Integration of drilling mud gas monitoring, downhole geophysical logging and drill core analysis identifies gas inflow zones in borehole COSC-1, Sweden

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Identification of gas inflow zones in the COSC-1 borehole (Jämtland, central Sweden) by drilling mud gas monitoring, downhole geophysical logging and drill core analysis

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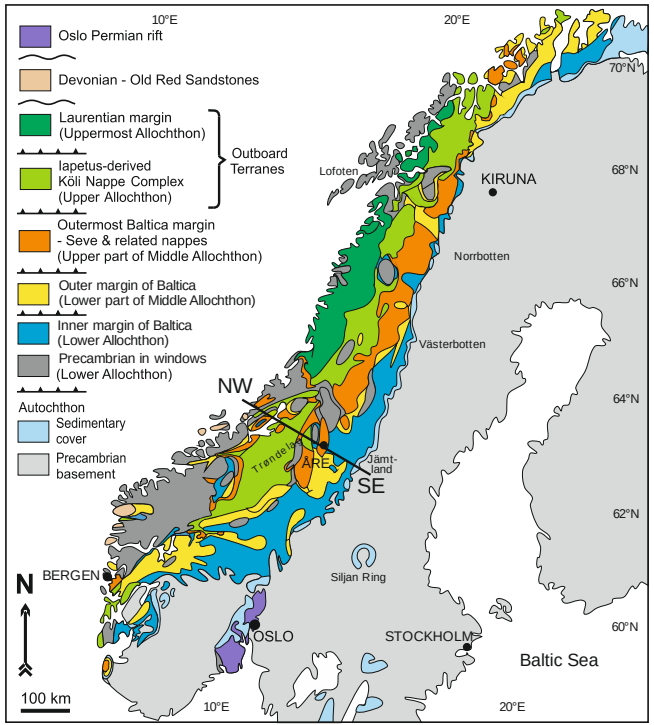
Key message

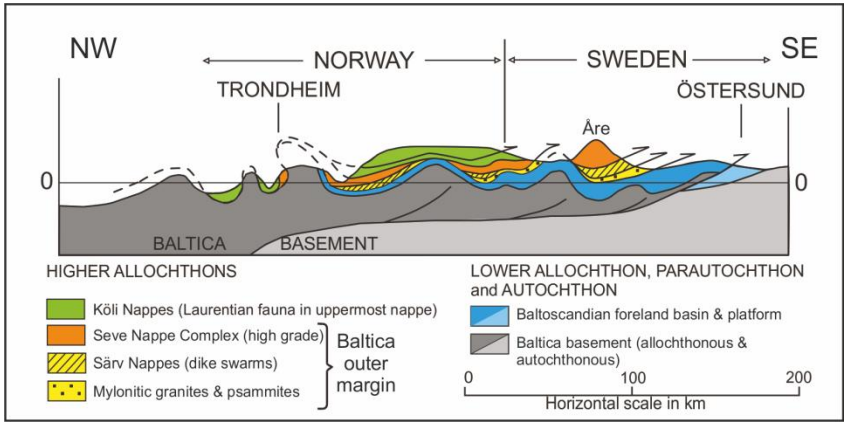
The COSC-1 borehole was investigated by geochemical and geophysical methods to identify gas bearing strata, including

- OnLine Gas Analysis of drilling mud (OLGA)
- Downhole geophysical logging (Borehole Televiewer BHTV, shallow and deep resistivity logging (DLL_s and DLL_d))
- Visual drill core inspection
- Optical 360° drill core scans

Integrated data analysis identified 16 gas bearing permeable zones between 700 and 1500 m depth

COSC-1 targets and achievments

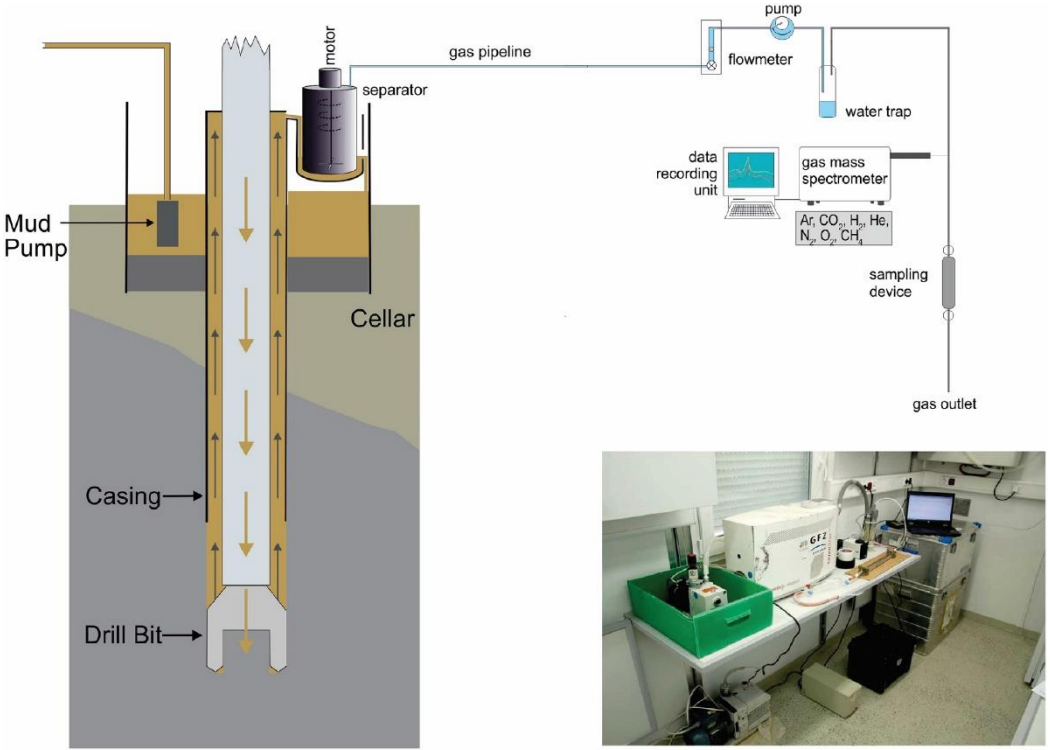




Lorenz et al. (2015), Scientific Drilling

- COSC aims to study mountain building processes in the Scandinavian Caledonides in Sweden (Åre, Jämtland).
- In 2014, the COSC-1 borehole was drilled to a total depth of 2496 m.
- It was fully cored below 103 m with almost 100 % core recovery.

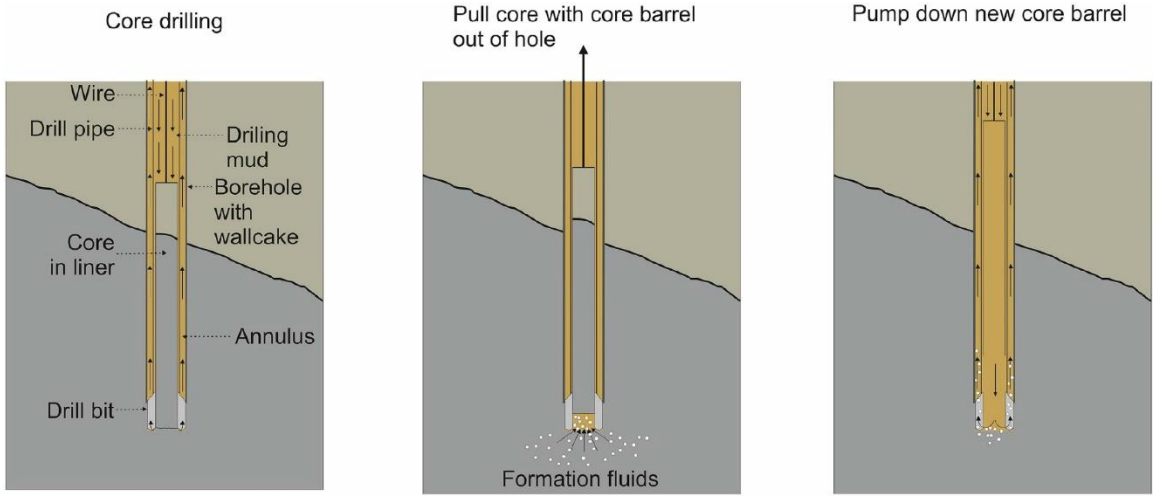
COSC-1 Methods (I)



Set up of OLGA system to detect gas content continuously during drilling of COSC-1 from the circulating drilling mud

Wiersberg et al. (2020), Appl. Geochem.

COSC-1 Methods (I)

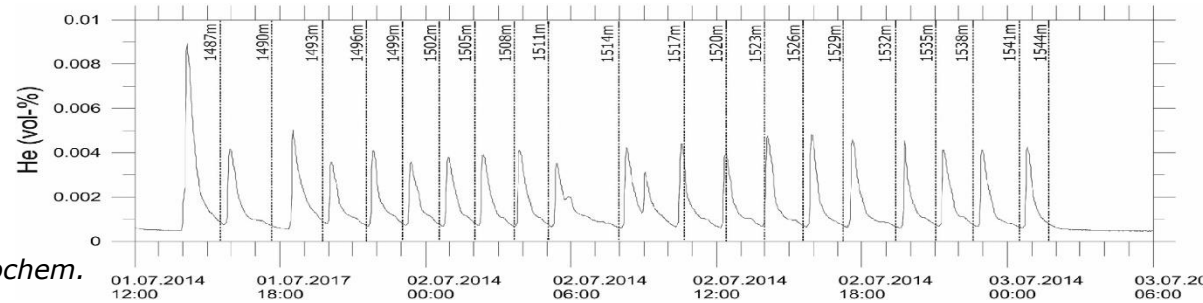


Downhole pressure reduction by core tripping results in formation fluid to flow into the borehole.

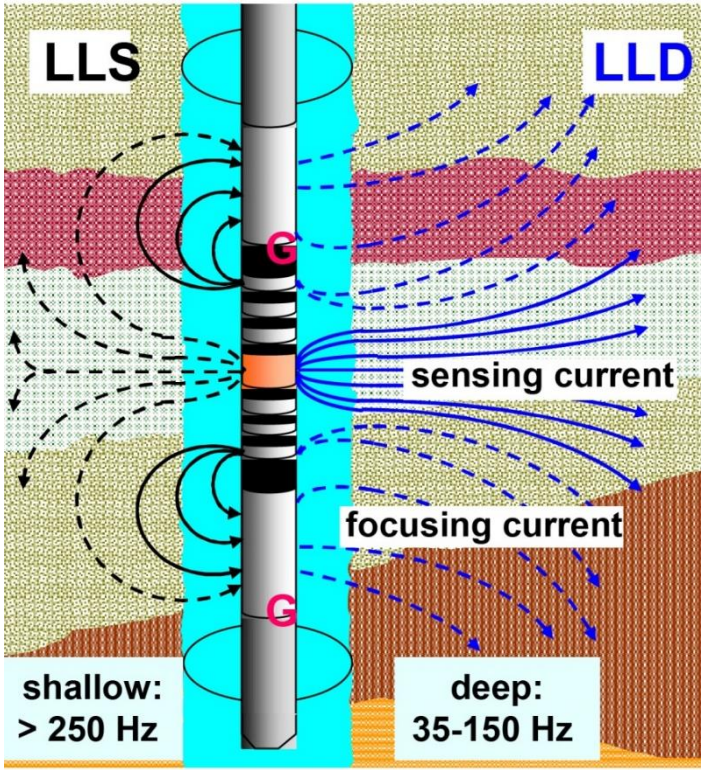
Wiersberg and Erzinger (2011)

Helium gas peaks and core arrival at the surface in a 42 h time window for the depth interval 1487–1544 m.

Wiersberg et al. (2020), Appl. Geochem.



COSC-1 Methods (II)

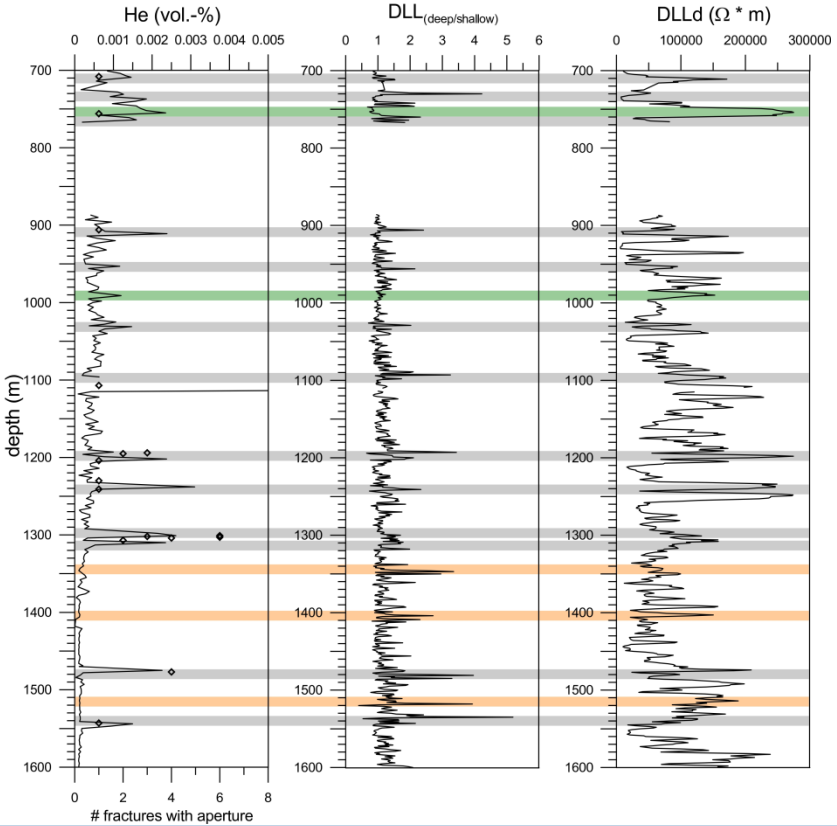


- **Resistivity** is a property of rocks that quantifies the ability of the medium to conduct electricity.

- DLL measurements provide two types of resistivity depths into the rock: DLL_S the zone invaded by drilling mud whereas DLL_D the virgin zone not affected by drilling process

  Two depths of investigation simultaneously:
  deep, LLD: 150 - 220 cm
  shallow, LLS: 60 - 90 cm
  vertical resolution: 60 cm

Data comparision



Enhanced He concentrations and DLLd/DLLs ratios >2 between 700 m and 1500 m indicating the presence of 13 **open fracture bearing zones** containing free gas, three areas containing **free gas (from DLLd/DLLs) without helium peaks**, and two zones display **helium peaks with no enhanced DLLd/DLLs** ratios.

Also shown is the number of fractures with apertures for some of the areas.

Wiersberg et al. (2020), Appl. Geochem.

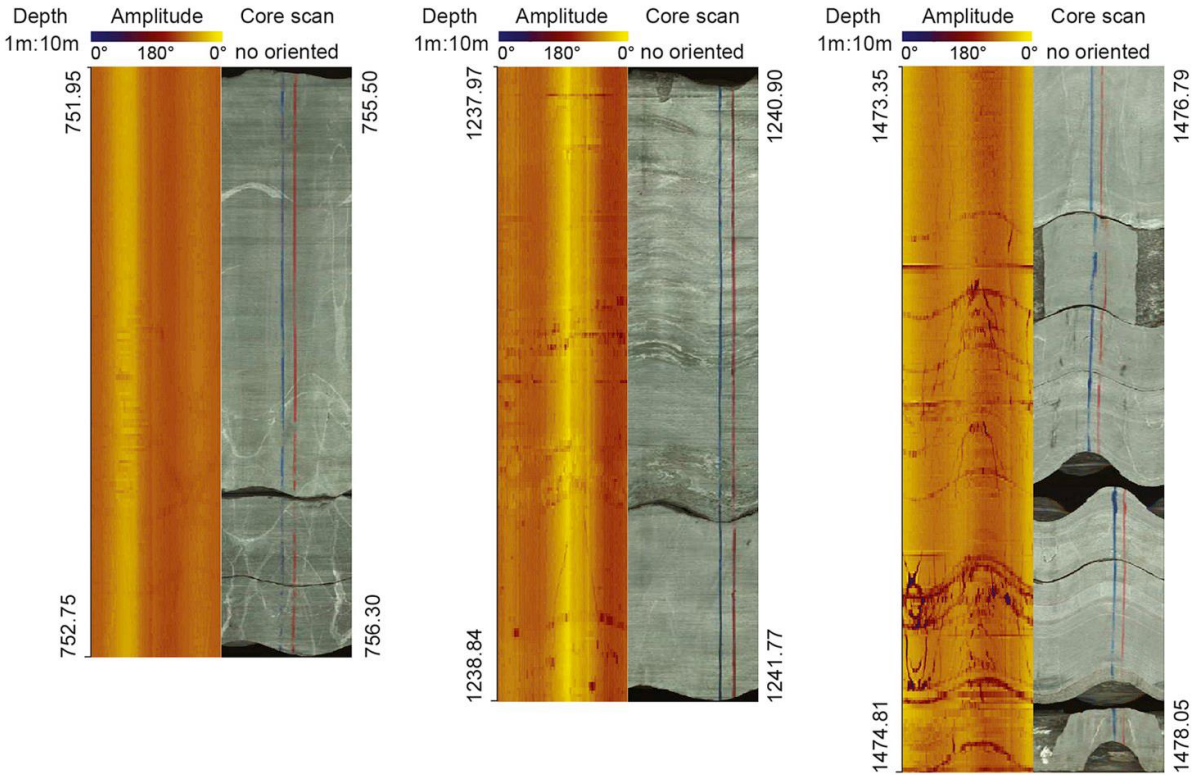
Results

Depth (m)	He from OLGA	DLL_d/DLL_s	BHTV	Fractures in Drill Core	Fracture aperture (mm)	FFEC
695-715	709	712	704.8	708.3	4	696
730	730	730	728.6	732.2	4	-
742-761	755	-	752.5, 757.7	756.1, 760.4	12, 6	-
900-919	911	906	904.1	906.8	4	-
952-956	952	956	n.a.	954.2	4	-
990	990	-	n.a.	988.8	4	-
1024-1030	1030	1029	1031.3	1034.2	8	-
1089-1107	1112*	1089, 1093	1104.4	1107.3	9	-
1191-1208	1201	1193, 1200	1201.8	1204.7	6	1214
1230-1249	1238	1241	1238.6	1241.5	9	1245
1293-1320	1300, 1309	1300, 1309, 1311	1298.4, 1304.3	1301.4, 1307.2	8, 6	-
1346-1350	-	1346, 1347, 1350	n.a.	n.a.	n.a.	-
1404-1412	-	1404, 1407, 1412	n.a.	n.a.	n.a.	-
1468-1486	1475	1480, 1481, 1485	1473.8, 1473.9	1477.2, 1477.4	6, 6	-
1510-1520	-	1517, 1518	n.a.	n.a.	n.a.	-
1532-1555	1544	1543	n.a.	1544.1	7	-

Depths (m) of He peaks identified by OLGA, enhanced DLLd/DLLs ratios indicating free gas, fluid flow from FFEC logging [*Tsang et al., 2016*], fractures with aperture from optical core scanning and visual core inspection, and BHTV [*Wenning et al., 2017*]. *No gas data between 1096 and 1112 m. n.a.= not analysed.

Wiersberg et al. (2020), Appl. Geochem.

Open Fractures



The gas enters the borehole through open fractures, identified by acoustic borehole log and core scan images (left and right, respectively). Dark and bright colours of the amplitude scale indicate low and high amplitude values, respectively. The core scan images are not oriented.

Wiersberg et al. (2020), Appl. Geochem.

Summary and Outlook

- The COSC-1 borehole drilling is the very first project where on-line mud gas monitoring was applied during continuous wireline coring.
- Identification of several gas inflow zones containing helium, methane and hydrogen.
- Several identified gas zones in the depth interval 662–1550 m match with areas of higher resistivity and with open fractures identified by optical core scanning.
- Comparison between OLGA data and DLL data can help to estimate degassing depths: at depths where OLGA identified formation gases, concurrent DLLd/ DLLs ratios >1.5 would be diagnostic for free gas, whereas lower values would imply gases dissolved in formation fluids.

References

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See also Kästner et al. in this session (EGU2020-13955)