First DynaQlim Meeting, Copenhagen, Denmark, Feb. 4-5, 2008

Program:

Monday February 4, 2008.
12:00 – 12:45 *Lunch can be purchased in the GEUS cafeteria at your own expense*

12:45 Opening

Markku Poutanen; FGI, FI	A short introduction of participants and purpose of the DynaQlim meeting

13:00 – 15:00 and
15:30 – 17:30 : Oral presentations ***(Length of presentations max. 20-25 minutes)***

It is possible to hang posters on the wall of the meeting room.

Martin Lidberg; LM, S	Recent results based on continuous GPS observations of the GIA process in Fennoscandia from BIFROST
Hans-Georg Scherneck; OSO, S	The contemporary strain rate field of Fennoscandia derived from BIFROST GPS
Pippa Whitehouse; ENS, F	Glacial isostatic adjustment in Fennoscandia and the effect of 3-D Earth structure
Jaakko Mäkinen; FGI, FI	Fennoscandian land uplift maps 1914-2008
Martin Vermeer; TKK, FI	Conceptually understanding the horizontal component of postglacial rebound
Paolo Stocchi; UniUrb, I	Influence of glacial isostatic adjustment upon current sea level variations in the Mediterranean
Riccardo Riva; TU-Delft, NL	GIA estimates through combination of GRACE and ICESat mission data
Holger Steffen; IfE, UHannover, D	Determination of GIA using GRACE
Erik Ivins; JPL, USA	Faulting at the Initial Stages of Crustal Loading by Water Load at the Margin of an Ancient Craton: An Ongoing Experiment at the Three Gorges River Dam Project, China
Søren Gregersen; GEUS, DK	Improvements in knowledge on uplift/subsidence in time scales 10s, 100s, 1000s of years in parts of Scandinavia.
18:00 - 20	***Symposia dinner donated by the host institution GEUS, Copenhagen***

Tuesday February 5

9:30 – 12:00 Oral presentations *(Length of presentations max. 20-25 minutes)*

Volker Klemann; GFZ Potsdam, D	Our ideas and visions for DynaQlim
Auke Barnhoorn; UUtrecht, NL	Application of mantle flow laws for the determination of paleo-rheology in a garnet peridotite body of the Norwegian Caledonides
Elena Kozlovskaya; UOulu, FI	Viscosity of the lithosphere in the Fennoscandian shield: constraints from seismic studies
Bert Vermeersen; TU-Delft, NL	Space Geodetic Constraints on Thermomechanical Models of the Shallow Earth
Jojanneke van den Berg; IMAU, UUtrecht, NL	The effect of glacial isostatic adjustment on ice sheet evolution in Eurasia; a comparison of a self gravitating viscoelastic earth model and the flexural approach
Sören Haubrock; GFZ Potsdam, D	IT, Data management and outreach
D. Zozulya, O. Korsakova, V. Kolka	Heat flow and the Late Weichselian deglaciation pattern of the Kola region, NW Russia (POSTER)

12:00 – 13:00 ***Lunch can be purchased in the GEUS cafeteria at your own expense***

13:00 – 14:30 and
15:00 – 16:00 : Discussion and decision on the structure, goals, tasks and future of DynaQlim

Action item 1: Structure of DynaQlim.
Discussion:

1) Geodesy, geodynamics, ocean dynamics;
2) Post-glacial uplift, contemporary movements and gravity;
3) Dynamic ice sheets, glaciology;
4) Quaternary paleoenvironments and climate;
5) Geology and tectonics;
6) Dynamics, structure, properties and composition of the lithosphere;
7) IT, data management and outreach

Proposal: The structure is accepted

Action item 2: Steering committee of DynaQlim
Discussion:
Proposal: Election of the Steering Committee

Action item 3: Chairpersons for the sub-projects
Discussion:
Proposal: Candidates nominated

Action item 4: Members of the sub-groups
Discussion:
Proposal: By everybody's own registration; membership open. Contacts by mailing lists.

Action item 5: Funding
Discussion: Use and rules of use of the ILP 4000€/year
Further possibilities for funding, national sources
Proposal: Accept the rules for using the money

Action item 6: Goals of DynaQlim
Discussion:
Proposal:

Action item 7: Decision of future meetings
Discussion: EGU, AGU, IAG, … own symposiums
Proposal:

Action item 8: Proceedings
Discussion: A peer-reviewed book / special volume in a periodical as the outcome of Copenhagen and EGU Vienna meetings.
Proposal:

Action item 9: AOB
Discussion:
Proposal:

Participants

Name		*Affiliation*
Barnhoorn	Auke	UUtrecht, NL
Gregersen	Søren	GEUS, DK
Haubrock	Sören	GFZ Potsdam, D
Ivins	Erik	JPL, USA
Klemann	Volker	GFZ Potsdam, D
Kollo	Karin	ELB, EE
Kozlovskaya	Elena	UOulu, FI
Lidberg	Martin	LM, S
Milne	Glenn	UDurham, UK
Mäkinen	Jaakko	FGI, FI
Nordman	Maaria	FGI, FI
Poutanen	Markku	FGI, FI
Riva	Riccardo	TU-Delft, NL
Scherneck	Hans-Georg	OSO, S
Steffen	Holger	IfE, UHannover, D
Stocchi	Paolo	UniUrb, I
van den Berg	Jojanneke	IMAU, UUtrecht, NL
Vermeer	Martin	TKK, FI
Vermeersen	Bert	TU-Delft, NL
Whitehouse	Pippa	ENS, F

Application of mantle flow laws for the determination of paleo-rheology in a garnet peridotite body of the Norwegian Caledonides

Auke Barnhoorn, Martyn R. Drury and Herman L.M.van Roermund

Faculty of Geosciences, Utrecht University, PO Box 80.021, 3508 TA Utrecht, The Netherlands.

The rheological properties of upper mantle rocks play an important role in controlling the dynamics of the lithosphere, mantle convection and glacial isostatic adjustment. We use a combination of microstructural information and experimentally determined flow laws of mantle materials to constrain the early deformation conditions in an ultra-high pressure peridotite body in the Norwegian Caledonides. Here we show field evidence from the geometry of folded compositional layering that garnet-rich mantle rocks can have lower solid-state viscosities than olivine-rich mantle rocks, the contrary to what is normally expected. Application of published experimental flow laws for olivine, garnet and clinopyroxenes confirms that garnet can indeed be weaker than olivine in a restricted range of deformation conditions, and only when the relatively fine-grained garnet in the garnet-rich layer deforms by diffusion creep while the coarse-grained olivine deforms by dislocation creep. This observation implies that upper mantle flow may locally be controlled by garnet and not by olivine, e.g. in the deep cratonic lithospheres and the deeper parts of subduction zones, similar to the origin of the Norwegian ultra-high pressure rocks. This research project is part of an effort to constrain the rheology of the upper mantle, which is currently used in the modeling of glacial isostatic rebound.

Improvements in knowledge on uplift/subsidence in time scales 10s, 100s, 1000s of years in parts of Scandinavia.

Soren Gregersen, Geological Survey of Denmark and Greenland (GEUS), Denmark.

Discussions continue on uplift/subsidence in Denmark/southern Scandinavia. The patterns in time scales of 10s, 100s and 1000s of years show some similarities and some differences. Geodetic observations exist for all of Scandinavia. Those describe the phenomenon in 10s – 100s of years scale. Earthquake observations in seismology are of relevance to the same time scales. Geological studies of dated shore lines describe the postglacial earth-surface motion in a quite different time scale of 100s – 1000s of years. There is a need for integration of these observations geographically. Further observations in the various time scales are planned together with process descriptions of the observed similarities and differences in the lithosphere project of this session, DynaQlim: Upper mantle dynamics and Quaternary climate in cratonic areas.

IT, Data management and outreach

Sören Haubrock, Jens Klump, Doris Dransch

Successful multidisciplinary research relies on mutual comprehension as well as exchange of concepts and ideas across disciplinary and organizational boundaries. Internet portals are a suitable means for providing a technical platform that can be used to achieve these goals. Additional concepts need to be applied to make data, information and knowledge accessible in a structured and aggregated way, and particularly to make them understandable and usable for scientists from every single discipline involved in the research process.

We will present conceptual ideas and technical implementations based on Internet portals developed in the framework of several multidisciplinary projects in Earth Sciences. Our ideas originating from different research disciplines in Information Technology and Geomatics will be sketched and their application and usability for the DynaClim project will be discussed, so further developments can be planned with respect to the demands of the community.

Faulting at the Initial Stages of Crustal Loading by Water Load at the Margin of an Ancient Craton: An Ongoing Experiment at the Three Gorges River Dam Project, China

Erik R. Ivins[1], Volker Klemann[2], Robert E. Crippen[1]
[1] JPL/Caltech, 4800 Oak Grove Dr., Pasadena CA 91109, USA
(Erik.R.Ivins@jpl.nasa.gov, FAX: 001-818-354-4785)
[2]GeoForschungZentrum, Telegrafenberg, Potsdam, Germany

An intriguing aspect of Quaternary faulting at the site of ice sheet buildup and collapse is the emergence of increased seismicity and faulting during decrease of the overburden stresses (Wu and Hasegawa, 1996). However, all theoretical studies show that the processes of load emplacement as ice sheets grow, also move the crust closer to the fracture failure state. There is little information that can be extracted from paleo-seismological study concerning such initial faulting, however. The loading by water empoundment at the site of the filling of the Three Gorges River Dam along the Yangtze River in China may provide us with some new insight as to how this Quaternary faulting of cratons in North America, Europe and Antarctica might occur. The preliminary statistics on the seismicity rate and spatial distribution following the initial hydrological loading of the Three Gorges River Dam in China show many of the same characteristics seen in other regions where such large scale loading and porous-elastic diffusion has occurred in the past. There are many characteristics of the Three Gorges River Dam, however, that make it unique. First is its enormity, and secondly its narrow shape along a landscape having little long wavelength slope in topography. Although this region of China is relatively aseismic, the loading occurs along 1000 km of crust at the boundary of the Yangzte cratonic platform. There has been at least on earthquake of surface wave magnitude exceeding 4.0 at moderate depth in the crust (20 km). These deep quakes occur at depths exceeding the porous diffusive length scale, and hence are telling us something about brittle frictional behavior of the crust at the onset of surface loading. Here we model the Coulomb and Mogi- von Mises fracture stresses to assess the role played by the gravitational/stress caused by water empoundment.

Our ideas and visions for DynaQlim

Volker Klemann[1], Zdeněk Martinec[1,2], Maik Thomas[1], Detlef Wolf[1,3], Mikhail Kaban[1]
[1]GeoForschungsZentrum Potsdam, Potsdam, Germany
[2]Charles University in Prague, Prague, Czech Republic
[3]University of Stuttgart, Stuttgart, Germany

An overview about the solid earth modelling, GIA modelling and expertise in ocean modelling of the section ‘Earth System Modelling’ at GFZ is given. The research group focuses on the simulation of mass, momentum and energy transport processes in the Earth system manifested in global monitoring data related to the static and time-variable gravity, surface deformation, sea-level variation and Earth rotation parameters. In addition to this, we will briefly outline the research activities already related to the topics addressed by DynaQlim.

Viscosity of the lithosphere in the Fennoscandian shield: constraints from seismic studies

E. Kozlovskaya,
Sodankylä Geophysical Observatory/Oulu unit, POB 3000, FIN-90014, University of Oulu, Finland, elena.kozlovskaya@oulu.fi

One of the common targets for glacial isostatic adjustement (GIA) studies and for seismic studies of the lithosphere in the Fennoscandian shield is estimation of the lithosphere thickness. However, its estimate obtained by GIA studies is systematically lower (up to 100 km) than the thickness obtained by seismic studies. This systematic underestimating of the lithosphere thicknes may be due to simplified models of the Earth used in GIA studies, in which it is generally assumed that the top layer of the solid Earth (crust and the lithosphere) has very high viscosity and is effectively elastic, while the low viscosity is mainly confined to the underlying asthenosphere. Numerous controlled-source and passive seismic experiments in the shield and rheological studies showed that the lithosphere structure there is more complex. Particularly important are zones of decreased velocity in the upper crust, revealed by wide-angle reflection and refraction experiments and receiver function studies. In these zones fluid-filled cracks and fractures could decrease the viscosity locally by several orders of magnitude. Spatial distribution of these zones is not uniform and confined to certain types of geological formations. On the contrary, the low-viscosity asthenosphere is absent from some parts of the shield. In addition, rheological and electromagnetic studies suggest that mechanically weak, low viscosity layers can be present also in the lower crust and upper mantle of the shield. This multi-layered and heterogeneous viscosity distribution inside the lithosphere is usually not taken into consideration in GIA modelling and this can explain large differences between estimates of lithosphere thickness obtained by both methods.

Recent results based on continuous GPS observations of the GIA process in Fennoscandia from BIFROST

Martin Lidberg (1,2)

(1) Lantmäteriet (The National Land Survey), Gävle, Sweden.
(2) Chalmers University of Technology, Onsala Space Observatory, Sweden.

We present our latest 3D velocity field of the Fennoscandian Glacial Isostatic Adjustment (GIA) process derived from more than 10 years of data at more than 80 permanent GPS sites in northern Europe. We have used two different software packages for the GPS analysis (GAMIT/GLOBK and GIPSY/OASIS II respectively). The solution has an internal accuracy at the level of 0.2 mm/yr (1 sigma) for horizontal velocities at the best sites. The two latest versions of the International Terrestrial Reference Frame (ITRF2000 and ITRF2005) have been used for the reference frame realization, and differences in achieved vertical rates will be discussed. Our vertical velocities agree with results derived from classic geodetic methods (tide-gauge, repeated levelling, and repeated gravity observations) at the 0.5 mm/yr level (1 sigma). We also compare the observations to predictions derived from a GIA model tuned to fit the new data and get agreement on the sub-millimeter level.

In the presentation, the problem of stability of the geodetic reference frame will be addressed. This is crucial in a number of key applications, such as when comparing results from space geodetic methods and tide gauges to study sea level change.

Fennoscandian land uplift maps 1914-2008

Jaakko Mäkinen
Finnish Geodetic Institute

The first map of the Fennoscandian uplift was apparently published by Blomqvist and Renqvist in 1914. It was based on the records of 18 Baltic tide gauges 1889-1912. After that there has been a profusion of land uplift maps. Maps determined from observations of vertical motion: tide gauges, repeated levelling, now continuous GPS. Maps synthetized from various observation sources or regional maps with hand drafting or with automated methods, maps showing predicted vertical motion from GIA models. Maps merging observations with GIA predictions. I present a review of Fennoscandian maps since 1914 but concentrate on reviewing the agreement of some recent maps with observed vertical motion.

GIA estimates through combination of GRACE and ICESat mission data

Riccardo Riva, Brian Gunter, Bert Vermeersen, Roderik Lindenbergh, Hugo Schotman
Dept. of Earth Observation and Space systems (DEOS), Delft University of Technology, The Netherlands
(contact: R.E.M.Riva@tudelft.nl)

Tim Urban
Center for Space Research (CSR), University of Texas at Austin, United States

Michiel Helsen
Institute for Marine and Atmospheric research Utrecht (IMAU), The Netherlands

The satellite missions GRACE and ICESat have been providing data for more than 5 years, allowing accurate estimates of temporal variations in the Earth's shape and mass distribution. The two missions provide entirely different measurement types, with GRACE measuring changes in gravity (mass) and ICESat measuring changes in surface height. Using only one of the data sets, it is difficult to separate changes in surface mass from those of GIA. With two data sets measuring the same phenomenon, however, the GIA and surface mass signals should be separable.
We test the combination of GRACE and ICESat mission data on Antarctica, where the contribution of GIA to present-day mass change has a magnitude comparable to the total signal variations. In addition, the inaccessibility of most of the internal regions has so far strongly limited the collection of field data, which reflects into large uncertainties in existing Pleistocene ice models.
We will present results from different forward GIA models, where both the Pleistocene ice model and the local Earth structure are varied within a range of plausible scenarios, and compare them to both gravity and altimetry measurements. Then, we will show our preliminary results for the combination of GRACE and ICESat, and discuss how the refinement of GIA models for Antarctica requires an interdisciplinary approach, integrating satellite based results with climate models and geological field studies.

The contemporary strain rate field of Fennoscandia derived from BIFROST GPS.

H.-G. Scherneck (1), **M. Lidberg** (2), J.M. Johansson (1), R. Haas (1), and G.A. Milne (3)

(1) Chalmers University of Technology, Göteborg, Sweden,
(2) National Land Survey, Gävle, Sweden,
(3) Department of Earth Sciences, Durham University, UK.

We use up to 4800 days of BIFROST GPS in Fennoscandia and surroundings in order to derive strain rates on a scale from 50 to 2000 km. Our investigations aim at discriminating limitations of current models of Glacial Isostatic Adjustment (GIA). The BIFROST network consists of 84 continuous GNSS stations with geodetic quality sites as a backbone. The GPS data has recently been reprocessed in order to reduce errors that probably relate to technical issues with new Block IIR satellites received at low elevation at some northern sites.

We ask the question, to what extent the residual deformation could be explained by more detailed models of the ice sheet history, by lateral heterogeneities in the lithosphere/ upper mantle structure and rheology, and by other (non-GIA) processes, such as contemporary tectonics? In our strain rate processing we apply two different methods: (i) minimise a strain energy function using polynomials as base functions; (ii) employ a least-squares collocation method. The strain rate calculation is considered as an efficient amplifier of regional features of the displacement field.

Determintion of GIA using GRACE

Holger Steffen and Jürgen Müller

Mass variations due to glacial isostatic adjustment (GIA) can be detected by various methods. Since April 2002, the GRACE satellite mission observes the Earth's gravity field, that shows variations due to the integral effect of mass variations in the atmosphere, hydrosphere and geosphere. Monthly solutions are provided by several institutions, e. g. GFZ Potsdam, CSR Austin, Texas, JPL Pasadena, ITG Bonn and CNES Toulouse.

We present the state-of-the-art of our investigation of mass variations in the areas of GIA on the Northern Hemisphere from GRACE data provided by the 5 different analysis centres mentioned above. Several filter techniques and their influence on the results are discussed. Furthermore, we investigate possible hydrologic signals with the help of the different global hydrology models WGHM, LaDWorld and GLDAS. In another step, we compare the uplift signal to geodynamic models determined with relative sea-level data.

Since 2003 annual absolute gravity (AG) measurements are performed by members of the Nordic Geodetic Commission (NKG) in Fennoscandia, which additionally offers a unique opportunity for validation and evaluation of the GRACE results. We compare results of absolute gravimetry based on the surveys from 2003 to 2007 with the FG5-220 gravimeter of our institute with those of GRACE.

Influence of glacial isostatic adjustment upon current sea level variations in the Mediterranean

P. Stocchi[1, 2], G. Spada[1]
[1] Institute of Physics, University of Urbino "Carlo Bo", Italy,
[2] On move to Delft University of Technology, Delft, The Netherlands,

Present-day sea level variations in the Mediterranean are affected by various factors, including recent climatic forcing, tectonic activity, anthropogenic effects, and glacio-isostatic adjustment. The latter depends significantly from mantle rheology and the spatio-temporal distribution of the late-Pleistocene ice sheets and is expected to produce a long-wavelength pattern of sea level variations across the Mediterranean, mostly determined by the response of the solid earth and of the geoid to the load effects of meltwater since the end of deglaciation. Modeling glacio-isostatic effects in this region is necessary for a correct interpretation of tide-gauges and GPS time-series, and thereby to constrain both the present-day climate-related sea level rise and regional or local geological, tectonic and human-driven displacements. By an exhaustive exploration of the parameters space of mantle rheology and ice sheets chronologies, in this work we aim to outline upper and lower bounds on the present-day rate of sea level variation associated with glacial isostatic adjustment in the Mediterranean. This may contribute to a full assessment of coastal vulnerability by sea level rise on a regional to local scale, as in the investigated case of Italy.

The effect of glacial isostatic adjustment on ice sheet evolution in Eurasia; a comparison of a self gravitating viscoelastic earth model and the flexural approach

Jojanneke van den Berg[1], Roderik van de Wal[1], Glenn Milne[2] and Hans Oerlemans[1]

[1]Institute for Marine and Atmospheric research Utrecht, Utrecht University, Princetonplein 5, 3584CC Utrecht, the Netherlands
[2]Department of Earth Sciences, University of Durham, Durham DH1 3LE, UK

Crustal subsidence of up to 1km is common for large ice sheets due to isostatic depression of the solid Earth. As snowfall and melt both depend on surface elevation, it is clear that isostatic adjustment is an important process when modelling dynamical ice sheet evolution. Nowadays, a wide variety of earth models are used to model the isostatic response to ice sheets, ranging from regional local or elastic lithospheres with a single relaxation time to account for temporal behaviour to global, three-dimensional models of the crust-mantle system. We compared an often used regional model with an elastic plate and a single relaxation time (ELRA) to a self gravitating viscoelastic earth model (SGVE) for a wide range of model parameters. No ELRA model was able to reproduce the SGVE response completely, due to the fact that the models have an intrinsically different spatial response. Differences in lithospheric strength cause large changes in the modelled ice sheets, with in general decreasing ice volumes for increasing rigidities due to the sensitivity of the ice sheets to differences in surface elevation near the ice margin. When applied to a full transient glacial cycle in Eurasia even the best fitting ELRA model underestimated the ice volume predicted by the SGVE model at the LGM by 30 percent. Moreover, the optimum values for the flexural rigidity and relaxation time varied over a transient glacial run and with parameters of interest. We conclude that for Eurasia these two types of earth model are incompatible. Results from Le Meur and Huybrechts (1996) for a study in Antarctica suggested the opposite, indicating that Antarctica is not representative for all Pleistocene ice sheets.

Le Meur, E. and P. Huybrechts, 1996. A comparison of different ways of dealing with isostasy: examples from modelling the Antarctic Ice sheet during the last glacial cycle. Annals of Glaciology (23): 309-317.

Conceptually understanding the horizontal component of postglacial rebound

Martin Vermeer and Karin Kollo
Helsinki University of Technology TKK, Department of Surveying

As part of the Academy of Finland -funded study project iRegional Crustal Deformation and Lithosphere Thickness Observed with Geodetic Techniques (RCD-LITO), nr. 123113j, we intend to engage in two dioeerent studies: 1) independent lithospheric thickness recovery, and 2) forward prediction of gravity change for comparison with terrestrial and satellite data.

From the BIFROST studies we know that in addition to the land uplift, there is a horizontal component of motion in which the surface moves away from the uplift centre. We believe that at -- least in the Fennoscandian area -- this eoeect can be conceptually explained by a locally rotational motion of rigid blocks of a thick lithosphere, and aim to recover by inversion lithospheric thicknesses based on this understanding. Results obtained will be compared with those from other sources.

As to forward prediction of gravity changes, we aim to use a simple multiple-interface model for this. The known interfaces are air-water, air-crust, water-crust and crust-mantle. Comparison with known gravity change data will verify our understanding of the position and density contrast of all these interfaces.

Space Geodetic Constraints on Thermomechanical Models of the Shallow Earth

H.H.A. Schotman (1,2), L.L.A. Vermeersen (2), P. Wu (3), M.R. Drury (4) and J.H.P. de Bresser (4)

(1) SRON, Utrecht, The Netherlands
(2) DEOS, Fac. Aerospace Engineering, TU Delft, The Netherlands
(3) Dept. Geoscience, University of Calgary, Canada
(4) Dept. Geosciences, Utrecht University, The Netherlands

Current constraints on the process of glacial-isostatic adjustment in Northern Europe are mainly provided by relative sea level data and GPS measurements. Due to a lack of resolving power in the shallow earth (down to about 200 km), these datasets only provide weak constraints on the shallow viscosity structure and thickness of the lithosphere. Future high-resolution gravity data, as expected from ESA's Gravity and Ocean Circulation Explorer (GOCE) satellite gravity mission to be launched May 15 2008, are predicted to provide additional information on the shallow earth, especially the viscosity structure. However, mass inhomogeneities due to chemical and thermal anomalies are expected to interfere with the gravity signals induced by shallow low-viscosity structures. We test therefore if heatflow data and laboratory-derived creep laws for the crust (plagioclase feldspars) and shallow upper mantle (olivine) can provide additional information on the shallow earth. For this, we use a thermal model constrained by surface heatflow data and a mechanical model based on the commercially available finite-element package Abaqus. We show estimates of lithospheric thickness and viscosities that can be expected in the shallow earth, and generate predictions for Northern Europe using heatflow data and representative creep laws.

Glacial isostatic adjustment in Fennoscandia and the effect of 3-D Earth structure

Pippa Whitehouse, Ecole Normale Superieure
Konstantin Latychev, University of Toronto
Glenn Milne, Durham University
Jerry Mitrovica, University of Toronto

Geophysical modelling of observations related to the glacial isostatic adjustment of Fennoscandia has led to constraints being placed upon both the glaciation history of this region and the sub-surface viscosity structure. The majority of studies have so far only considered models whose rheological structure varies with depth. We consider the effect of realistic 3-D variations in Earth structure upon predictions of relative sea-level and present-day crustal motion, and demonstrate that the resulting perturbations exceed the observational uncertainty of GPS and relative sea-level measurements. This suggests that the applicability of 1-D Earth models to GIA modelling in Fennoscandia is limited, and that previous attempts to constrain past ice history and Earth structure in this region may be biased. We also consider the potential of sea level and GPS data to constraint 3-D properties of the subsurface beneath Fennoscandia.

Heat flow and the Late Weichselian deglaciation pattern of the Kola region, NW Russia

Zozulya D., Korsakova O., Kolka V.
Geological Institute, Kola Science Centre, Russia, zozulya@geoksc.apatity.ru

Some evidences of dependence of the ice sheet structure and dynamics, deglaciation rate in Kola region (NW Russia) from the heat flow are presented. For this purpose, the P-T parameters of the pyrope and chrome diopside grains recovered from the Quaternary sediments of the southern, central and northern parts of the Kola region were determined. Representing either mantle xenocrysts or constituents of mantle xenoliths, the pyropes and chrome diopsides contain valuable information on the composition of the lithospheric mantle and its thermal properties. Ni-thermometry of Ryan et al. (1996) on pyropes gives a range of temperatures between 650-1250°C, corresponding to a sampling interval of ca. 75-190 km (Zozulya et al., 2007a). From the distribution of the different pyrope genetic groups, stratified structure of the southern Kola Craton lithospheric mantle is inferred: the shallow mantle horizon (75-110 km) which is the main source of lherzolitic pyropes, while deeper mantle horizon between 110 and 190 km has contributed abundant harzburgitic pyropes to magmas. P-T values for peridotitic chrome diopsides using the single-grain thermobarometer of Nimis & Taylor (2000) imply that the maximum depth of xenocryst sampling varies from up to 200 km in the south-eastern and south-western Kola, to 170 km in central Kola, and down to 140 km in the northern Kola region, assuming possibly the different thickness of lithosphere.

The P-T values for chrome diopsides also imply significant regional variations in the heat flow (Zozulya et al., 2007b). Within the southern part of the Kola, adjacent to the Kandalaksha graben (White Sea rift system), the chrome diopside data is consistent with the 38-44 mW/m^2 model geotherm of Pollack & Chapman (1977). Importantly, towards east and west, away from Kandalaksha graben to south, the lithosphere appears to become thicker and the heat flow corresponds to the cool cratonic model geotherm of 35-38 mW/m^2. The central Kola, in turn, is characterized by more elevated heat flow of ca. 38-44 mW/m^2. The highest heat flow values (up to 50 mW/m^2) are observed in the northernmost Kola region, adjacent to the Barents rift system.

Regional variation in the heat flow appears to be one of the factors responsible for the deglaciation pattern of the Scandinavian ice sheet during the Late Weichselian. During the last glacial maximum time (23 ÷ 16-17 ka BP) the ice sheet covered the Kola Peninsula and the adjacent Barents and White (as far as to Kanin Peninsula at east) seas. The ice thickness amounted of 2500 m. Initially the deglaciation processes were displayed in areas with relatively high heat flow. At 14.7-13 ka BP the adjacent Barents shelf becomes free of ice (Evzerov, 2007) and two glacial lobes (Barents one in the northern and Belomorian one in the central and southern parts) were still active in the Kola Peninsula and in the White Sea. Start from 12.5-11 ka BP the periglacial basin forms in White Sea depression as the continental Kola was still covered by ice. After that time the Barents (more actively) and Belomorian lobes degraded from east to west, and at ca. 10 ka BP the Kola region becomes almost free of ice.

Evzerov V. Deglaciation model of the Kola region during the Late Pleistocene and Holocene // Proc. 5th All-Russian Conf. "Fundamental Problems of Quarter" (Moscow, November 7-9, 2007), 2007, P. 119-122.

Nimis P., Taylor W.R. Single clinopyroxene thermobarometry for garnet peridotites. Part I. Calibration and testing of a Cr-in-cpx barometer and an enstatite-in-cpx thermometer // Contrib. Mineral. Petrol., 2000, V. 139, P. 541-554.

Pollack H.N., Chapman D.S. On the regional variations of heat flow, geotherms and lithosphere thickness // Tectonophysics, 1977, V. 38, P. 279-296.

Ryan C.G., Griffin W.L., Pearson N.J. Garnet geotherms: Pressure-temperature data from Cr-pyrope garnet xenocrysts in volcanic rocks // J. Geophys. Res., 1996, V. 101, P. 5611-5625.

Zozulya D., Peltonen P., O'Brien H. Pyropes and chrome-diopsides as indicators of the mantle structure and diamond-bearing facies in Kola Region // Zapiski RMO (Proc. Russ. Mineral. Soc.), 2007a, V. 136, N 4, P. 1-15.

Zozulya D., Peltonen P., O´Brien H., Lehtonen M. P-T parameters of mantle pyroxenes' crystallization and geotherms of the Kola region // Proc. Sci. Conf. "Geology and minerageny of the Kola region" (Apatity, June 4-6, 2007), 2007b, P. 162-164.