Supplementary file

Dynamic elastic properties, petrophysical parameters and brittleness of hot dry rocks from prospective areas of Central Europe

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(a) (b) (c) (d)

Fig. S1. Rock samples: (a) Sandstone from Mogilno-Łódź Trough area, (b) granite from Karkonosze Mountains, (c) and (d) rhyolite from Gorzów Block ((c) is GW-2 well and (d) is J-4 well). Scale in centimeters.

Table S1. Permeability, porosity and density of the samples.

Type of the rock/number of samples	Location	Statistical parameters	Permeability (mD)	Grain density (g/cm^3)	Bulk density (g/cm^3)	Effective porosity (%)
Granite/38	Karkonosze Mountains CP-1 well	Minimum	< 0.001	2.607	2.527	0.503
		Maximum	0.518	2.643	2.621	3.436
		Average/Standard deviation	0.038/0.094	2.622/0.009	2.582/0.029	1.529/0.862
Sandstone/36	Mogilno-Łódź Trough PT-1 well	Minimum	0.008	2.640	2.460	2.720
		Maximum	0.160	2.710	2.592	7.669
		Average/Standard deviation	0.049/0.039	2.673/0.015	2.525/0.043	5.563/1.409
Rhyolite/8	Gorzów Block GW-2 well	Minimum	< 0.001	2.595	2.415	5.923
		Maximum	0.021	2.635	2.467	7.673
		Average/Standard deviation	0.004/0.007	2.621/0.011	2.443/0.018	6.772/0.678
Rhyolite/11	Gorzów Block J-4 well	Minimum	< 0.001	2.520	2.454	0.770
		Maximum	0.085	2.606	2.570	3.393
		Average/Standard deviation	0.009/0.024	2.557/0.033	2.507/0.046	1.959/0.914

Table S2. Mineral composition of the measured samples.

Mineral	Statistical parameters	Granite, Karkonosze Mountains, CP-1 well (%)	Sandstone, Mogilno-Łódź Trough, PT-1 well (%)	Rhyolite, Gorzów, Block, GW-2 well (%)	Rhyolite, Gorzów Block, J-4 well (%)
Quartz	Minimum	18.3	14.5	37.1	18.5
	Maximum	28.6	71.4	37.8	29.2
	Average	23.1	52.4	37.5	22.4
Calcite/Dolomite	Minimum	-/-	0.5/0.1	-/-	-/-
	Maximum	-/-	13.0/5.4	-/-	-/-
	Average	-/-	3.8/2.2	-/-	-/-
Orthoclase/Microcline	Minimum	8.5/15.5	0.8/-	41.1/-	-/21.3
	Maximum	21.1/24.5	16.8/-	41.2/-	-/27.2
	Average	14.9/19.0	9.7/-	41.2/-	-/24.0
Albite	Minimum	28.6	10.2	16.5	14.5
	Maximum	35.4	18.3	16.8	22.9
	Average	33.1	14.0	16.7	17.9
Biotite	Minimum	0.7	0.1	0.8	1.9
	Maximum	2.8	0.3	1.0	4.3
	Average	1.7	0.2	0.9	2.8
Kaolinite/Illite/Chlorite	Minimum	0.7/3.8/2.9	0.5/1.3/0.6	-/2.7/0.7	3.8/-/4.6
	Maximum	1.6/4.3/10.7	9.7/33.2/12.7	-/3.0/0.8	3.8/-/33.0
	Average	1.1/4.1/5.6	2.5/14.0/3.4	-/2.9/0.8	3.8/-/16.7
Magnetite/Hematite	Minimum	-/-	-/-	0.2/-	-/0.1
	Maximum	-/-	-/-	0.3/-	-/1.7
	Average	-/-	-/-	0.3/-	-/0.9
Clinopyroksene/Pyrope/ Antigorite/Lawsonite	Minimum	-/-/-/-	-/-/-/-	-/-/-/-	1.1/0.8/1.3/2.4
	Maximum	-/-/-/-	-/-/-/-	-/-/-/-	2.6/0.8/26.1/2.4
	Average	-/-/-/-	-/-/-/-	-/-/-/-	1.7/0.8/10.5/2.4

Table S3. Summary of the dynamic elastic parameters of the measured samples. Minimum, maximum, and average values are presented for 55 MPa axial pressure in triaxial condition tests, where radial pressure is within the range 15-55 MPa.

Area, rock type	Sampling depth (m)	Statistical parameter	Velocity (m/s)		V_P/V_S	ν	E (GPa)	K(GPa)	G(GPa)	N
			P-wave	S-wave						
Karkonosze Mountains Region, granite	CP-1 138.0-144.0	Minimum	4,470	2,255	1.70	0.24	34.6	31.0	13.0	5
		Maximum	4,767	2,798	1.98	0.33	49.6	37.1	20.0	5
		Average/Standard deviation	4,667/103.76	2,559/194.15	1.83/0.11	0.28/0.04	43.1/5.28	33.3/2.17	16.9/2.52	5
	CP-1 155.0-184.0	Minimum	5,381	2,871	1.75	0.26	57.0	43.1	21.6	7
		Maximum	5,627	3,188	1.95	0.32	67.3	53.6	26.6	7
		Average/Standard deviation	5,533/85.61	3,103/103.25	1.78/0.07	0.27/0.02	63.9/3.28	46.4/3.30	25.2/1.62	7
Gorzów Block, rhyolite	GW-2 3,348.0-3,356.0	Minimum	3,805	2,093	1.72	0.24	27.4	19.6	10.6	3
		Maximum	3,826	2,216	1.83	0.29	30.0	21.4	12.1	3
		Average/Standard deviation	3,814/8.60	2,149/50.68	1.78/0.04	0.27/0.02	28.6/1.09	20.5/0.71	11.3/0.58	3
	J-4 3,264.0-3,277.0	Minimum	3,520	1,920	1.55	0.15	23.3	16.1	9.0	6
		Maximum	4,958	3,192	2.09	0.35	60.0	39.4	26.2	6
		Average/Standard deviation	4,142/555.15	2,406/397/86	1.74/0.18	0.23/0.07	35.2/11.69	22.6/8.58	14.5/5.43	6
Mogilno-Łódź Trough, sandstone	PT-1 3,912.5-3,977.0	Minimum	2,646	1,554	1.52	0.12	15.4	8.1	6.2	6
		Maximum	2,989	1,879	1.71	0.24	21.4	10.9	9.1	6
		Average/Standard deviation	2,756/111.18	1,691/117.74	1.63/0.07	0.20/0.04	17.6/1.99	9.7/0.83	7.4/1.03	6
	PT-1 4,189.5-4,286.0	Minimum	1,826	1,146	1.52	0.12	7.6	3.9	3.2	6
		Maximum	2192	1426	1.67	0.22	11.4	6.2	5.0	6
		Average/Standard deviation	2044/138.56	1279/112.38	1.60/0.06	0.18/0.04	9.6/1.49	5.0/0.69	4.1/0.73	6

Table S4. Mineral composition of reservoir rocks from selected EGS sites in Europe.

Rock type	Soultz-sous-Forêts rockbody, granite (Ledésert and , 2012)	Groß Schönebeck GtGrSk4/05 well, Rotliegend, volcanic (Regenspurg et al., 2016)	Groß Schönebeck GtGrSk4/05 well, Rotliegend, sedimentary (Regenspurg et al., 2016)	Groß Schönebeck area, Dethlingen formation (Rotliegend sandstone) (McCann, 1998)
Quartz	28.4	10-60	30-80	70-78.3
Plagioclase	39.9 (Oligoclase)	30-60	0-30	1.7-7.5
K-feldspar	18.8	No data	No data	≤ 0.5
Biotite/Mica	8.4	< 10 (Mica)	< 10 (Mica)	No data
Carbonate	$\leq 1.8 - 18$	< 10 (Calcite)	0-30 (Calcite)	≤ 13.3
Chlorite/Clay	< 1/-	-/< 10	-/< 10	No data
Sericite	Up to several % (Illite)	No data	No data	No data
Pyroxene	4.5 (Amphibole)	No data	No data	No data
Epidote	< 1	No data	No data	No data
Anhydrite	0	< 10 (Celestine/Anhydrite)	No data	≤ 1.33
Hematite	No data	< 10	< 10	No data

Notes: Data from Soultz-sous-Forêts concern composition of the main rock body. The composition of fractured and altered zones is strongly modified, especially by the dissolution of quartz and the increase in the amount of clay minerals.

Table S5. Comparison of selected tectonic and geomechanical parameters from Western European EGS sites and prospective EGS areas in Central Europe.

EGS site, rock type	Target zone depth (m) /temperature (°C)/stress regime	S_V, S_H, S_h, P_p (MPa)	V_P, V_S (m/s)	E (GPa); v
Soultz-sous-Forêts (France), granite	5,200.0/200/ Mixed, normal and strike-slip (Baujard et al., 2017)	At 2,200.0 m: S_V is 54.8; S_V >or< σ_H; S_h is 29.6; P_P is 22.5; calculated, based on equations from (Lengliné et al., 2017)	V_P, 4,390-5,200, for coarse-grained, biotite–muscovite-bearing granite from Saint Pierre Bois quarry (Kushnir et al., 2018)	Estimated E for pure granite at the target zone-up to 80 GPa, in zones of increased hydraulic conductivity, and clay content, may be significantly lower. (Meller and Ledésert, 2017), from 1-2 for fractured zones up 40 GPa for intact rock (Villeneuve et al., 2018).
Soultz-sous-Forêts (France), granite	5,200.0/200/Mixed, normal and strike-slip (Baujard et al., 2017)	At 2,200.0 m: S_V is 54.8; S_V >or< σ_H; S_h is 29.6; P_P-22.5; calculated, based on equations from Lengliné et al. (2017)	V_P, 4,390-5,200, for coarse-grained, biotite-muscovite-bearing granite from Saint Pierre Bois quarry (Kushnir et al., 2018)	Estimated E for pure granite at the target zone-up to 80 GPa, in zones of increased hydraulic conductivity, and clay content, may be significantly lower. (Meller and Ledésert, 2017), from 1-2 for fractured zones up 40 GPa for intact rock (Villeneuve et al., 2018).
Groß Schönebeck (Germany), volcanite	4,100.0/149/ Normal-strike-slip $S_h \geq 0.55 \cdot S_V$, $S_H \leq 0.78 - 1.00 \cdot S_V$ (Moeck et al., 2009)	S_V is 100, S_H is 78-100, S_h is 55 (Moeck et al., 2009), P_P is 44.9 at 4,220.0 m (Huenges et al., 2007)	No data available	E is 55, v is 0.20 (Zimmermann et al., 2010)
Groß Schönebeck (Germany), sedimentary	4,100.0/149/ Normal-strike-slip $S_h \geq 0.55 \cdot S_V$, $S_H \leq 0.78 - 1.00 \cdot S_V$ (Moeck et al., 2009)	S_V is 100, S_H is 78-100, S_h is 55 (Moeck et al., 2009), P_P is 44.9 at 4,220.0 m (Huenges et al., 2007)	No data available	E is 55, v is 0.18 (Zimmermann et al., 2010)
Karkonosze Mountains Region (Poland), (granite)	4,000.0/165/ Normal-strike slip (Jarosiński, 2005; Zuchiewicz et al., 2007)	Based on average rock density S_V: 96 (Jarosiński, 2005)	Depending on the depth of the sampling and individual sample conditions: V_P is 4,470-5,628, V_S is 2,254-3,188 (this study)	Depending on the sampling depth and individual sample conditions: E is 34.6-67.3, v is 0.24-0.33 (this study)
Gorzów Block (Poland), volcanite (rhyolite)	4,300.0/160/ Normal-strike slip (Jarosiński, 2005; Zuchiewicz et al., 2007)	Based on average rock density S_V: (Jarosiński, 2005)	Depending on the well and depth of samples collected: V_P is 3,802-4,958, V_S is 1,920-3,191 (this study)	Depending on the well and sampling depth: E is 7.5-23.3-60.0, v is 0.15-0.35 (this study)
Mogilno-Łódź Trough (Poland), sedimentary (sandstone)	5,000.0-6,500.0/165-195/Normal-strike slip (Jarosiński, 2005; Zuchiewicz et al., 2007)	Based on the average rock density S_V: (Jarosiński, 2005)	Depending on the depth of the sampling and individual sample conditions: V_P is 1,826-2,989, V_S is 1,146-1,879 (this study)	Depending on the sampling depth and individual sample conditions: E is 7.5-21.5, v is 0.12-0.24 (this study)

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