Living on the Edge, Unit 3 Divergent Plate Boundary Hazards
Handouts for in class group activity (Part 3)

This data can be used for the Group Activity in Unit 3 in which students compile the characteristics of one of three subaerial divergent plate boundaries.

Handouts instructions:

1. Each student should have one copy of Unit3_StudentDataTables.docx (most will bring these with their pre-work)
2. Each group should have one copy of Unit3_StudentDataFiles, but only the relevant pages for their group as follows:
    - Iceland, Grímsvötn 2004, Slides 2-5
    - Afar Rift, Dabbahu 2005, Slides 6-8
    - Central East African Rift, Nyiragongo 2002, Slides 9-11

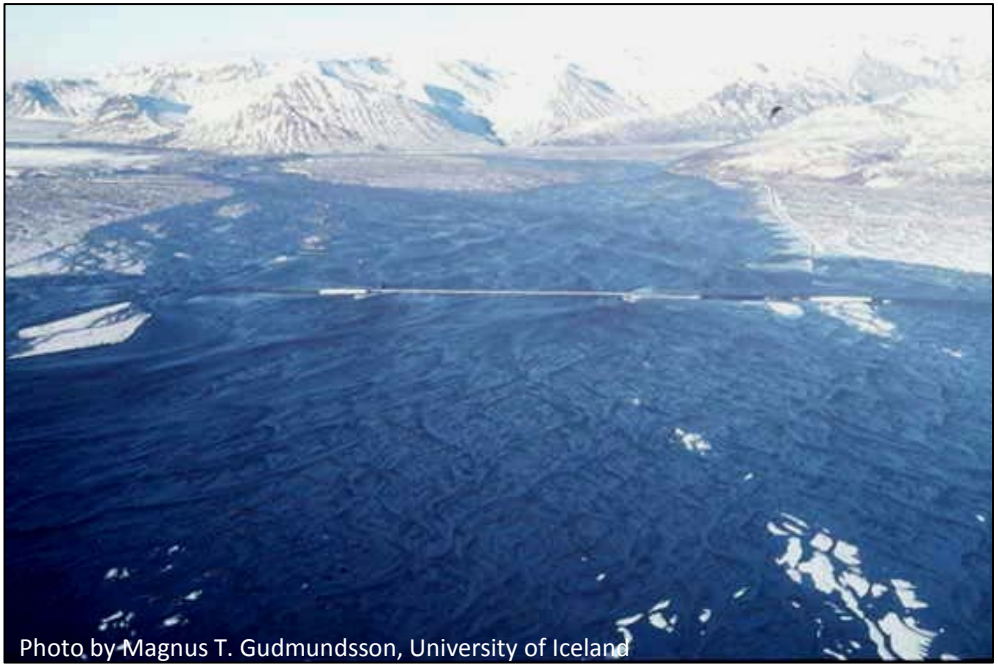
Iceland, Grímsvötn eruption November 1, 2004

Data: Divergent Plate Boundaries

The 2004 Grímsvötn eruption was preceded by both long-term and short-term precursors. **Seismicity** originally increased at the volcano in mid-2003, as uplift of the volcano surpassed uplift prior to the 1998 Grímsvötn eruption. Seismicity increased in late October 2004. About 3 hours before the eruption began an intense swarm of volcanic earthquakes started. Seismicity became continuous at the onset of the eruption.

An ice melting event at the Grímsvötn subglacial caldera released a giant outburst flood (***jökulhlaup***, see below). The loss of ice released overburden pressure from volcano, triggering the eruption. The drop in water level in the Grímsvötn caldera at the onset of the eruption was probably on the order of 10-20 m, corresponding to a modest pressure change, but the internal pressure in the Grímsvötn shallow magma chamber was high from continuous inflow of magma since 1998.

Below is a view northwards, showing the east part of the 2004 jökulhlaup and the 900 m long Skeiar bridge. At the time, about 15,000 m^3/s was flowing down this part of the alluvial plane. The bridge remained intact until a few hours later when the east end washed away.



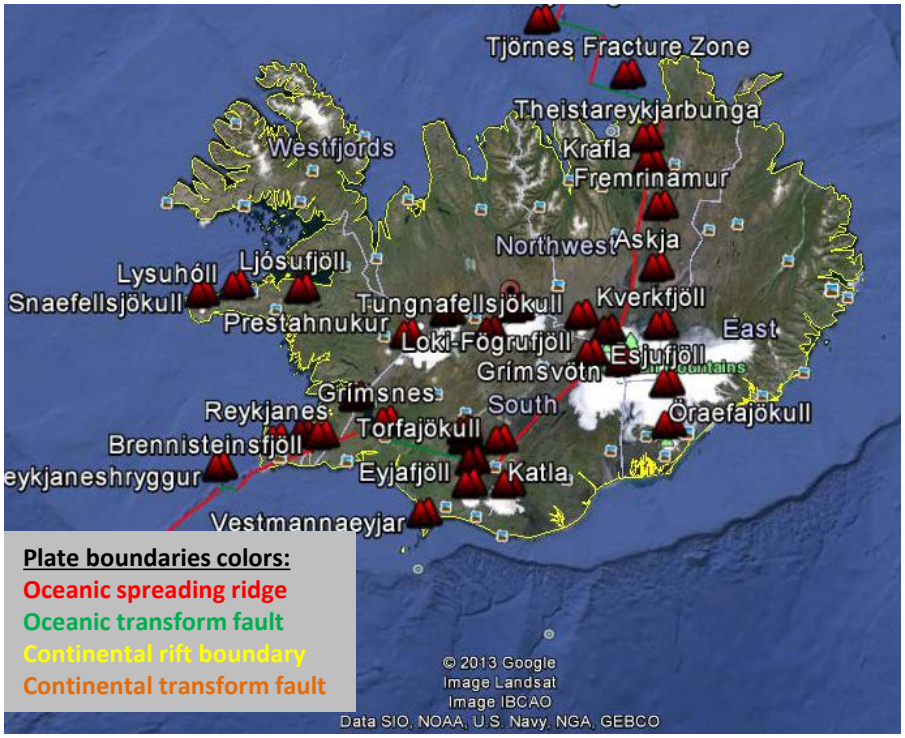


Plate Boundaries and volcanoes of Iceland (GoogleEarth)

http://www.volcano.si.edu/volcano.cfm?vn=373010#October2004

Iceland, Grímsvötn eruption November 2004
Topography, Earthquakes, Volcanism

Data: Divergent Plate Boundaries

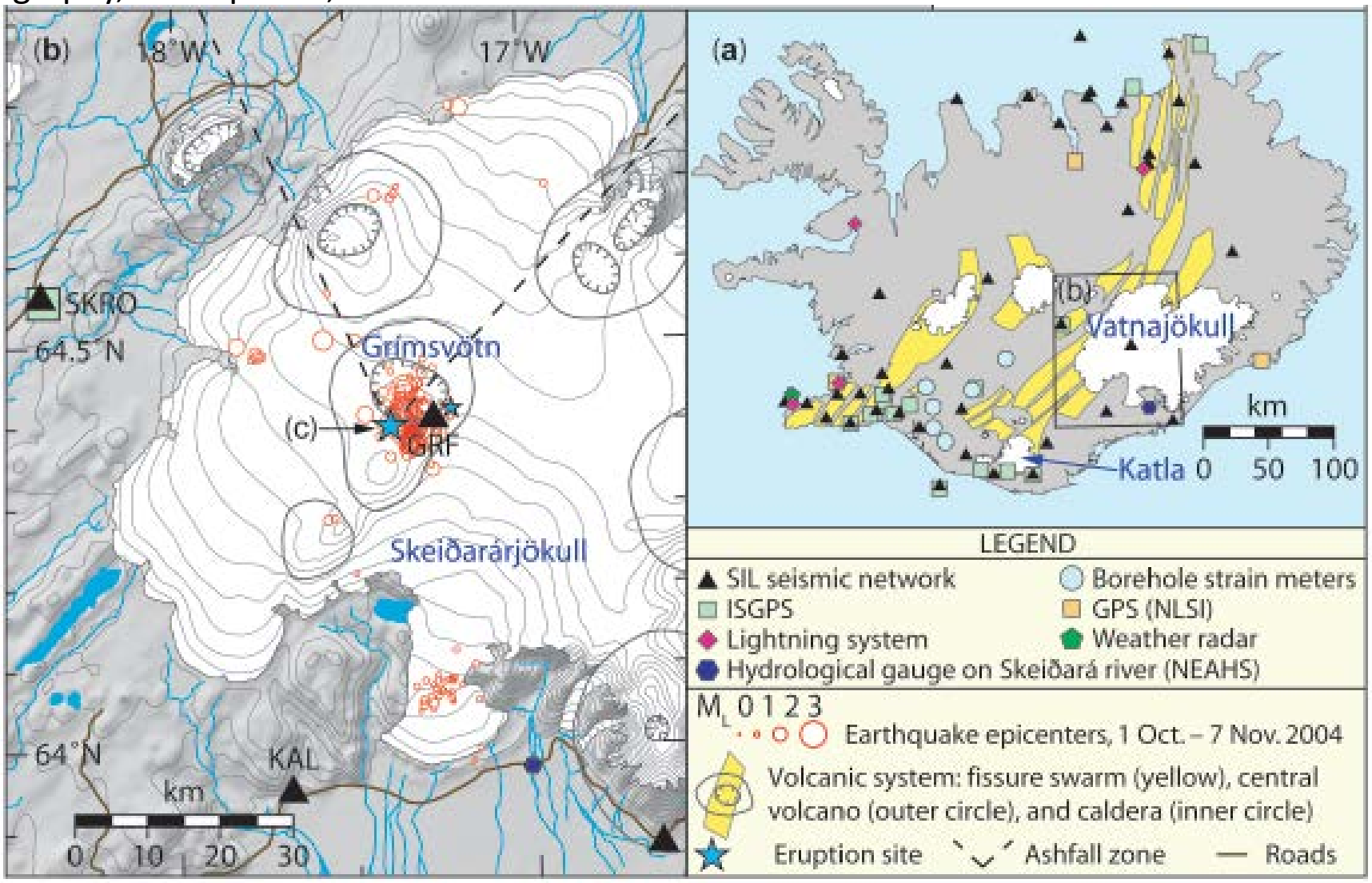
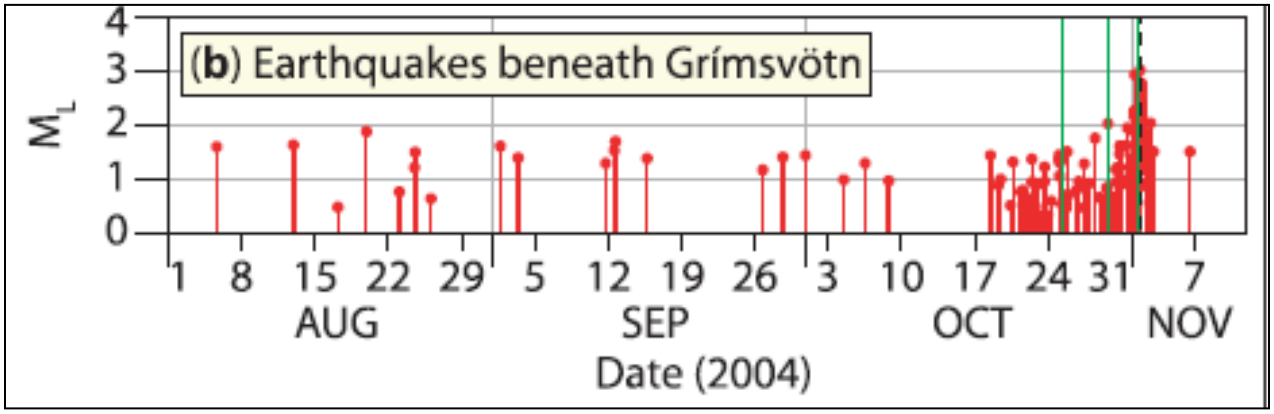


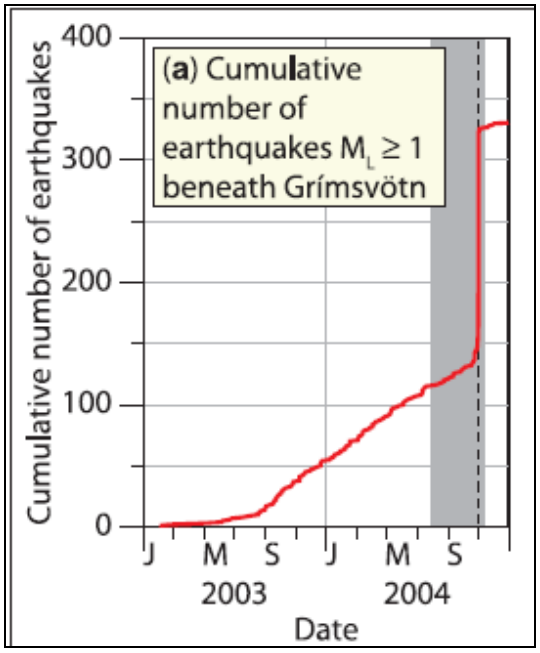
Image a (upper right): Map of Iceland illustrating the location of monitoring networks in the Grímsvötn area. Image b (upper left): Map of the eruption November 1, 2004 eruption site- earthquake locations in the month preceding the eruption and the Vatnajökull ice cap, which in part overlies Grímsvötn. Earthquake epicenters in Skeidarárjökull outlet glacier represent ice-quakes induced by the jökulhlaup. Dashed outline is the zone of ash deposition. Maps from Vogfjörd et al., 2005; Copyright 2005 by the American Geophysical Union.

Iceland, Grímsvötn eruption November 1, 2004

Data: Divergent Plate Boundaries

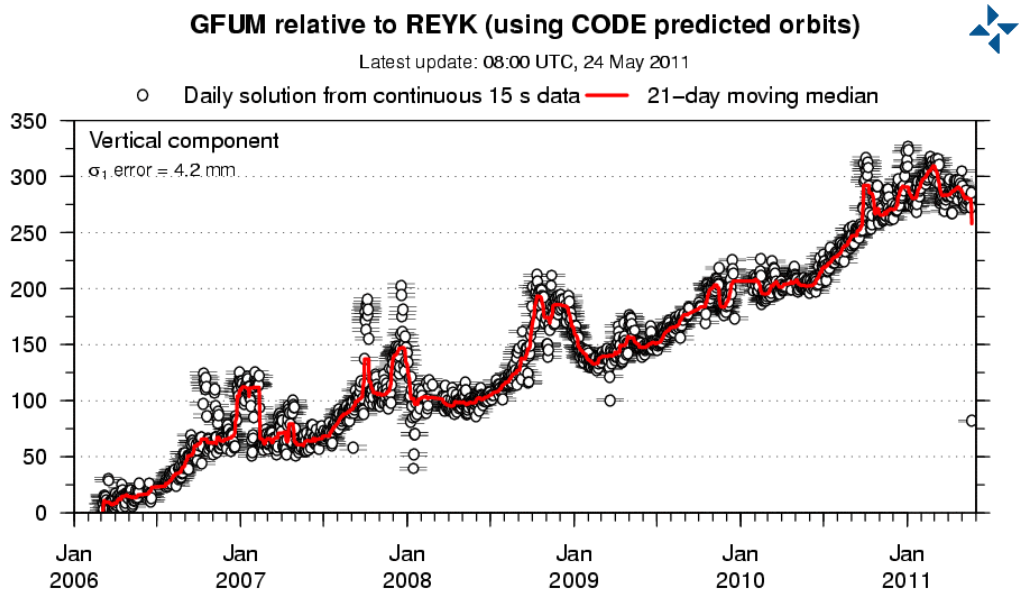
Precursory signals: Figure a: Cumulative number of earthquakes beneath Grímsvötn from 2002-2004, showing the increase in activity in July 2003. (b) Local magnitude (ML) of Grímsvötn earthquakes in the months preceding the eruption, showing the sudden increase in seismicity on 18 October. From Vogfjörd et al., 2005; Copyright 2005 by the American Geophysical Union.





GPS data from Grímsvötn, recording inflation of the volcano from 2006-2011. The final data points record deflation during the 2011 eruption.

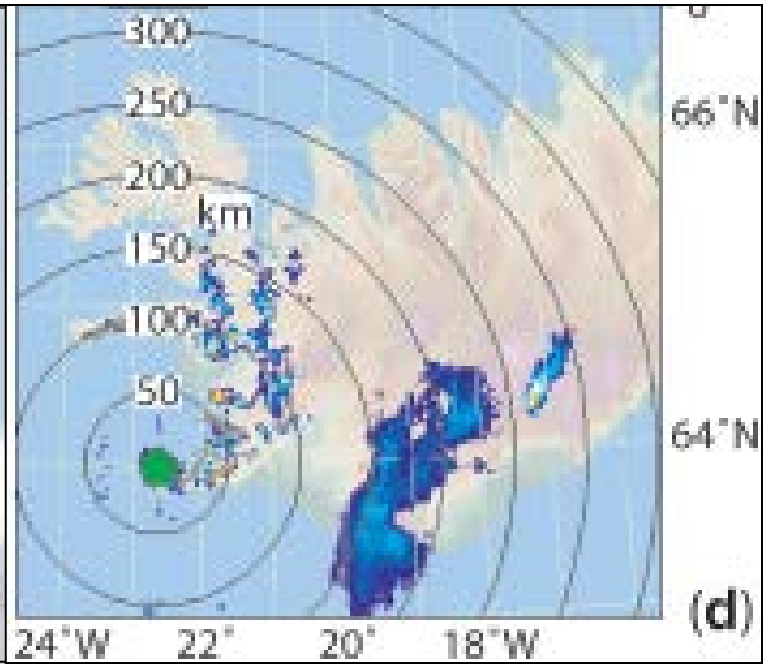
The plot comes from the Icelandic Met Office website.
Accessed from: http://all-geo.org/volcan01010/2011/05/grimsvotn-eruption-more-questions-and-answers/



Iceland, Grímsvötn eruption November 1, 2004

Data: Divergent Plate Boundaries

Image c: Aerial view from west of the tephra plume at Grímsvötn on 2 November. Note the ash fall from the plume. Image d Weather radar image at 0400 UTC on 2 November, grey areas represent the extent of the plume. From Vogfjörd *et al.,* 2005, Photo by M. J. Roberts.



The ash plume produced from the eruption reached a height of ~12.2 km a.s.l. The eruption occurred in an unpopulated region so no evacuations were needed, but air traffic was diverted away from the region and impacted air travel over the North Atlantic.

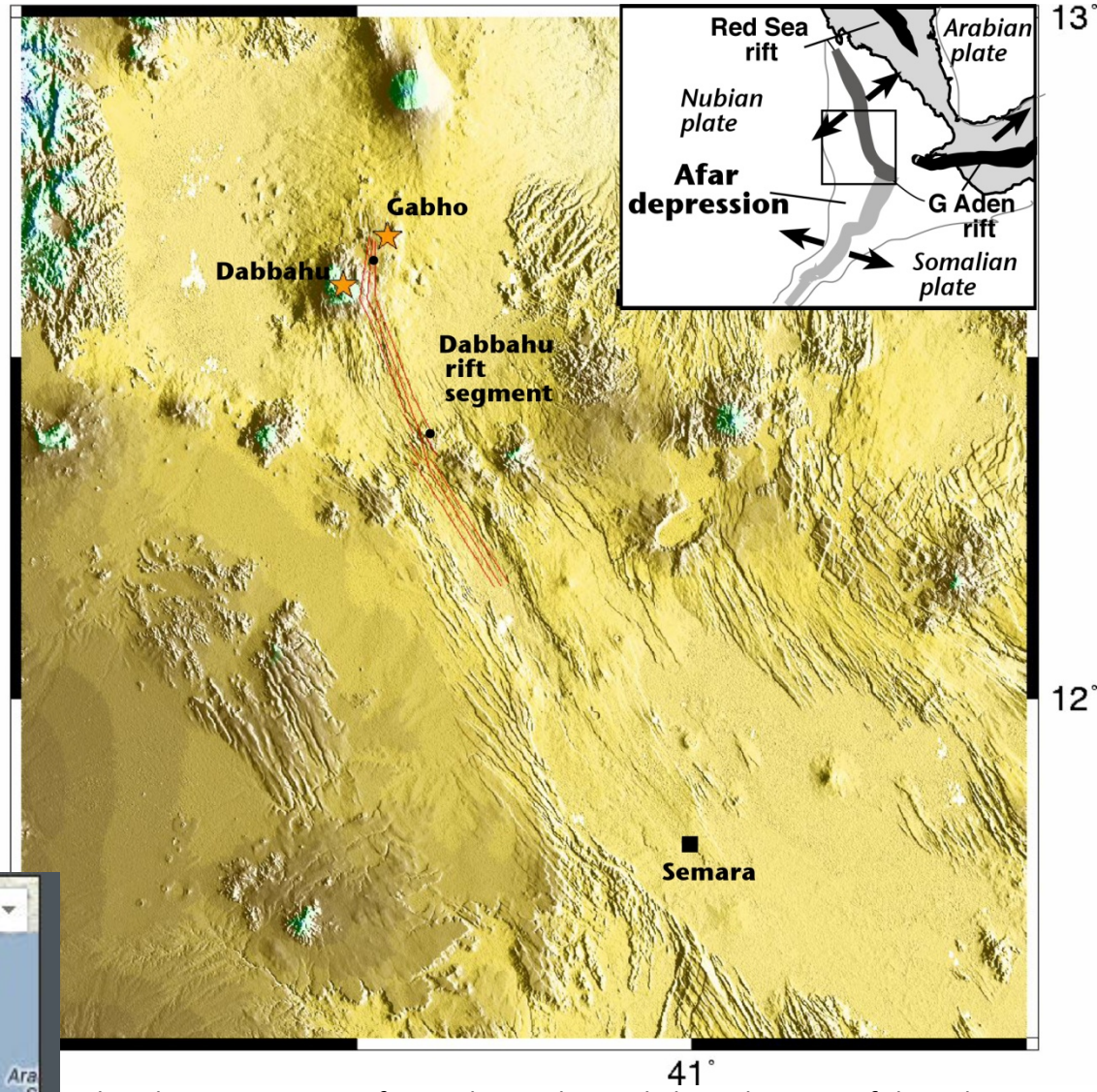
Observations on 2 November revealed that the eruption was from a circular vent ~1 km in diameter in the SE part of the volcano's crater. The ice thickness in this part of the Grímsvötn caldera was ~200 m prior to the eruption. On 3 November, eruptive activity occurred in pulses, resulting in a changing eruption column height from 8-9 km to 13-14 km above the volcano. Ash fall from the plume extended at least 150 km from the eruption site. The distal ash plume was observed in Norway, Finland, and Sweden.
Sources: Vogfjörd et al., 2005; Copyright 2005 by the American Geophysical Union, Institute of Earth Sciences , London Volcanic Ash Advisory Centre (VAAC)

East African Rift: Afar Rift, Dabbahu eruption September 2005,

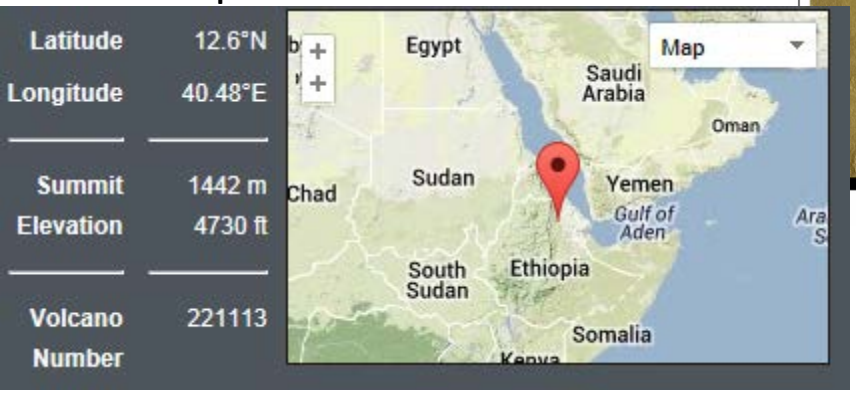
Data: Divergent Plate Boundaries

A team of scientists visited the Da'Ure area, just NE of the Dabbahu volcano complex on October 4-5, 2005 after receiving reports of volcanic activity there on September 26. People in the area noted that on September 26th at about 1:00 PM local time, a very strong earthquake shook the area, and was followed by a dark column of "smoke" that rose high into the atmosphere and spread out to form a cloud, which darkened the area for 3 days and 3 nights. The scientists determined that a minor explosive eruption occurred from two semi-circular vents, producing ash fall that was ~5 cm thick near the vent. Ash deposits extended more than 500 m from the vent. Boulders emitted during the eruption were as large as 3 m diameter, and were deposited as far as 20 meters away. The scientists noted intense degassing from the vents, the scent of sulfur dioxide, and the sound of boiling water in the vents. As of about October 10th, the Addis Ababa University Geophysical Observatory reported that seismic activity in the area was continuing.

Sources: Gezahegn Yirgu, Department of Earth Sciences, Addis Ababa University



Dabbahu Ethiopia Location:



From Global Volcanism Network http://www.volcano.si.edu/volcano.cfm?vn=221113

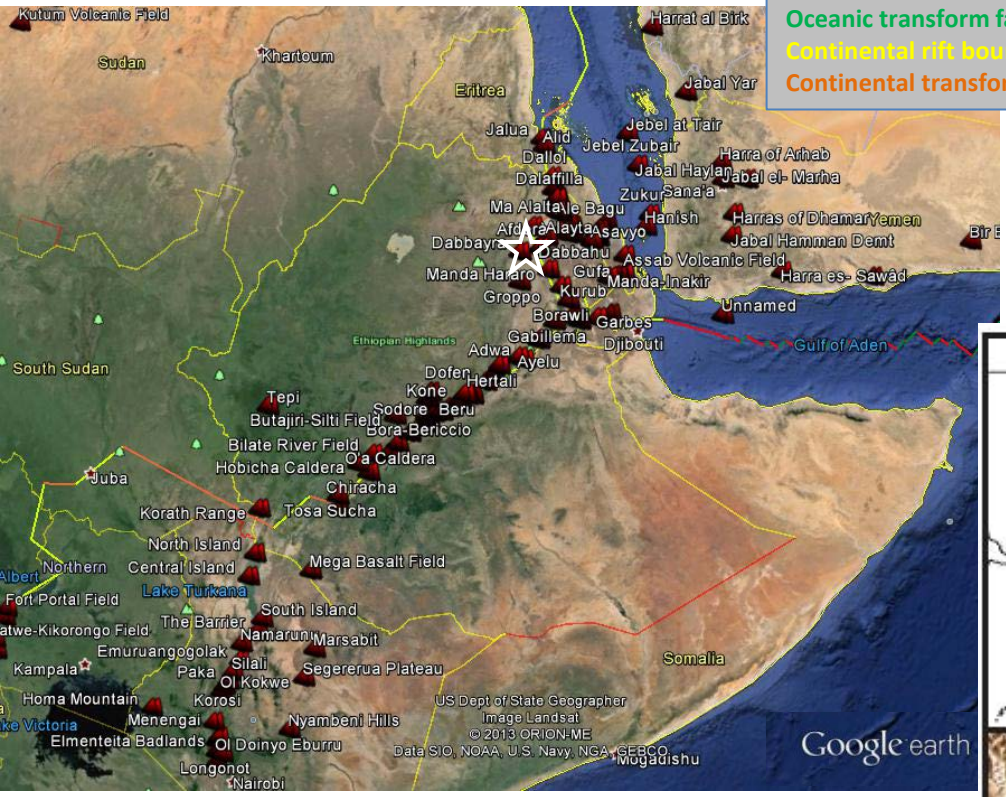
Abundant gas emission fumaroles are located along the crest of the volcano and extend NE. The first historical eruption of Dabbahu took place from a fissure vent on the NE flank of the volcano in September 2005, which produced ash fall deposits and a small pumice dome. More than 6000 persons were evacuated from neighboring villages.

Map from: http://homepages.see.leeds.ac.uk/~eartjw/dabbahu/fig1.jpg

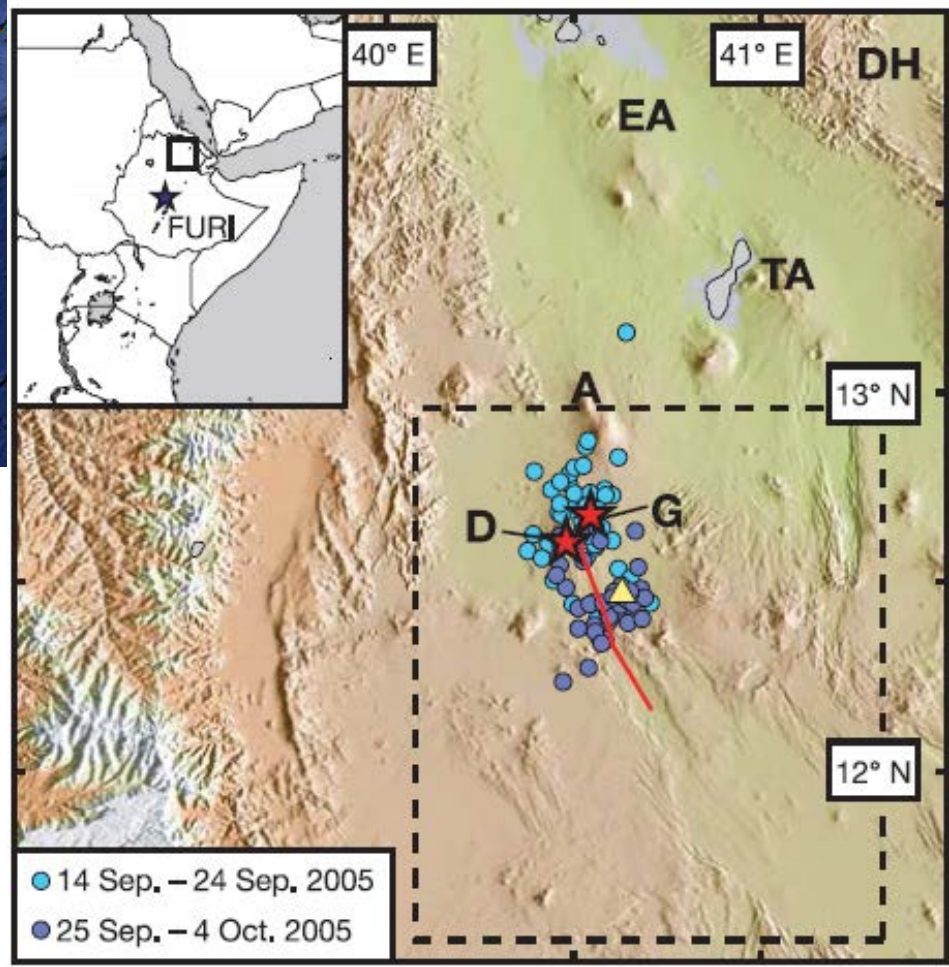
East African Rift: Afar Rift, Dabbahu eruption September 2005

Data: Divergent Plate Boundaries

Plate boundaries (color codes)
Oceanic spreading ridge
Oceanic transform fault
Continental rift boundary
Continental transform fault



Left: Volcanoes and Plate Boundaries of the Afar Rift region of the East African Rift, Ethiopia (left). White star shows Dabbahu volcano. *Map from Google Earth, Map Data from US Dept of State Geography, 2014, ORION ME Image Landsat; Volcano locations compiled by the Global Volcanism Program, Smithsonian Institution; http://www.volcano.si.edu/ge/GVPWorldVolcanoes-List.kmz; Plate boundaries from* plate boundaries, Geochemistry Geophysics Geosystems, 4, 1027 http://element.ess.ucla.edu/publications/2003_PB2002/2003_PB2002.htm Converted into Google Earth format by Thomas Christian Chust.



Right: Color shaded relief map for northern Afar, with Dabbahu volcano and earthquakes. Main figure shows the location of the magmatic dike (red line) intruded along the entire Dabbahu magmatic segment.

Red stars are Dabbahu (D) and Gabho (G) volcanoes.

Filled circles are earthquake epicenter locations, most earthquakes occurred between September 20 and 29, 2005. Note the relationship between earthquakes and plate boundaries related to the Dabbahu geologic activity.

Dabbahu Earthquakes

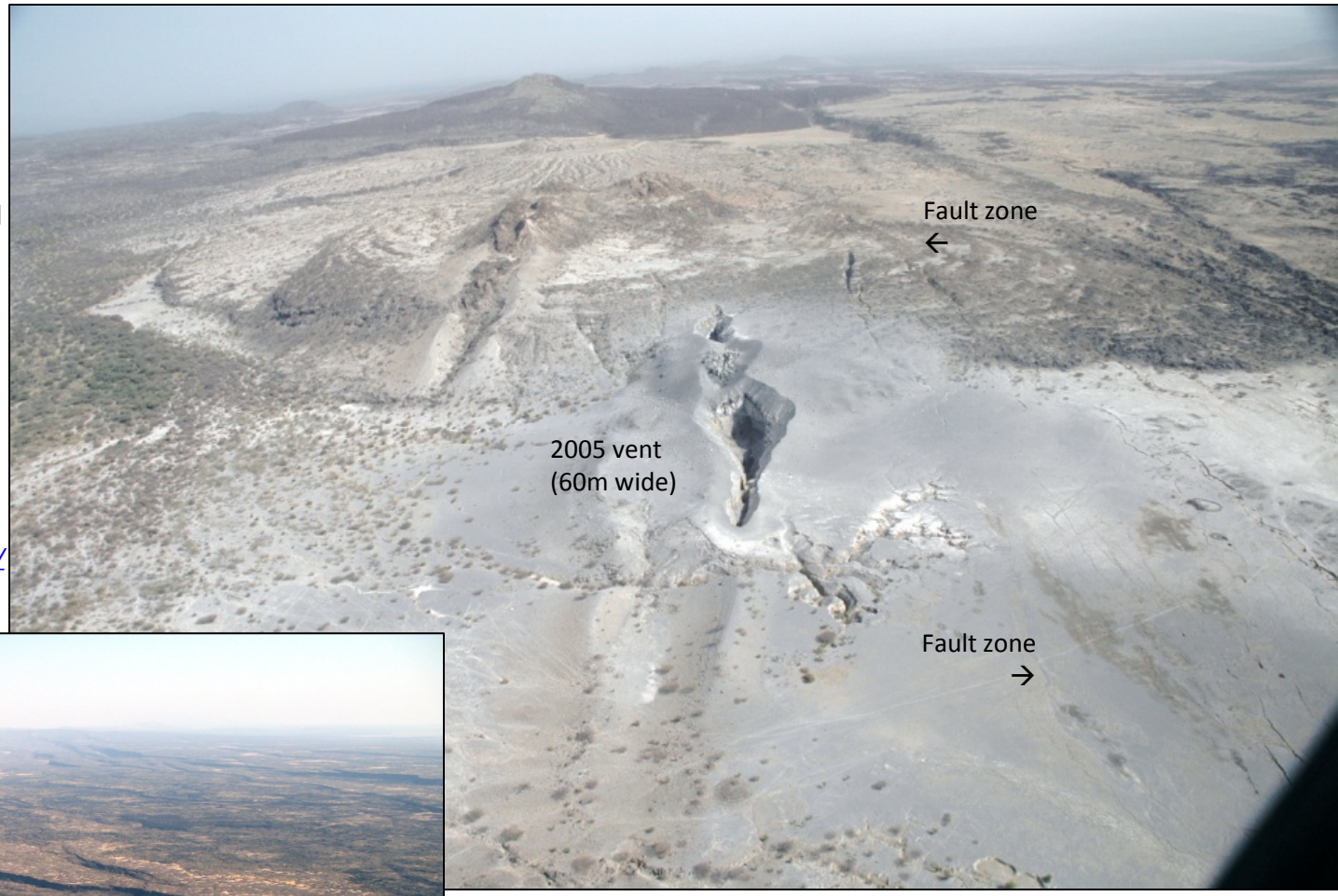
From Wright et al., 2006; Shaded relief map derived from the Shuttle Radar Topographic Mission elevation model.

East African Rift: Afar Rift, Dabbahu eruption September 2005

Data: Divergent Plate Boundaries

Photo looking N of the explosive vent that opened on September 26, after two days of nearly continuous seismic activity. To the right of the ~60 m-wide vent lies a 200 m-wide, 4 km-long zone of open fissures and normal faults that may mark the subsurface location of the dike that transported magma to the surface. The fault zone continues to the top of the photo to the right of the small rhyolite centre.

Photo Elizabeth Baker, Royal Holloway, University of London
http://homepages.see.leeds.ac.uk/~eartjw/dabbahu/fig4.jpg



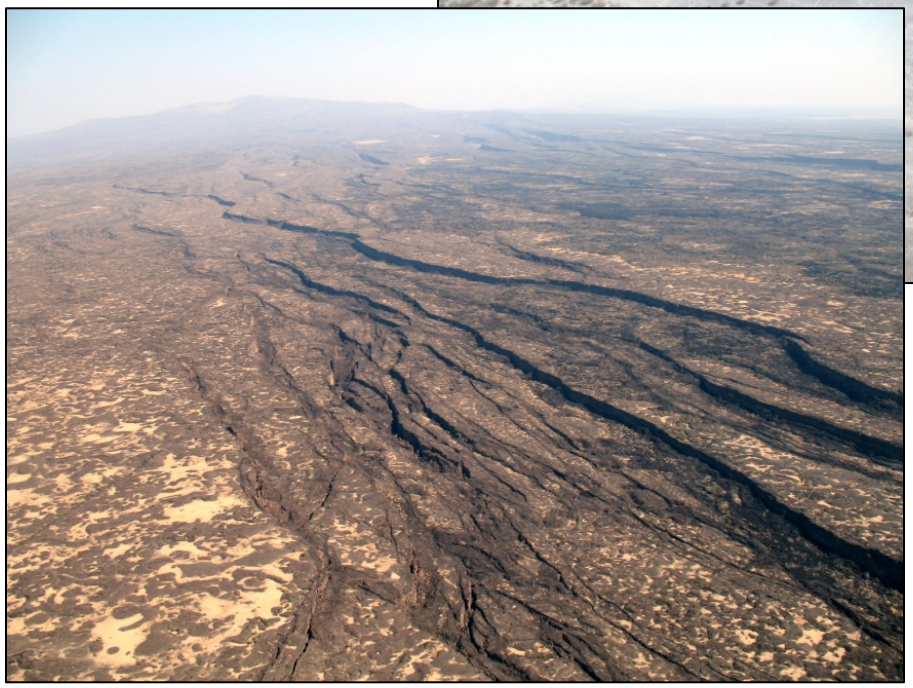


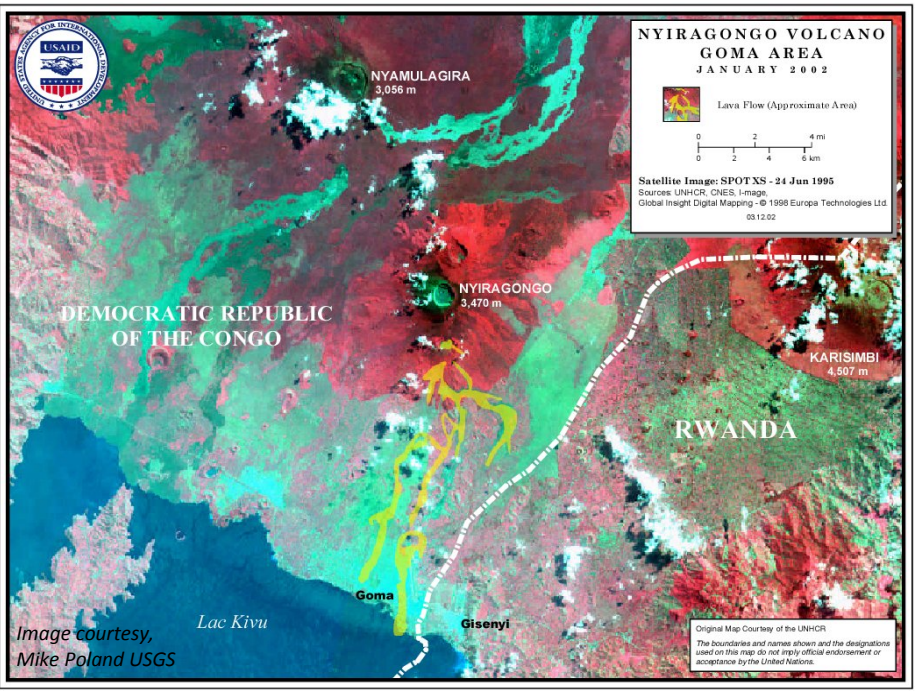
Photo looking NNW from the central part of the eastern flank of the Dabbahu rift segment. Dabbahu volcano is ~30 km NW of this site (see rift zone and volcano on figure previous page). Steep scarps were formed by many episodes of offset along dipping fault surfaces; some faults show more than 3 m of movement from the 2005 episode. Faults displace basaltic lavas (dark rocks) and small pockets of windblown ash and dust (white rocks).

Photo by Cindy Ebinger, University of Rochester, New York.
http://homepages.see.leeds.ac.uk/~eartjw/dabbahu/fig6.jpg

East African Rift, Nyiragongo eruption January 2002

Data: Divergent Plate Boundaries

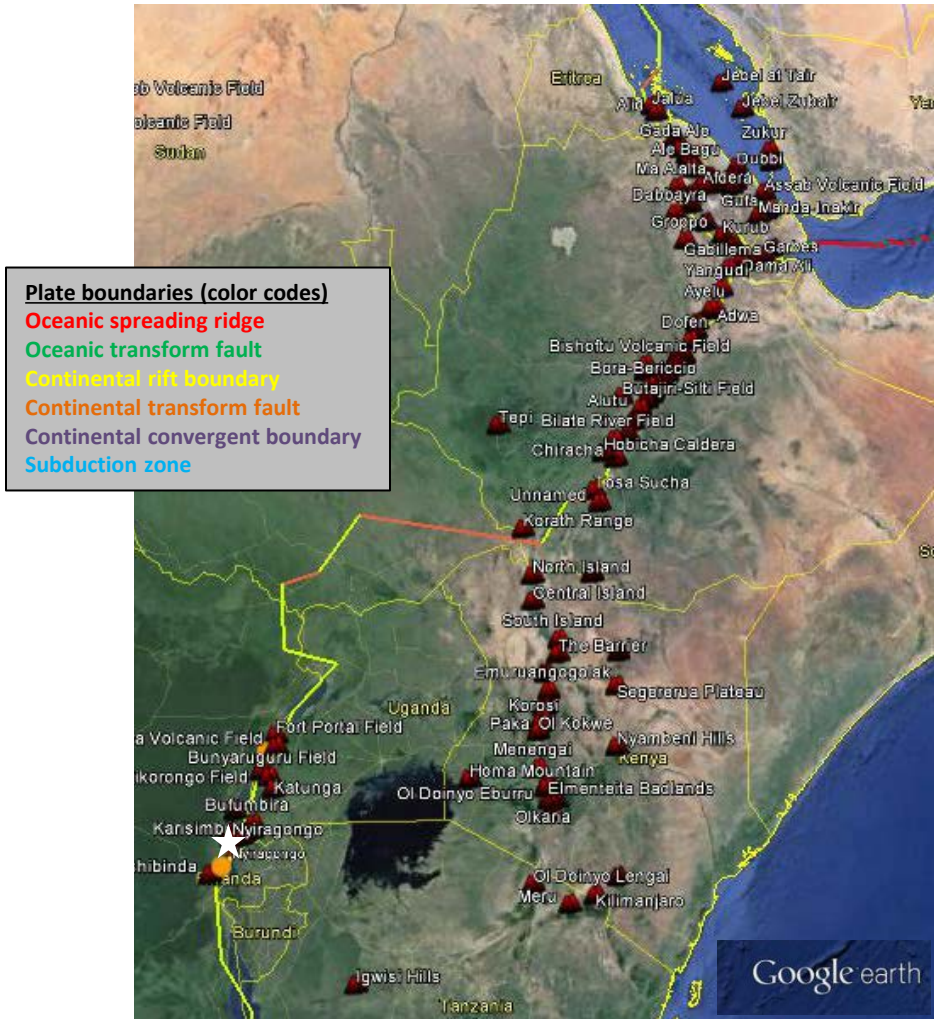
An eruption began at Nyiragongo on January 17, 2002 and, according to news reports, as of January 18th lava flows had destroyed parts of 14 villages and 45 people had been killed. Fissures north of the Goma Airport opened and lava flowed from them at an estimated 2-3 m/min (1.2-1.8 km/hour) towards the town of Goma, ~10 km S of the volcano.



Late in the day, at least one flow had advanced more than 17 km into Goma (population 400,000). Gas stations exploded as the flows advanced through Goma, cutting a reported 35-70 m swath through the town as it flowed towards Lake Kivu. In places, the low viscosity basaltic lava flows were 2 meters high and 30 m wide. Lava flows damaged 14 villages as they destroyed everything in their paths including, buildings, homes, and the port in Goma.

Global Volcanism Network:
www.volcano.si.edu/volcano.cfm?vn=223030#January2002

Below: Google Earth map of volcanoes and plate boundaries of the central part of the East African Rift in the area of Nyiragongo (white star). *Map from Google Earth, Map Data from US Dept of State Geography, 2014, ORION ME Image Landsat; Volcano locations compiled by the Global Volcanism Program, Smithsonian Institution; http://www.volcano.si.edu/ge/GVPWorldVolcanoes-List.kmz; Plate boundaries from*, Geochemistry Geophysics Geosystems, 4(3), 1027; http://element.ess.ucla.edu/publications/2003_PB2002/2003_PB2002.htm. Converted into Google Earth format by Thomas Christian Chust.



East African Rift, Nyiragongo eruption January 2002

A Goma resident indicated that by the morning of January 18th, earthquake activity had died down from "about one every 40 seconds to one per hour."
Lava continued to flow, but was no longer a threat to the road linking Goma with Rwanda.

On January 28th, a UN Volcano Surveillance Team visited Nyiragongo's main crater and observed that the crater floor had almost completely collapsed - more than 600 m. At that time they saw neither ongoing volcanism nor active fumaroles at the bottom of the crater, although they could smell SO_2 gas. A few weak steam vents were visible on the inner crater wall and a small gas plume was seen above the northeast crater rim.

The city of Goma and surrounding areas evacuated, with about 300,000 people moving east towards Rwanda to the town of Gisenyi. Others moved west on the road toward the town of Sake. United Nations officials reported that 45 people were killed by the eruption as of January 18, possibly as a result of remaining in their homes which burned or collapsed.

50-100 people were killed when hot lava caused gas station tanks to explode at 0830 on January 21st. Approximately 400 people suffered from injuries including burns. Beginning around January 19th, many Goma residents returned to the city. By January 21st there were ~12,000 homeless families in Goma.

As the eruption progressed, some scientists were concerned that either seismic activity or lava entering Lake Kivu, could cause overturn of the lake and release significant amounts of carbon dioxide and methane gas lying at the bottom of the lake. This happened at Lake Nyos, Cameroon in 1986, resulting in the asphyxiation of nearly 1800 people. Fortunately, overturn and gas emissions did not occur during the 2002 Nyiragongo eruption, but Lake Kivu is known to have high concentrations of dissolved gases, so remains a concern for future seismic and eruptive activity.

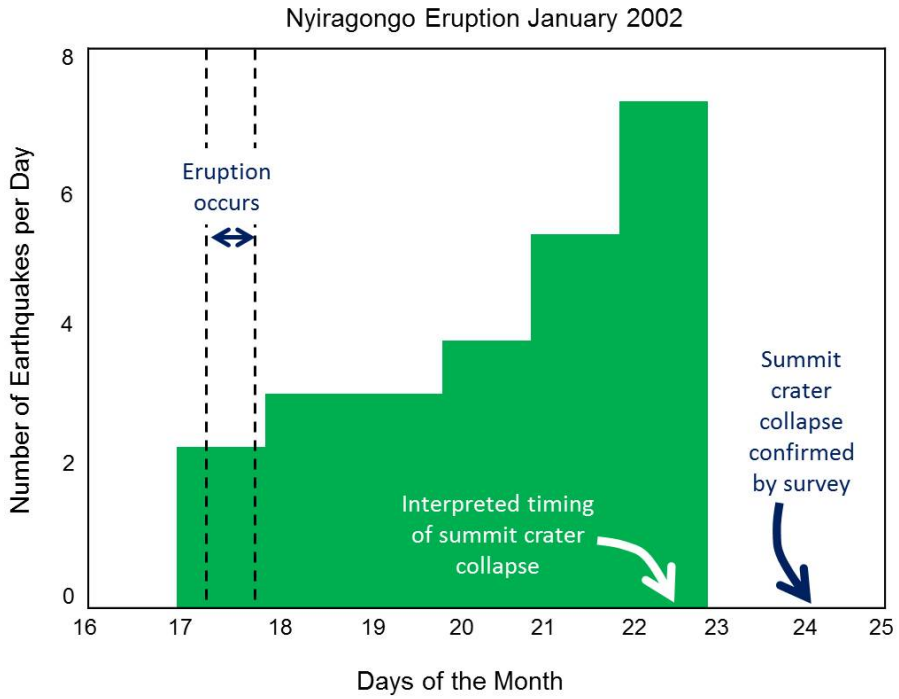
Information from Global Volcanism Network:
http://www.volcano.si.edu/volcano.cfm?vn=223030#January2002
Upper photos courtesy, Jack Lockwood, USGS

East African Rift, Nyiragongo eruption January 2002

Data: Divergent Plate Boundaries

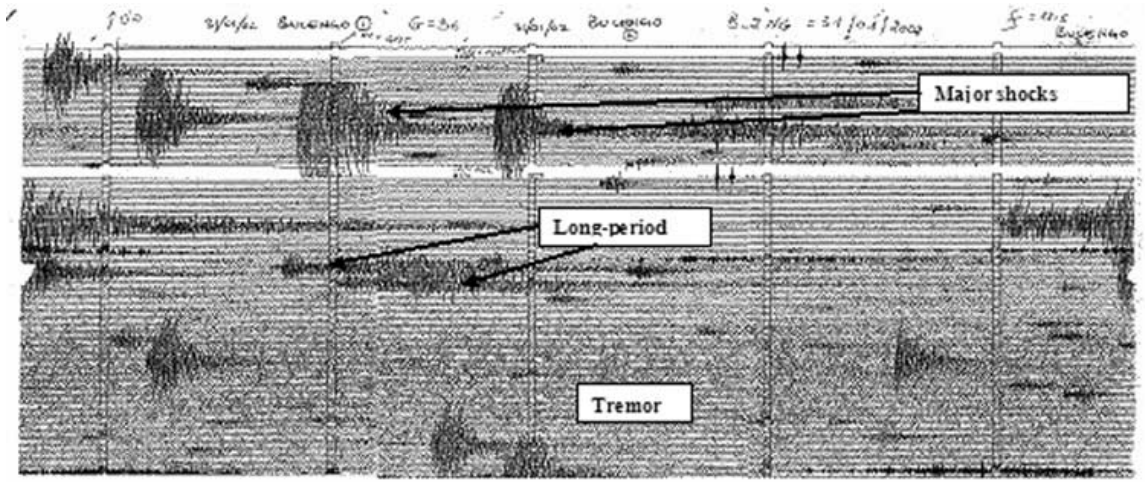
An unusual number of tectonic earthquakes in the Goma-Nyiragongo region occurred in the region at approximately 5:00 AM local time on January 17th, which was about 9 hours *after* Nyiragongo's first reported lava flows. The seismic sequence included about 100 earthquakes of M 3.5 or larger. The largest earthquake was M 5; it struck just after midnight on January 20th. According to news reports, several earthquakes were of sufficient magnitude to have been felt in the Goma region.

Information from Global Volcanism Network:
http://www.volcano.si.edu/volcano.cfm?vn=223030#January2002



The figure at right shows the number of earthquakes (green bars) that occurred each day before and after the 2002 eruption of Nyiragongo. The white arrow on Jan 22 represents the time when the collapse of the summit crater is thought to have occurred, according to seismic observations and local reports. The blue arrow indicates the date when the crater collapse was confirmed by a helicopter survey (Jan 24).

Note that the large earthquakes occurred after the start of the eruption, but before the crater collapse. Seismicity increased *after* the eruption, reaching its maximum on the day of the crater collapse event. Data from Shuler et al., 2009.



Right: Typical seismogram a week *after* the eruption (January 31, 2002). Three types of earthquake are visible: major (tectonic) shocks, long-period earthquakes, and volcanic tremor.

From Tedesco et al., 2007

Image credits slide 2:
Top Right: Google Earth with data from: Landsat, IBCAO, SIO, NOAA, US Navy, NGA, GEBCO
Bottom Left: Image from Magnus T Gudmundsson, University of Iceland, used with permission
Lower Right: from Smithsonian Institution, Global Volcanism Network (GVN), available at, http://www.volcano.si.edu/volcano.cfm?vn=373010#October2004 accessed December 2013
Image credits slides 3-5:
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Right: From Tim Wright, available at http://homepages.see.leeds.ac.uk/~eartjw/dabbahu/fig1.jpg, Accessed December 2013, used with permission
Left: from Global Volcanism Network http://www.volcano.si.edu/volcano.cfm?vn=221113, accessed December 2013
Image Credit slide 7:
Left Map: Map Data from US Dept of State Geography, 2014, ORION ME Image Landsat; Volcano locations compiled by the Global Volcanism Program, Smithsonian Institution; http://www.volcano.si.edu/ge/GVPWorldVolcanoes-List.kmz; Plate boundaries from plate boundaries, Geochemistry Geophysics Geosystems, 4, 1027 http://element.ess.ucla.edu/publications/2003_PB2002/2003_PB2002.htm Converted into Google Earth format by Thomas Christian Chust.
Map lower right: From Wright et al., 2006; Shaded relief map derived from the Shuttle Radar Topographic Mission elevation model.
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Right: from Google Earth with image from Landsat, 2013 ORION-ME and data from SIO, NOAA, US Navy, NGA, GEBCO
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