**Arbeitskreis "Geowissenschaftliche Islandforschung"**

# Workshop on Geoscience of Iceland in Braunschweig

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An interdisciplinary group of about 20 researchers met in Braunschweig (Inst. f. Geodäsie u. Photogrammetrie) for a two days workshop (Feb 5 – 6, 2004) to discuss about current research on Iceland in the fields of geophysics, geodesy and geochemistry. The aim was to exchange experience and results from the German Research Programme "Hotspot – Ridge Interaction: Crust formation and Plate Divergence in and around Iceland" (DFG-Bündel), as well as other results from scientific research related to the Iceland plume. The projects of the DFG-Bündel are in a productive stage, some projects are in the second stage, some research groups are in the stage of application for continuation. In a relaxed atmosphere, plenty of time was provided for discussion and interaction between scientists involved in different disciplines. Here an attempt is made to summarize the main points emerged from the numerous presentations and discussions.

An overview about the driving forces was given by the first presentations on the *Iceland plume in a surrounding of an active ridge*. In the first talk of the day GABRIELE MARQUART[1] presented flow models of the Iceland plume based on seismic tomography and a fit to geoid data. While in the south a SW oriented flow field parallel to the Reykjanes ridge was obtained, the flow field in the north is dominated by a ridge perpendicular component. A comparison with seismic anisotropy data shows that in some regions the seismological fast axis is subparallel to the flow direction, but in other regions not. This is not surprising as there does not exist a unique relation between anisotropy and flow particularly in plume head regions. PETER MIHALFFY[2] presented an approach of the 3D flow field that models the plume-ridge interaction in the North Atlantic using kinematic boundary conditions of the surface motion in the Muller et al. reference frame and at the sides given by a large-scale mantle flow model based on global tomography. A backward computation gives the initial plume position at the starting time of the model at 60 Ma ago, when the plume is still situated under the Greenland shield and while the spreading begins at 56 Ma in the North Atlantic. This model predicts a hotspot position at 33 Ma near the Jan Mayan fracture zone, which raised some controversial discussions.

In the first presentation of the section *the Icelandic crust and melting processes due to the Iceland plume*, DANIELA KÜHN[3] presented models on dyke – dyke interaction during dyke ascent. She pointed out that dyke propagation beneath a spreading ridge depends both on the external stress field and the stress field produced by previously ascended dykes. The models show that a sheeted dyke complex will be the result of propagating neighbouring dykes under the constraints of an external extensive stress field. Without extension, several dykes will accumulate near to each other following their ascent through the crust and probably result in the formation of a magma chamber.

WOLFGANG R. JACOBY[4] and T. FEDOROVA[4] developed a new crustal model for Iceland and its surroundings based on seismic reflection and refraction profiles in and around Iceland. To interpolate Moho-depths at regions not sampled by seismic profiles, gravity was inverted using additional constraints given by topography, age of the lithosphere and sediment distribution. A new map of the Mohorovičić discontinuity was presented, showing for example a continuous region of thickened crust between East Iceland and the Jan Mayen block. Jacoby proposed the hypothesis that this segment may represent a continental fragment.

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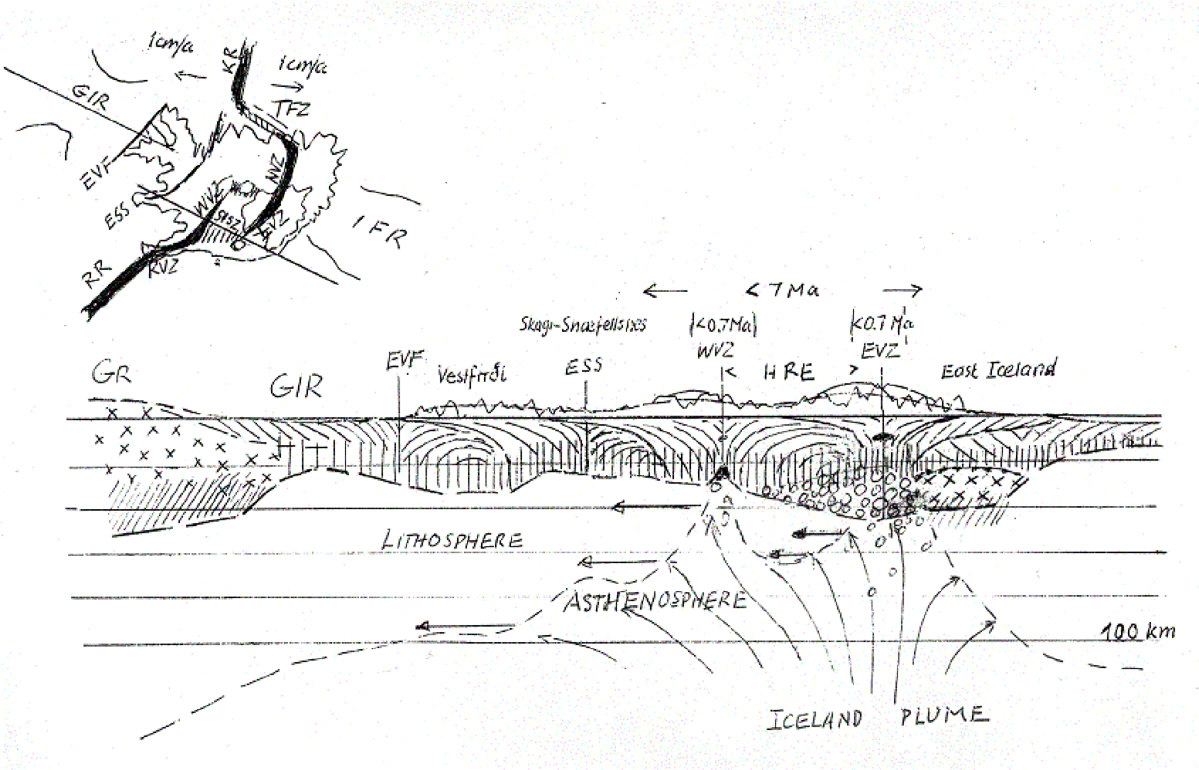


Fig. 1. Jacoby's sketch of the Icelandic crust formed as a consequence of successive ridge jumps. Note the continental fragment beneath East Iceland.

equations of mass, momentum and energy conservation have been solved by Harro Schmeling[2] and Gabriele Marquart[1] to model crustal accretion above the Iceland Plume. If melted material is extracted out of the mantle and forced back into the model at the top as extrusive layers, these layers move to the sides and dip towards the ridge depending of the increasing distance of the accretion zone (c.f. Palmason's kinematic model of dipping tertiary basalt layers). Alternatively, a model was shown in which crustal accretion is accomplished by deep, intermediate or shallow magma emplacement. If accumulation is concentrated in deep dykes, the model yields a strong layering of the resulting crust. Intermediate magma chambers generate a mixed crust. If the material is forced to accumulate in shallow dykes, the resulting crust shows a downward thickening with increasing distance of the accretion zone. The comparison with seismic data indicates a preference of deep or intermediate crustal accretion modes.

The third section on *electro-magnetic processes due to the Iceland plume* started with the presentation of Andreas Junge[2] and Anja Kreutzmann[2] about the electrical conductivity within the Icelandic crust. The frequency dependence of the electromagnetic transfer function allows to invert for the conductance (conductivity times thickness) of layers at different depths. The present approach has been done for layers with 10 km thickness. It can be shown that there exists a conductive layer in a depth of 0-30 km, which correlates well with the western Neovolcanic zone and is bounded to the north by the Tertiary boundary.

In his talk Steven Golden[2] presented new results from long period magnetotellurics at several stations on Iceland. A single station analysis shows a good crustal conductor in 20-30 km depth and a second good conductor in the upper mantle in 100-200 km depth, which might be due to a plume head. Although source field effects caused by the polar electrojet are a disturbing factor in these measurements, it was shown that their influence on the derived transfer functions is smaller than expected. Static shift, another disturbing factor, was addressed in a special campaign in 2003, in which several measurements were carried out in the vicinity of one selected long term field station.

To increase the measurement stability, a new lake-bottom datalogger was developed and installed, from which first results are expected in 2004.

In the section *near coastal and off-shore seismicity due to the tectonics driven by plume-ridge interaction* TORSTEN DAHM[3] gave an overview over the first results of the passive seismic off-shore OBS network south of Iceland. This pilot experiment was designed to quantify the seismic noise and the detection threshold for teleseismic earthquakes. The most powerful stations are comparable to land stations. The seafloor noise induced by water waves causes problems for the detection of seismic events. For example in the frequency domain around 0,3 Hz this noise suppresses the detection of P-waves of events with magnitudes smaller than $M_w$ 6.5. The seismic noise could be correlated with high sea waves near Great Britain. If the source of the noise would be known, array techniques might be applicable to reduce the noise level. The study is summarized in a manuscript to be submitted to BSSA

CASTEN RIEDEL presented a compilation of various kinds of tectonic data of the Tjörnes Fracture Zone. Between 1994 and 2002 about 8000 earthquakes have been observed, which have been used for 1D, 2D and 3D inversions of compressional ($v_p$) and shear wave velocity ($v_s$). The resulting local earthquake tomography shows a gradual decrease of crustal thickness from 20 km at the Húsavík-Flatey Fault (HFF) to 8 km along the Grimsey Lineament. This crust is underlain by a material characterized by velocities above 7.4 $^{km}/_{s}$, which could be very hot mantle material or MgO rich magmatic underplating. Low velocity lineaments at 12 km depth indicate the presence of magmatic intrusions along a line between Flatey and Grimsey island, where low $v_p$ is coupled with a high $v_p/v_s$ ratio, and a high crack density of dry cracks along the offshore part of the Húsavík-Flatey fault, where low $v_p$ is not coupled to an unusual $v_p/v_s$ ratio. The intrusions could form a further fissure swarm of the North Volcanic Zone of Iceland more westerly than Þeistareykir.

COLIN DEVEY[5] presented results of the chemical analysis of basalt samples, which have been collected during the Poseidon cruise at the Tjörnes Fracture Zone in 2002. The concentration of magnesium oxide and the potassium-oxide - titanium dioxide relation of the samples are distinguishing parameters to separate the samples in depleted mid ocean ridge basalts (MORB) or enriched Iceland plume material. According to these results, the northern border of plume material distribution is found at 67°12’ North in the off shore region of Tjörnes peninsula, while the Kolbeinsey ridge represents normal MORB material from of a source getting hotter towards the Tjörnes Fracture Zone.

In the section *dynamic crustal processes due to seismicity* Sandra M. RICHWALSKI[6] and FRANK ROTH[6] presented viscoelastic models of shear and Coulomb stress changes due to the seismic event series in the South Icelandic Seismic Zone for the time period 1706-2000. A general problem for such models are the initial stress distribution and yearly stress build-up due to plate motion, which strongly affect the subsequent stress field. The first results of the Coulomb stress change modelling on NS-striking vertical faults at 5 km depth indicate that most of the subsequent M6 events of an activity series of a few days lie in positive Coulomb stress areas, while often the first events of a new series of earthquakes do not.

In his talk ÁGÚST GUÐMUNDSSON pointed out that dyke injections may change the stress field in the surroundings in a way that seismic events can be triggered or suppressed. Such a mechanical interaction between volcanic and seismic zones in Iceland has been observed after dyke injections in the northern part of the Northern Volcanic Zone, when seismicity stopped along the Húsavík-Flatey-Fault (HFF) for several years. Afterwards seismic activity migrated slowly from the Kolbeinsey ridge along the HFF towards the North Iceland Volcanic Zone indicating a gradually unlocking of the HFF. He also pointed out that fault zones represent zones of mechanical weakness, and therefore strongly affect the regional stress field.

In hear talk ANKE FRIEDRICH[6] drew the attention to another region under extension, the Basin and Range in the Western US. Using GPS and paleoseismic indicators she was able to identify three

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orders of deformation: the tectonic fault system is active on the order of $10^7$ years, fault system dynamics act on a $10^4$ yr time scale, while the 3rd order deformation of earthquake strain transients has a timescale of years. Because these measurements record different processes, geodetic, geologic, and paleoseismic rates should not be expected to agree, but rather provide complementary information about active deformation mechanism.
In the section g*eometrical processes due to the tectonics driven by plume-ridge interaction* the first talk was given by JAMES PERLT[7]. Different institutions have carried out several GPS-campaigns on varying networks. The combination of these results can only be managed by creating point families, in which every point is assumed to have the same velocity. Disturbing local and short time effects must be taken out to yield a recent crustal deformation grid over the complex structures in the south of Iceland. Interpolation of the measured velocities to a regular grid is improved by introducing geological boundaries allowing for high slip rates.
SIGURJÓN JÓNSSON[8], RIKKE PEDERSEN[9], ÞÓRA ÁRNADÓTTIR[9], and FREYSTEINN SIGMUNDSSON[9] presented GPS and InSAR observations of the co-seismic and post-seismic crustal deformation due to the two June 2000 $M_w$6.5 earthquakes in South Iceland. The fault geometry and slip distribution of the two events were derived from the co-seismic deformation and Coulomb stress changes calculated. The stress changes caused by the first event indicate triggering of the second earthquake, which originated in a region of high positive Coulomb stress. The observed post-seismic deformation with a transient time of ~2 months could be modelled by post-seismic poro-elastic rebound, an interpretation that is supported by water level changes observed in numerous geothermal wells in the South Icelandic Seismic Zone. In the second part of his talk SIGURJÓN JÓNSSON presented a new initiative to establish a shared international geophysical observatory in Iceland: *Mid-Ocean Ridge Experiment on Iceland (MORE-Iceland)*. The plan is to seek international funding from Iceland, the US and Europe to install and operate (for 10 years) a network of borehole strain-meters, strong motion, broad-band and short period seismometers, continuous GPS stations, gravity and tilt meters, and gas sampling devices. Data from this monitoring network will be freely available to the scientific community. MORE-Iceland workshop is scheduled in July 2004 where scientific aims associated with this project will be formulated, possible funding bodies identified, and the proposal writing planned.
In the last presentation MICHAEL HEINERT[7] showed the impact of the June 2000 earthquakes on the time series of GPS-baselines between the permanent IGS stations REYK, HOFN and ONSA. The time series have to pass a phase-free adapted Kalman-filtering to reduce systematic outliers, level shifts introduced through sensor changes and white noise. To reduce the periodical impacts on the time series, a set of Fourier parameters was estimated using a Quasi-Newton minimisation model. Both filter techniques do not require equidistant observations. The final comparison between the filtered actual measurements and the expected long-time motion from NUVEL yields an exponential increase of their differences until the 2000 events.
The workshop was concluded by a general discussion. The German Iceland Research Group expressed their strong interest in MORE-Iceland initiative this initiative. The possibility of German funding shall be explored. It was decided that the German Group should formulate important scientific questions with respect to Hotspot-ridge interaction or other important topics, and that these questions should be forwarded to or presented at the MORE-Iceland workshop in July. Finally it was decided that the next workshop should be held January or February 2005, probably in Hamburg.

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