**GSA DATA REPOSITORY 2010143**

## Methodology

Around 100-200 g of fresh material was used, taken from larger samples of each fault gouge zone collected in the tunnel. Samples were subsequently gently disaggregated using a repetitive freezing and thawing technique to avoid artificial grain size reduction of rock components and contamination with K-bearing minerals such as K-feldspars and micas (Liewig et al., 1987). Smaller 2, 2-6, and 6-10 μm fractions were separated in distilled water according to Stoke's law. Grain size fractions < 0.4 and 0.1 μm were separated using a high-speed centrifuge. Coarse grain sizes 2-6 and 6-10 μm were investigated to evaluate influence of potential detrital contamination. In addition, K-feldspar fractions were separated from host rock fragments in two samples (Table 3) using standard techniques utilizing heavy liquids (TBE tetrabromoethane) and magnetic separation (Frantz). The K-feldspar grainsize distribution was measured with a laser particle sizer (Malvern mastersizer) yielding a median grainsize of ~ 400 μm. Analytical methods used were XRD (normal and glycolated runs), SEM, TEM and conventional K-Ar dating. The K-Ar dating technique follows standard methods described in detail by Faure (1986). During the course of the study, the international standards GL-O and HD-B1 (Odin et al., 1982; Hess and Lippolt, 1994) were measured several times. The error for Ar analyses is below 1.00 % (Table 5 supplementary material) and the $^{40}Ar/^{36}Ar$ value for airshots averaged 294.17 ± 0.21 ($n$ =12). The K-Ar ages were calculated using $^{40}K$ abundance and decay constants recommended by Steiger and Jäger (1977).

## References

Faure, G., 1986, Principles of isotope geology, John Wiley & Sons, New York, 589 p.

Hess J.C. and Lippolt H.J., 1994, Compilation of K/Ar measurements on HD-B1 standard biotite; 1994 status report., in G. S. Odin (Ed.), Phanerozoic Time Scale, Bulletin de Liaison et d'information, IUGS Subcommission, Geochronology, Paris, 1994, p. 19-23.

Liewig, N., Clauer, N. and Sommer, F., 1987, Rb-Sr and K-Ar dating of clay diagenesis in Jurassic sandstone oil reservoirs, North Sea, American Association of Petroleum Geology Bulletin, v. 71, p. 1467-1474.

Odin, G.S. and 35 collaborators, 1982, Interlaboratory standards for dating purposes, in: Odin, G. S. (Ed.), Numerical Dating in Stratigraphy, Part 1, John Wiley and Sons, Chichester, p. 123-148.

Steiger R.H. and E. Jäger, E.,1977, Subcommission on Geochronology: convention on the use of decay constants in geo-and cosmochronology, Earth and Planetary Science Letters, v. 36, p. 359-362.

**Table DR1: Fault locations and characteristics**

| Fault ID | Tunnel chainage[1] | Swiss Coords[2] | Swiss Coords[3] | Orientation[4] | Mappable Length[5] | Fault width | Measured Gouge width |
|---|---|---|---|---|---|---|---|
| A1 | 154’124 | 712’825 | 138’948 | 240/25 | 650 m | 3-5 m | 5-100 cm |
| A2 | 154’115 | 712’820 | 138’960 | | | | |
| B | 150’995 | 711’560 | 140’900 | 220/80 | 150 m | 1.5 m | 5-15 cm |
| C | 248’602 | 709’780 | 143’600 | 065/30 | 16 m | 5-20 cm | 5-20 cm |
| D | 146’780 | 708’528 | 145’585 | 050/45 | 250 m | 5-20 cm | 5-20 cm |
| E | 245’133 | 707’729 | 146’812 | 052/70 | 35 m | < 5 cm | < 5 cm |
| F | 143’330 | 706’700 | 148’400 | 045/75 | 400 m | 2-4 m | 5-20 cm |
| G | 240’713 | 705’500 | 150’220 | 070/70 | 840 m | 4-6 m | 5-100 cm |
| H1 | 139’765 | 705’021 | 151’040 | 050/70 | 920 m | 20 m | 5-200 cm |
| H2 | 239’204 | 704’697 | 151’508 | | | | |

Notes: 1 First digit is for tunnel identification (1 east, 2 west), the following digits refers to tunnel meters between Erstfeld (00’000) and Bodio (57’000); 2: Swiss National Coordinate system, Easting; 3: Northing; 4: Fault orientation at sample location as dip direction / dip; 5: Minimum horizontal length of the fault from mapped intersection with tunnels or drill core.

**Table DR2: Quantitative mineralogy**

| Sample | Grainsize [μm] | Quartz | Smectite | Illite 1M/1$M_d$ | Illite $2M_1$ | Chlorite | Albite | Orthoclase |
|---|---|---|---|---|---|---|---|---|
| A1 | < 0.4 | - | 28 | 50 | 20 | 2 | - | - |
| A1 | < 2 | - | 34 | 40 | 16 | 10 | - | - |
| A1 | 2-6 | 3 | 15 | 31 | 28 | 10 | 7 | 6 |
| A1 | 6-10 | 6 | 17 | 20 | 29 | 10 | 10 | 8 |
| A2 | < 0.4 | - | - | 45 | - | 55 | - | - |
| A2 | < 2 | - | - | 55 | 18 | 27 | - | - |
| A2 | 2-6 | 1 | - | 27 | 34 | 37 | 1 | 1 |
| A2 | 6-10 | 5 | - | 28 | 17 | 41 | 4 | 5 |
| B | < 2 | - | - | 64 | 19 | 17 | - | - |
| C | < 2 | 2 | 22 | 25 | 27 | 4 | 6 | 14 |
| D | < 0.4 | - | 25 | 17 | 39 | 8 | 4 | 7 |
| D | < 2 | - | 26 | 15 | 42 | 6 | 4 | 7 |
| D | 2-6 | 4 | 34 | 3 | 56 | 2 | - | 2 |
| D | 6-10 | 3 | 32 | 2 | 59 | 2 | - | 2 |
| E | < 2 | - | 28 | 17 | 24 | 21 | 6 | 4 |
| F | < 2 | - | 4 | 7 | 74 | 11 | 4 | - |
| G | < 0.4 | - | 20 | 41 | 18 | 17 | 4 | - |
| G | < 2 | - | 37 | 18 | 29 | 3 | 8 | 5 |
| G | 2-6 | 6 | 17 | 8 | 37 | 15 | 12 | 3 |
| H1 | < 0.4 | - | 38 | 11 | 42 | 10 | - | - |
| H1 | < 2 | 2 | 32 | 4 | 42 | 6 | 8 | 6 |
| H1 | 2-6 | 5 | 28 | 10 | 24 | 9 | 13 | 11 |
| H2 | < 2 | 3 | 31 | 3 | 29 | 22 | 7 | 5 |

Random oriented powder samples were lightly pressed into shallow stainless steel holders for X-ray diffraction analysis. Oriented samples were prepared by dispersing approximately 40 mg of material using ultrasonic agitation in approximately 5 ml of deionised water. The slurries were deposited under suction onto 0.22 μm Duropore© filter membranes, then magnesium saturated twice using 1M $MgCl_2$. The films were washed 5 times with deionised water, then 5 drops of glycerol were added and gently spread over the entire clay surface. The samples remained on the vacuum manifold until all traces of liquid glycerol were gone. The oriented samples were placed onto absorbent paper towels to remove excess glycerol on the backs of the samples before mounting onto 25 mm aluminium discs with double sided tape.

XRD patterns were recorded with a PANalytical X'Pert Pro microprocessor-controlled diffractometer using Fe filtered Co Ka radiation, ¼˚ divergence slit, ½˚ anti-scatter slit and X'Celerator fast Si strip detector. The diffraction patterns were recorded in steps of 0.016˚ 2q with a 1 second counting time per step, and logged to

data files on a PC for analysis using HighScore Plus and XPLOT. Quantitative analysis was performed using SIROQUANT from Sietronics Pty Ltd.

Due to limited sample size it was not possible to obtain XRD polytype data of all sample fractions.

**Table DR3: Age results**

| Sample ID | Grainsize [µm] | K [%] | Rad 40Ar [mol/g] | Rad 40Ar [%] | Age [Ma] | Error [Ma] |
|---|---|---|---|---|---|---|
| A1 | < 0.1 | 5.41 | 3.67700E-11 | 13.42 | 3.91 | 1.48 |
| A1 | < 0.4 | 7.23 | 9.68310E-11 | 41.93 | 7.71 | 0.22 |
| A1 | < 2 | 7.14 | 1.03490E-10 | 60.30 | 8.34 | 0.22 |
| A1 | 2-6 | 7.16 | 1.03490E-10 | 54.46 | 8.31 | 0.18 |
| A1 | 6-10 | 6.82 | 1.04170E-10 | 61.37 | 8.78 | 0.19 |
| A2 | < 0.1 | 5.40 | 6.09240E-11 | 17.56 | 6.49 | 0.40 |
| A2 | < 0.4 | 5.56 | 5.92500E-11 | 19.25 | 6.13 | 0.26 |
| A2 | < 2 | 4.05 | 4.98650E-11 | 42.04 | 7.08 | 0.21 |
| A2 | 2-6 | 4.12 | 5.72340E-11 | 33.26 | 7.99 | 0.21 |
| A2 | 6-10 | 4.03 | 6.35020E-11 | 41.28 | 9.06 | 0.21 |
| B | < 0.1 | 5.96 | 6.52530E-11 | 15.39 | 6.30 | 0.19 |
| B | < 0.4 | 6.21 | 7.41860E-11 | 25.19 | 6.87 | 0.18 |
| B | < 2 | 5.51 | 8.14110E-11 | 23.77 | 8.50 | 0.22 |
| B | 2-6 | 5.44 | 9.19440E-11 | 38.11 | 9.72 | 0.20 |
| B | 6-10 | 4.96 | 8.63020E-11 | 54.62 | 10.00 | 0.24 |
| C | < 0.1 | 5.12 | 4.58160E-11 | 17.08 | 5.15 | 0.24 |
| C | < 0.4 | 5.16 | 5.46860E-11 | 22.88 | 6.10 | 0.26 |
| C | < 2 | 5.16 | 7.03770E-11 | 44.42 | 7.85 | 0.17 |
| C | 2-6 | 5.35 | 7.56030E-11 | 46.45 | 8.13 | 0.19 |
| D | < 0.1 | 6.24 | 7.42020E-11 | 40.23 | 6.84 | 0.30 |
| D | < 0.4 | 5.91 | 9.37330E-11 | 47.64 | 9.12 | 0.21 |
| D | < 2 | 6.01 | 9.27470E-11 | 41.56 | 8.88 | 0.21 |
| D | 2-6 | 6.54 | 1.03460E-10 | 61.91 | 9.10 | 0.21 |
| D | 6-10 | 6.63 | 1.02740E-10 | 60.63 | 8.91 | 0.24 |
| E | < 2 | 5.25 | 7.71050E-11 | 44.79 | 8.45 | 0.18 |
| F | < 0.1 | 6.44 | 7.19670E-11 | 44.42 | 6.43 | 0.28 |
| F | < 0.4 | 6.67 | 9.30370E-11 | 59.60 | 8.02 | 0.17 |
| F | < 2 | 7.24 | 1.10330E-10 | 55.82 | 8.76 | 0.19 |
| F | 2-6 | 7.09 | 1.24450E-10 | 78.42 | 10.09 | 0.22 |
| F | 6-10 | 7.08 | 1.22130E-10 | 77.69 | 9.92 | 0.21 |
| G | < 0.1 | 4.13 | 5.16300E-11 | 19.50 | 7.19 | 0.26 |
| G | < 0.4 | 4.19 | 5.36330E-11 | 22.47 | 7.36 | 0.18 |
| G | < 2 | 4.48 | 7.12020E-11 | 39.03 | 9.14 | 0.22 |
| G | 2-6 | 4.83 | 8.90410E-11 | 57.20 | 10.60 | 0.24 |
| H1 | < 0.1 | 4.97 | 5.19010E-11 | 30.34 | 6.01 | 0.15 |
| H1 | < 0.4 | 4.65 | 5.87910E-11 | 37.22 | 7.27 | 0.21 |
| H1 | < 2 | 5.74 | 8.39690E-11 | 55.15 | 8.41 | 0.18 |
| H1 | 2-6 | 5.41 | 8.60160E-11 | 64.01 | 9.14 | 0.20 |
| H1 | 6-10 | 5.47 | 8.55500E-11 | 64.15 | 8.99 | 0.20 |
| H2 | < 2 | 4.18 | 6.89330E-11 | 46.11 | 9.48 | 0.23 |
| C KF | 400 | 8.71 | 2.05080E-10 | 72.89 | 13.52 | 0.29 |
| D KF | 400 | 11.46 | 2.71040E-10 | 75.71 | 13.58 | 0.28 |

KF: K-feldspar fraction

**Table DR4: Contamination parameters**

| Sample C < 2 μm | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Constants | | | Illite gouge measured | | | K-feldspar measured | | | | |
| Weight (g) | | | | | 0.03703 | | | | | |
| Amount of contamination (weight %) | | | | | | | | | | |
| Radiogenic Ar40 (mol/g) | | | | | 7.0377E-11 | | | | | |
| K (%) | | | | | 5.16 | | | | 8.71 | |
| Measured Age (Ma) | | | | | 7.85 | | | | 13.52 | |
| | | | | | | | | | | |
| Contaminant amount (%) | 0 | 1 | 2 | 3 | 4 | 5 | 10 | 13 | 14 | 15 |
| Corrected age (Ma) | 7.85 | 7.75 | 7.65 | 7.54 | 7.43 | 7.32 | 6.69 | 6.25 | 6.09 | 5.92 |
| Contaminant RadAr40 (%): | 0 | 2.91 | 5.83 | 8.74 | 11.65 | 14.57 | 29.13 | 37.87 | 40.67 | 43.70 |
| Contaminant K40 (%): | 0 | 1.69 | 3.38 | 5.06 | 6.75 | 8.44 | 16.88 | 21.94 | 23.56 | 25.32 |

Basic age contamination modeling carried out using the standard age equation from Dalrymple and Lanphere (1969). Calculations are based on age data of the possible source rock K-feldspars and of corresponding illite fractions analyzed in this study.

**Table DR5: Age standard results**

| Standard ID | K [%] | Rad 40Ar [mol/g] | Rad 40Ar [%] | Age [Ma] | Error [Ma] | Difference to reference [%] |
|---|---|---|---|---|---|---|
| GLO-93 | 6.55 | 1.1170E-09 | 93.07 | 95.74 | 1.44 | 0.75 |
| GLO-94 | 6.55 | 1.1113E-09 | 94.14 | 95.26 | 1.43 | -0.24 |
| GLO-95 | 6.55 | 1.1214E-09 | 92.74 | 96.10 | 1.44 | 1.13 |
| HDB1-66 | 7.96 | 3.3439E-10 | 90.71 | 24.07 | 0.35 | -0.58 |
| HDB1-67 | 7.96 | 3.3792E-10 | 92.32 | 24.32 | 0.37 | 0.45 |
| HDB1-68 | 7.96 | 3.3537E-10 | 90.58 | 24.14 | 0.35 | -0.29 |