WORKSHOP NOTES

These notes were taken by Gillian. Read with reference to the workshop agenda at http://www.mantleplumes.org/NAWorkshop/NAWorkshop2.html

Intraplate deformation

Rift obliquity - Dieter & Tony to send paper Sacha Brune et al. (2012). Jim asked what we are trying to achieve at the current workshop. Laurent Geof.: magmatic/non-magmatic margins - latter store magma in the mantle?

Ármann: Ridge ages W Iceland 14.2, 9.9, 5.3 and 2.0 Ma.

What is the spreading rate N of the CGFZ? Same as Iceland. South of Bight FZ - a mini Iceland? - diffuse volcanic and scoria cones = CO_2 excess. A lot of off-axis volcanism also N of Bight FZ. Peridotite in core complexes at BFZ. Reykjanes Ridge has been re-orienting since 25 Ma = when Aegir Ridge became extinct. Malcolm: Snaefells basalts "uniquely odd". Jim: hi/lo Ti. Dieter: why RR homogeneous if very different processes with latitude?

RR propagation talk: 30-40˚ oblique strike. ~ C18 (40 Ma) change in strike of boundary - Labrador Sea cessation of spreading. Hey et al. (1988). Previous transforms visible in bathymetry signal of younger rocks. Jim: Ridge shortening itself by going from orthogonal ridge-transform geometry to oblique ridge? [Gillian: ...actually, when you think of it, if a ridge goes from spreading-orthogonal ridge-transform geometry to "oblique", i.e. very many en-echelon overlapping segments, then the total amount of ridge is increasing and it is getting wider because of the overlaps...]

Norway/Greenland: L. Geof: grav/mag magmatism correlates with structure in oceanic domain. C24 seen all the way to the N pole. Skaergaard etc. magmatic systems long lived ~ 1 Ma, = segmentation existed from the start. Spacing related to lithosphere thickness. Small-scale convection (SSC) appears at the time of breakup? What could happen in N Atlantic to develop SSC cells?

Dieter: Cruise to JMFZ and N in Sept. Eldholm (2002) volume estimates may be biased by amount of study. Norway/Greenland VMs not symmetrical. Near W end of JMFZ - conventional wisdom least SDR/volcanics where largest LCHVB's - does not make sense. Therefore Dieter suggests LCBs much later than VMs. Laurent Gern: Hogur(?) LCB velocity

7-8 km/s controls breakup, therefore pre-dates breakup. L. Geof: highly stretched in the Jurassic, very thick crust, much intrusives. Dieter: mismatch between thickness of LCB from Greenland to Norway. Southerly decrease in magma volume. S propagating rift.

Laurent Geof.: suggests oceanic accretion requires 6-7-km-thick crust, otherwise continental extension with large faults. Dieter suggests C24 traceable across but breakup occurred later in S. Questions SDR NE of JMMC in SA - big difference between SDR on W & E coasts. Prefer explanation of oblique breakup N of JMFZ. Norway Basin - C25 Eurasian Basin & N of JMFZ - C24. N of JMFZ - Eurasian Basin - later - ~ C18 (40 Ma).

Laurent Gern: full breakup ~ C7-6 (~23-25 Ma). No magmatism associated with W Norway boundary. LCB's - W Norway, Vøring Basin, continental margins and in oceanic domain (control breakup so cannot be underplating - pre-existing in LC - Caledonides - agrees with gravity, disagrees with Lundin/Doré idea which involves weak serpentinised material. 7.1 Vp - no demagnetisation thus no serpentinisation?

Grabens on RR: Nick: Polotus(?) margin? Dieter: graben = lacking magma, inward dipping faults with magma? Large amount of literature on rift formation on slow-spreading ridges. Palmason model. Ármann thinks this is rubbish. (why?)

Laurent Gern.: SDR divided W of main axis of Mesozoic xtension. Initial hyperextension and exhumed mantle and serpentinisation. Randell: Is it possible to have sea-floor spreading and hyperextention together? Nick: hyperextension/hyper-thinning? Thinning to 10 km may not be enough to result in serpentinisation. Laurent Gern: what relationship between hyperextension, serpentinisation and localisation of breakup? Do all the LCBs represent serpentinisation? Some existed before breakup. LCB 7.12 - 7.5 km/s "outside volcanic province". LCBs Reynisson et al. (2011). Osmundsen et al. (2017) comparison of Iberia and Møre margins flawed because Møre much thicker crust. Nick: Osmundsen paper over-interpreted. Iberian margin 20-30 Ma breakup period. Møre - Tony Doré modelling compressions around Iceland arc? Dieter: Nature of LCBs. Nick: when breakup started? - Jurassic? Cretaceous? - how early? How relevant is this?

Tony Doré talk: Did Atlantic re-open in same place as before - Wilson hypothesis. Answer: No. or qualified yes. Caledonian suture passes through Scotland, Denmark, Norway margin. GeoTech Atlas. N Atlantic originally pre-disposed to breakup by transform motion. 80 Ma. N Atlantic breakup predisposed by shear. Palaeocene rifting? None except for Hel graben? Releasing bend at Iceland? Dyking in Faeroes? Extensional dykes prior to breakup. Laurent Geof: NS transtension. Malcolm: geochemistry in wells and subaerial material. Laurent Gern: Palaeocene, not Campanian start of breakup. Nick: sharpness of breakup SE Greenland consistent with strike-slip line.

Discussion: Dieter idea: open file and type bullet points. Pauline Chenin work on inheritance. 1. Review, 2. How applicable is Wilson cycle? Maybe paper finish with where it works and where it doesn't.

Laurent Geof. talk: C24 - kinematic change in Labrador Sea. C13 - end of LBA spreading, shift from Aegir -> Kolbeinsey. Which is the driver? Timing: 2 hypotheses: 1. magnetic lineation = oceanic crust, 2. cannot have continuous stretching and sea-floor-spreading simultaneously. C27-24 DS transtension, transpressive further N. Baffin Bay Palaeocene

crust? no. Details of region in NW Greenland in Baffin Bay. Continental extension seen in SDR Palaeocene. 400% of crustal extension strictly continental - real oceanic crust in BB all Eocene or younger. Breakup of LBA same time as NA (C24n?). Far field stresses or mantle dynamics? Ungava syn-magmatic barrier. Randell: FFS. Nielsen paper Nielsen et al., (2007). Tony: what propels Greenland N? BB 55. Nick: BB linked to Eurasian Basin, not so much N Atlantic. Tony: little motion on "Wegener Fault". Melville Graben (120-100 Ma) NW Greenland - very spectacular. Continental rift with 20 km heave? More extension than Viking Graben. Randell: Cretaceous extension also around Baffin Bay. Nick: original rift proposed before Labrador Sea opens. 25 Ma Iceland cut off from mainland.

Ármann Iceland paper: freshwater miocrobes in Iceland that separated at 25 Ma = when Aegir Ridge died. Small mammal bone. Laurent Geof.: Laxmi basin W of India = continental block. Is Iceland exactly the same? Thickness 20 km in Laxmi, Iceland up to 30/40 km? Stuff should be in Alex paper? Shifting of plate boundaries? zircons. Laurent Gern: need data from IFR. Nick: analog with Afar. Jim: Iceland geochemistry interaction of MORB with silicic material.

Søren talk delivered by Christian: fission track data. a) Paul Green/Japsen, b) McGregor thesis, Randell supervisor. Uplift LS Jurassic? No evidence? Data from Norway, Britain. Vivi involvement? Overview of all uplift? Glaciated surface, need paper on whole uplift saga of N Atlantic margins. Tony, Martyn, Vivi, Bremen group. Cornelia Spiegel (Bremen) including offshore signature - sediment. Modelling of some anomalous tracks. Nussaq case history local - need review of whole NA province.

Malcolm presentation: A) Well 211715-1 N of Faeroes. 2.6 km basalts, unconformity, enriched above, MORB below, basin-wide repeated uplift/subsidence, B) experimental damp melting ppm water in olivine UM - 50-200. 1st contraint melting 60˚ hotter UM required = 1410˚ ridges. Sarafian, Science 355, 942 (2017). Iceland 1480 + 200 ppm = 1410˚, only ~ 30˚ higher than MOR. Azores 570-680 ppm H_2O -> Tp 1420 - 10˚ higher than MOR. Oxidation state (input for modelling T) - more FeO - higher T's. Oxidation state affected by H_2O and O states may be different top and bottom of melting column. Tests on RR reduced by 50˚ if oxidation state taken into consideration. Dry peridotite cannot generate enough melt. Pyroxenite can but where is it? No evidence of pyroxenite in Iceland source, c.f. Hawaii so must appeal to water. Are regions of excess magma produced just where H_2O is? Nick: H_2O can explain post-breakup magmatism.

Jim talk: "you do not mainline the mantle!" Cannot use olivine fractionation modelling. Al-in-olivine might help? No. Spinel: grows on boundaries of olivines. Olivine contains excess Cr-spinel (black) [Al-spinel brown]. Not equilibrium crystallization. Phosphorous in olivine. Phosphorous zoning in olivines. Because of complications get various T's from olivine-spinel geothermometer. Wan et al. spiked their samples and result in higher T from geothermometer. Not equilibrium results. Mathews et al. (2016). Iceland. Hottest thing Borgarhraun, Theistareykir, possibly up to 1400+something. Malcolm: Jan Mayen basalts similar to Snaefells (-jökull or in the E?). Not good theory for H_2O in olivine.

Discussion of T paper: Include LCB's? [Malcolm straw man paper framework]. Laurent Geof: Rudnick compilation of LCBs L crust > 7 km/s explanation for inner margin but not outer? suggest LC sheared. Why dips toward continents? Possibly because shear at UC/LC

boundary? i.e. UC decoupled from LC and LC flowing. Malcolm: need recycled material to explain geochemistry. Could be source. Jim: Lower crust oceanic rocks must be deformed but layering described by Laurent Geof. not seen. Reflectors amphibolites? Temperature paper split into two? Compilation of ages of magmatic rocks into overview paper (Malcolm to provide). Single map format? Dieter? Placeholder titles and framework to GRF.

Nick presentation: outline for paper projected and questions. Date 1.2 Ga (= Congo craton) for RGR granites. 130 Ma separation of RGR/Walvis Ridge, 15 Ma later N of RGR/Walvis ridge. Ridge jump series W of RGR, fan-shaped opening E of MOR at ~ 80 Ma. RGR W different W -> E across RGR. Description of Crozet/Reunion/Laxmi ridge, evolution of Central Atlantic, restoration to 150 Ma. New England seamounts = boundary of N African craton. M0 anomaly changes character radically across seamount chain. Lanzaroitti/ Venturfurata continental sliver pulled off Africa.

Questions:

-Why ridge jumps & magmatism?

- Why continental crust

- are these regions underlain by continental crust?

- do ridges jump to rheological weaknesses?

- can it be explained by H_2O?

- Overlap with Alex paper?

Nick: Iceland and Mauritius already published in *Nature Geoscience* and *PNAS*. Malcolm, Jim and two Laurents to join Nick paper? Dieter: high praise for Nick presentation, suggests attacking plume hypothesis. Title is critical. Leave title to last? 2 figs and ~ 5 pages each of 5 cases.

Alex talk given by Jordan: Describes a field area in E Newfoundland. Field assessment of stress directions, basement fabric, modelling of extension to separate Newfoundland and Greenland results in NE-trending split. Numerical modelling of interaction of pre-existing fabric and extensional stress.

Randell talk: Basin inversion linking of opening with basin inversions Nielsen (2007) paper. Relaxation of European plate results in shift of depositional basins. Question: do we have to have a hot lithosphere? paper called "Hot and Wet"? on back-arc basins but there very cold lithosphere. Discussion of ESR paper. Plan to extend work to larger area including rest of world. Nick: Tornquist line. [Niels Balling, Aarhus, an expert on the Tessyere/Tornqusit zone.] Since he will be anyways invol ved in the “strucutre” paper, together with me, he might be able to contribute to this topic.]Radial fracture system in Pangea modelling heatflow in shortening basin. Sediments less thermally conductive than surrounding rocks results in thermal effect guiding formation of new faults and deformation style. *Nature Geocience* paper (2009). Eurekan orogeny crustal geophysical survey of Ellesmere Island. C24 change in kinematics. Greenland collides with Ellesmere Island = Eurekan orogeny. Oakey & Stephenson (2008?). Schiffer (2016) paper structure of Ellesmere Island. New paper Stephenson et al. (2017= cross-section of Ellesmere Island and Schiffer & Stephenson

(2017). Karsten Piepjohn geological cross section (Piepjohn & von Gosen (2017)? 10's of km of shortening at most Eurekan orogeny.

Dieter talk: Initial opening of E basin Bergler et al. No compression N Jessup Rise, Yermak Plateau (Fig 1). Lines shot. Initial rifting perpendicular to today's. Transform motion along strike-slip fault along N edge of continental shelf. Split off Lomonosov Ridge C24-25 of Baja California. Continent/ocean edge very sharp - suggests transform. Nick: discussion of complex breakup of Arctic. Dieter: Eurasian basin Carboniferous sedimentary basin broke up C24. How old pre-breakup thinning? Edge (Minakov paper) very sharp - fast? Randell paper: -> Eurekan to Caspian Sea. Looking for reactivated faults without Ellesmere Island and Svalbard. Common approach to reconstructions.

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Durham, May 2017