.

In 1978 the University acquired an "Institut Dr. Förster" static four-probe fluxgate magnetometer which has been in constant use since then. In this instrument the x,y, and z components of the dipole moment of a 1" rock specimen are each measured in eight positions, and the results averaged. It is very convenient in use, and comparisons with results from other magnetometers abroad have given excellent agreement. A "Molspin" AF tumbler demagnetizer was obtained in 1989, replacing older equipment constructed at the Science Institute.

Due to the high stability of the primary directions in the lavas (after removal of viscous remanence, usually complete by 10 mT treatment), collecting four samples from each lava flow and demagnetizing at 3-5 steps has been found to be quite adequate to obtain excellent within-site agreement (average directions with a 95% confidence radius of 5° or less in recent years). Low-field susceptibility data and thermomagnetic curves (obtained with a "Bartington" MS2W furnace meter which the University acquired in the early 1990's) and ARM observations (using an attachment provided with the Molspin demagnetizer) have aided in interpreting some of the remanence measurements.

Emphasis has been on obtaining results from lava flows with minimal alteration (< 100°C secondary heating) and small tectonic tilts (< 6° or so). Most summers since 1979, of the order of 100 or more lava flows have been sampled by L. Kristjansson. Lavas of > 2 Ma age have mostly been targeted, as in younger rocks stratigraphic complications occur due to glaciations and rapid erosion. However, some studies have involved younger lava flows, e.g. on the "Skalamaelifell geomagnetic excursion" in SW-Iceland estimated to have occurred about 40 ka ago. Part of a study on Quaternary lavas around Skaftafell, SE-Iceland carried out by J. Helgason, also used the laboratory's facilities.

As a by-product of these stratigraphic surveys, a large body of high-quality paleomagnetic direction and intensity data from Iceland is available, in fact mostly published in detail. These data are in many ways unique, as there are no other regions in the world where a comparable number of relatively fresh lava flows covering a complete 15-Ma interval are easily accessible. They have been used for statistical studies of some overall properties of paleomagnetic field in Iceland. It should be kept in mind that such studies have limitations due firstly to the time elapsing between successive lava flows in the pile (which is highly variable but averaging 5-10 ka), and secondly to the rather small number of radiometric age determinations so far carried out on Icelandic rocks. Nevertheless, the analysis of these data has led to interesting results. Among these is the observation of a significant reduction in the scatter of paleomagnetic poles taking place since 15 Ma ago, and an estimate of the variation of the mean geomagnetic dipole moment as the virtual pole moves away from the geographic pole. See the following diagrams.



Left: Angular standard deviation of grouped virtual geomagnetic poles in Icelandic lava flows. 5025 flows with a stable reliably determined remanence direction are included in the top graph. Different rejection criteria are applied in the lower ones. Right: The central set of points (joined by a smooth curve) indicate the variation of the relative Earth's magnetic dipole moment with the latitude (north or south) of the virtual geomagnetic pole. The diagram was derived from remanence intensities in 4970 Icelandic lava flows. Typical standard errors are shown. Both the diagrams are from a review by L. Kristjansson in Jökull 58, 2008.

In addition to the instruments already mentioned, the paleomagnetic laboratory has three portable fluxgate magnetometers, two gasoline-powered 1” diamond core drills, and various other minor equipment. The only permanent staff member is L. Kristjansson; assistance with computer work etc. is provided by G. Jonsson (part-time, since 1987), and students are employed occasionally in field work and routine measurements. The laboratory has not been involved in any graduate student theses. Through the years, rock samples and paleomagnetic data have been supplied on request to several parties abroad; advice and logistic assistance has also been provided to numerous expeditions.

In continuation of the magnetic surveys mentioned above, aeromagnetic measurements over parts of the shelf were carried out by the laboratory in 1985-86 and 1990-92. A detailed survey of the Reykjavik area, made in 1993, has also been published. No surveys have been made subsequently, but the data from the older ones have been digitized and interpreted. The laboratory owns two proton magnetometers which are used for teaching purposes and as backup for instruments at the University’s observatory.

Recent and current projects; opportunities

A major recently completed project concerns the Arnarfjördur-Breidafjördur area of NW-Iceland where 360 lavas of 12-13 Ma age were sampled for paleomagnetic measurements in 2004-08. A paper on this project is in press in the journal Jökull. Projects currently in progress include detailed studies on lavas of the 40 ka Skalamaelifell excursion, and on some reversals of 1-2 Ma age in South Iceland. The laboratory has in the last few years participated in investigations initiated by the University of Aarhus in Denmark, comparing magnetic minerals in Icelandic rocks with those analysed by Mars landers.

In the last decade or so, only a handful of foreign expeditions have visited Iceland to collect samples for paleomagnetic or rock magnetic studies. However, many opportunities exist for interesting and significant projects in both fields. This applies e.g. to stratigraphic mapping and correlation, analysis of long-term properties of the secular variation, radiometric dating of geomagnetic polarity transitions and major excursions, within-unit variations of magnetic properties, magnetic anomaly modelling, and effects of hydrothermal alteration.

(Revision Oct. 2009, L.Kr.)