Structural Geology Field Course in Iceland

Field Course in structural geology, behavior of extensional faults, fault linkage and selected interesting geology of Southern Iceland.

The Structural Geology Group is proud to establish a field course in Iceland in close cooperation with Professor Agust Gudmundsson from Royal Holloway, University of London. The course in structural geology will take place in June 2014, and Agust Gudmundsson will be the instructor on the field course.

The course is targeting especially non-structural geologists, reservoir engineers, petrophycisists, geophycicists and structural geologists who wish to brush up their spatial understanding of the structural framework. The aim of establishing this course is to illustrate and explain how extensional structures are initiated, how faults are linked and forming relay ramps, and how and when the structures are detached from each other. This is highly relevant when evaluating prospects and has significant implications for the sediment distribution and hydrocarbon migration.

It is our hope that the field course participants will return to their companies with an improved understanding of structural geology and will be able to better integrate it in prospect evaluation and field development in the future.

Please see Course Content and Plan on the following pages.

Course dates: excluding travel to and from Iceland

DAY 1: Monday 2nd of June
DAY 2: Tuesday 3rd of June
DAY 3: Wednesday 4th of June

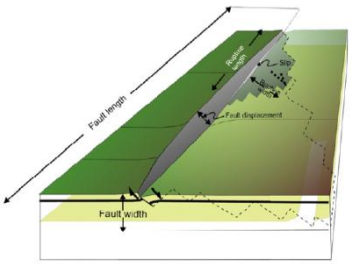


Figure from Gudmundsson, A., de Guidi, G., Scudero, S., 2013.

Day 4 is optional, and comes with an additional cost of 3.000 NOK

Price: 10.000 NOK.
Flight to Iceland, transport to and from the hotel, hotel stay and dinners comes in addition.

Max No.: 20

Location: Southern Iceland

Registration: http://force.org/Seminars/Field-course-in-structural-geology---Iceland/

Content of the course:

These topics will, amongst others, be discussed in the field and at the outcrop sites:

- **Mechanical principles**
  - fault formation and growth
  - mechanical layering effects on fault propagation and arrest
  - fluid transport as a function of fracture type (extensional and shear)
  - stress concentration effects
  - scaling laws in fractures and faults
  - thermodynamic principles
  - heat flow
  - the cubic law
  - Darcy's law
  - fracture mechanics
  - rock physics
  - etc.

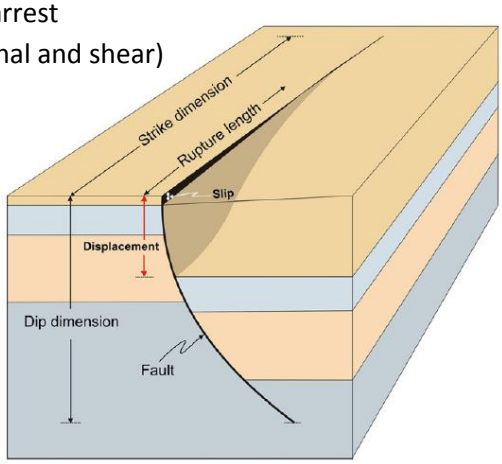


Figure from Gudmundsson, A., de Guidi, G., Scudero, S., 2013.

- **Fractured reservoirs, extension fractures, and faults**

- **Active faulting in relation to seismicity**
  - stress drops (driving stresses for fault displacement)
  - fault linkage
  - etc.

More information on the topic:

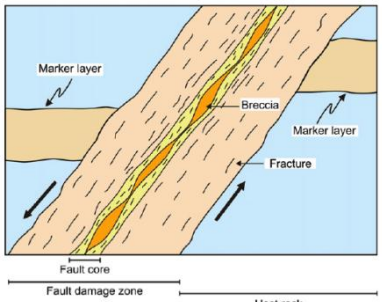


Figure from Gudmundsson, A., de Guidi, G., Scudero, S., 2013.

http://agustgudmundsson.co.uk/
http://www.researchgate.net/profile/Agust_Gudmundsson/
http://uk.linkedin.com/pub/agust-gudmundsson/68/3b7/959
http://community.frontiersin.org/people/AgustGudmundsson/92172
http://scholar.google.co.uk/citations?user=LcTUo5kAAAAJ&hl=en

Recommended reading:

'Rock Fractures in Geological Processes', Cambridge University Press, 2011

Gudmundsson, A., de Guidi, G., Scudero, S., 2013. Length-displacement scaling and fault growth. Tectonophysics 608, 1298-1309

Gudmundsson, A., Mohajeri, N., 2013. Relations between the scaling exponents, entropies, and energies of fracture networks. Bull Soc geol France 184 (4), 377-387

Gudmundsson, A., 2013. Great challenges in structural geology and tectonics. Frontiers in Earth Science doi: 10.3389/feart.2013.00002, published 12 November 2013

Phillipp, S.L., Afsar, F., Gudmundsson, A., 2013. Effects of mechanical layering on hydrofracture emplacement and fluid transport in reservoirs. Frontiers in Earth Science doi: 10.3389/feart.2013.00004, published 20 December 2013

Course Plan – flexible due to weather and possibly closed roads due to remaining snow

DAY 1: Monday 2nd of June

Hengill-Thingvellir - (Gullfoss and Geysir)

- Pleistocene – Holocene normal faults and grabens in Hengill (a central/stratovolcano and the main geothermal field and power plants for Reykjavik). Fault displacements up to 200 m. Grabens and faults very well exposed. There are also other faults I shall point out in the distance with displacements of 400 m.

- The Thingvellir Graben. Holocene (about 9000-year-old) normal faults (displacements up to 40 m, opening up to 60 m, length up to 10 km) and tension fractures (openings up to 15 m) in the Thingvellir Graben. Last major subsidence (about 1 m) during earthquakes in 1789. Continuous deformation across the graben measured by GPS and other geodetic techniques over decades.

Figure from Gudmundsson and Mohajeri, 2013

- Shield volcanoes (lava shields) – Skjaldbreiður from a distance, Lyngdalsheiði (drive across). On the way to lake Laugarvatn stop at hyaloclastite (basaltic breccia) mountain to look at hyaloclastites, caves, and among the most beautiful pillow lavas known in Iceland.

- To Geysir – erupting Strokkur (erupts every 5-10 minutes) and then to the Gullfoss waterfall, the second largest in Iceland and located in a large, partly tectonic, canyon. Hekla should be seen if the visibility is good.

- Drive back to Reykjavik and perhaps stop at the main geothermal power plant in Iceland (Hellisheidi – open to visitors).

DAY 2: Tuesday 3rd of June

Hvalfjörður – grabens, faults, dykes, and sills, fossil volcanoes, tablemountains

- Landslides in the mountain Esja; inclined sheets and dykes and geothermal alteration in Esja.

Figure from Phillipp et al., 2013

Dykes and faults on the coast close to Hvalfjarðareyri – exceptionally well exposed with beautiful columnar joints and secondary minerals (quartz, zeolites, etc). The fjord is eroded to a depth of 1200 m below the original surface of the rift zone, so we are seeing into the old (1-3 million year old) rift zone. And all the structures seen here originated in the Thingvellir Rift Zone and drifted to the west because of spreading (plate movements).

- Cross-section through a beautiful graben in Múlafjall. This graben has faults at 800 m depth below the original surface that are very similar to the ones seen at the surface at Thingvellir today. So we get a three-dimensional view of the rifting process. There are several other very large faults in the area, but not as clear as these. If there is interest, we drive in Botnsdalur to look at all the big faults.

- Botnsdalur – the innermost part of Hvalfjörður. Hvalfell, one of the beautiful tablemountains in Iceland. On the coast a lot of amygdales (zeolites, quartz, calcite, etc).

- The Tertiary volcano Skarðsheiði and the glacially eroded lake Skorradalsvatn. Many faults and dykes seen on the way.

- The volcano Hafnarfjall – a Tertiary volcano and the Borgarnes anticline. If you want to we can walk into the mountain gullies, but takes some hours.

- Back to Reykjavik through the tunnel under Halfjörður.

DAY 3: Wednesday 4th of June

The highland Kaldidalur (north of Thingvellir) - depends on time and weather.

- Hyaloclastite mountains, Ármanssfell and Hrafnabjörg, cut by large faults.The faults here are exceptional and can be followed for many kilometers. They are a part of the Thingvellir Graben but cut through hyaloclastites.

- The shield volcano Skjaldbreiður.

- The glaciers Ok, Þórisjökull and Langjökull, in addition to numerous beautiful tablemountains and hyaloclastite ridges.

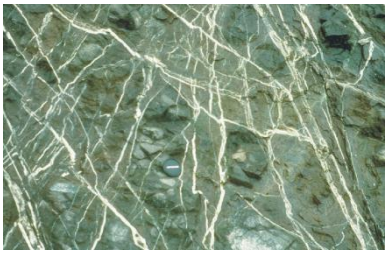
- Drive up to the edge of Langjökull and short walk on the glacier – if people like.

- The Holocene lava field of Hallmundarhraun, the central volcano Húsafell, and drive down to the school/hotel/farm Reykholt – geothermal activity but also the 'cultural aspect' of the excursion. Snorri Sturluson lived and wrote his books on Norwegian kings in Reykholt.

- Drive to the northeast to the Holocene lava flows and crater cones of Grábrók in Norðurárdalur and then to the laccolith of Baula, nearby.

- Drive back to Reykjavik. Departure for those who are travelling home.

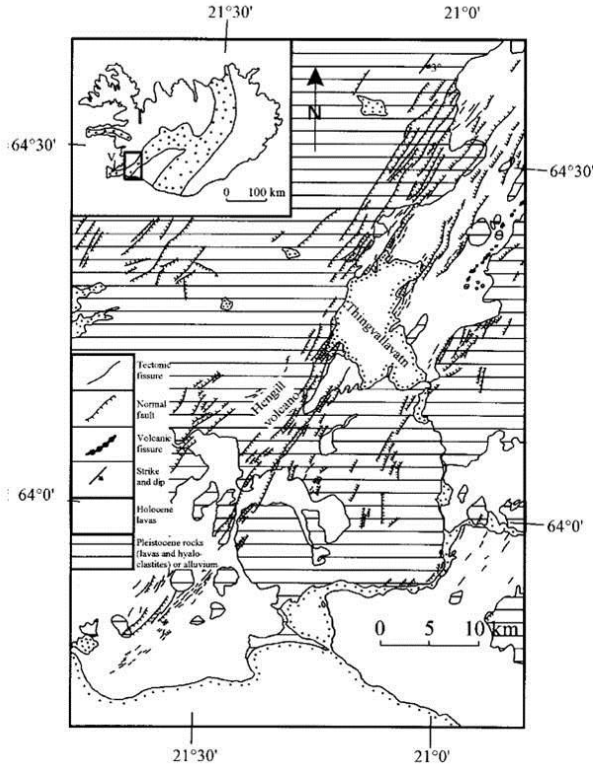
END OF COURSE – DAY 4 IS OPTIONAL



DAY 4 (optional)

Eyjafjallajökull and South Iceland waterfalls, sands, and coast

- Drive to Eyjafjallajökull which erupted in 2010.
- Stop in South Iceland (Hella or Hvolsvöllur). Explain the South Iceland Seismic Zone, where the largest earthquakes in Iceland occur – last ones in the years 2000 and 2008. How they relate to the volcanoes of Hekla (should be seen) and Eyjafjallajökull. Earthquake monitoring.
- Stop at Seljalandsfoss - a beautiful waterfall from an old ca. 60 m high sea cliff. You can walk behind it if you like.
- Stop on the way to look at the very complex internal structure of Eyjafjallajökull and how this complexity affected the 2010 eruptions. Explain volcano monitoring.
- Stop at Skógarfoss – a beautiful waterfall over a former sea cliff.
- Reynisfjara close to Vík in Mýrdal. The beautiful columnar joints in the intrusions and the sandy beach, both being famous geological features.
- Vík in Mýrdalur, a little village with particularly well-exposed layering in the hyaloclastite rocks.
- Mýrdalssandur and Katla, the notorious volcano. The floods, the changes in the shore line during the past 1100 years due to the eruptions and floods (jökulhlaups).
- Back to Reykjavik.
- Departure.



Map from: Gudmundsson, A.: Dynamics of Volcanic Systems in Iceland: Example of Tectonism and Volcanism at Juxtaposed Hot Spot and Mid-Ocean Ridge Systems.
(http://www.frontiersin.org/Journal/10.3389/feart.2013.00002/full)