# Bitumen and hydrocarbon fluid inclusions in the Ilimaussaq alkaline intrusion, South Greenland

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The Ilimaussaq intrusion belonging to the Gardar rift zone solidified at 3-4 km depth 1.16 Ga ago. The exposed rocks of the intrusion have attracted much attention, due to their richness in rare minerals. The rocks were also found to be rich in hydrocarbon fluid inclusions mostly secondary in origin containing up 500 ppm C by weight in the mineral sodalite [1]. Hydrocarbon gases released by crushing are rich in methane with up to 20 percent C2+ by weight. From isotopic analyses of the gases ($\delta^{13}C$-$CH_4$: -1 to -7 ‰; $\delta^{13}C$-$C_2H_6$: -10 to -15 ‰) it was concluded that the hydrocarbons were abiotic most likely magmatic in origin [2, 3]. Bitumen extracted by chloroform and analyzed by infrared spectroscopy was also considered to be abiotic in origin [2].

New analyses of the bitumen, up to 300 ppm by weight in whole rock samples, by GCMS and GCMS/MS revealed the presence of biomarkers suggesting a biological origin of the bitumen. Furthermore, the presence of bicadinane among the biomarkers constrain the age of the organic source, or part of it, to Late Cretaceous or later. Oil seeps containing this particular biomarker were also observed much further north in West Greenland around Disko [4], in an area which had been subjected to subsidence and subsequent up-lift during Cretaceous-Palaeogene times [5].

The area around Ilimaussaq consists of granitic bedrock, Proterozoic continental sandstones and lavas devoid of organic matter. However, recent studies including apatite fission-track analysis suggests that this area too, has been subjected to subsidence and up-lift (Japsen, pers. comm.), thereby offering an explanation for the presence of bitumen.

Severe degradation of the bitumen might have been expected considering the high calculated temperatures of entrapment of hydrocarbons 450°C or more for inclusions in the matrix minerals [1] and 200-300°C for vein minerals, but this is not the case. New hydrocarbon gas isotopic data [6] indicate that hydrocarbon entrapment occurred more than once, which may explain the discrepancy between calculated temperatures and expected degree of degradation.

[1] Konnerup-Madsen *et al*. (1979) *Bull. Minéral*. **102**, 642-653. [2] Petersilie & Sørensen (1970) *Lithos* **3**, 59-76. [3] Konnerup-Madsen *et al*. (1988) *Bull. Minéral*. **111**, 567-576. [4] Bojesen-Koefoed *et al*. (2007) *J Petrol. Geol*. **30**, 219-236 [5] Japsen *et al.* (2009) *ESPL* **34**, DOI: 10.1002/esp1766. [6] Graser *et al*. (2008) *Lithos* **106**, 207-221.

# Aerosol radiative forcing estimated from *in situ* measurements at the NCO-P station (5100m, Nepal)

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The presence of optically active material such as Black Carbon (BC) in aerosol particles affects the energy budget of the atmosphere. Recent findings of very elevated BC concentrations at the high altitude station of Nepal Climate Observatory- Pyramid (Nepal, 5100 m) [2] raised concerned about potential consequences of regional pollution on the mountain environment. The transport of anthropogenic BC up to the high altitude, partly driven by orographic lifting, and its impact on atmospheric radiative forcing with respect to natural optically-active aerosols (mineral dust) must therefore be assessed. In addition, BC deposits to nearby snow surfaces, absorbs light, thus decreases the albedo of the snow and alters the energy budget of snow surfaces. Flanner *et al*. [3] calculated that the instantaneous forcing over the Tibetan Plateau, due to the presence of BC in snow, exceeds 20 $Wm^{-2}$ in some places confirming that snow darkening is an important component of carbon aerosol climate forcing.

In this work, we present a 3-year survey of aerosol optical properties (AOD, scattering and absoption coefficients) at the NCO-Pyramid station located in the Khumbu valley (5100 m, Nepal). Optically active material emitted in the within the Nepal/Indian plains travelled up mountain slopes to high elevations. In addition, episodes of long-range transport from India and Pakistan also contribute to elevated levels of BC and dust measured at the station. Based on air mass back-trajectory analysis, we provide the first estimates of local aerosol radiative forcing for typical conditions encountered in the high altitude in the Himalaya area.

[1] Venzac *et al*. (2008) *PNAS* **105** (41), 15666-15671 [2] Bonasoni *et al*. (2008) *Sci. Total Environ*. **391** (2-3), 252-261. [3] Flanner *et al*. (2007) *J. Geophys. Res.* **112**, D11202.