CLEAN AIR TASK FORCE

Larderello, Italy

KEY STATS:

- Number of SHR wells drilled: **6**
- Deepest well: **4,092 m**
- Hottest well: **515°C**

PROJECT DETAILS:

Reservoir Lithology

With the deeper superhot wells, a fractured metamorphic basement (Paleozoic - Precambrian) was encountered in wells Sasso-22 and Quercenne-3. These boreholes were drilled through quartzitic phyllites metamorphic basement rock. Granites, however, were encountered at Radicondoli 29. No major fracture systems were intersected within the metamorphic geothermal reservoir during the drilling of the most recent well, Venelle-02.

Geological Setting

No extrusive volcanics are present at Larderello. However, the Larderello geothermal system is linked to young granitic intrusions, at depth, that originated between 2.5-3.5 Ma. Recent deep wells have shown very high temperatures and important hydrothermal alteration of basement phyllite and micaschist. Where encountered, the igneous rocks found in Larderello field are high-Al, S-type granite with significant F and B content (Gianelli et al., 1997; Manzella et al., 1998). It is hypothesized that these granites are differentiates of deeper acidic intrusions (Cavarretta and Puxeddu, 1999). It has been estimated that the young host leucogranitic rocks of Larderello may occur at approximately 6 km depth, which is near present-day melting conditions (Gianelli et al., 1997; Manzella et al., 1998).

Tectonic Setting

Extensional – Back Arc Basin: Larderello is located on the western margin of the Apennine Mountain chain in a present-day back-arc basin extensional setting. The Northern Apennine fold-and-thrust belt was generated by the westward subduction of the Adria plate underneath the European plate, originating as early as the middle Eocene (~40 Ma). Recent rollback of the subducted slab led to the eastward migration of the compressional front (Carmignani et al., 1994, Jolivet et al., 1998). In the west, this resulted in early-middle Miocene extension. The back-arc extension resulted in the formation of the Tyrrhenian Sea. The extensional processes resulted in rapid crustal thinning, a shallow Moho (~22 km) and a rapid rising of the asthenosphere (Calcagnile and Panza, 1981). This was associated with a prolonged magmatic activity that in southern Tuscany produced intense hydrothermal circulation documented by both fossil (ore deposits) and active (geothermal fields) systems.

Projects/Players

- The DESCRAMBLE project (**D**rilling in d**E**ep, Super-**CR**itical **AMB**ients of continenta**L** **E**urope) ran from May 2015- April 2018.
- DESCRAMBLE was a joint effort to develop a proof-of-concept drilling project for reaching supercritical resources.
- The research consortium consisted of: ENEL Green Power, E.ON Energy, CNR, CAU, SINTEF

Notes

- Larderello geothermal power station is located in Pomarance, Tuscany (central Italy). Today the power plant produces 800 MWe (Unwin, 2019) and is presently owned by ENEL. At a 95% capacity factor, Larderllo produces 6,658 GWe annually.
- Larderello is the site where the first practical demonstration of geothermal power was exhibited (ENEL, 2018).
- Sasso 22, drilled in the period 1978 to 1980, reached a final depth of 4092 m. This is still the deepest geothermal borehole in Italy. It was the first to encounter temperatures in the order of 400°C. The hottest well is now attributed to Velelle-2, which reached 515 °C.
- Venelle-02, as well as other geothermal wells at Lardarello, recorded high amounts of H_2.
- String failures occurred while drilling San Pompeo-2, mainly due to corrosion from hydrogen expelled from the reservoir. During drilling at a depth of 2930 m, a violent hydrogen gas explosion was experienced: CH_4 contents of 5% and H_2 contents of 10% (Batini 1984).
- The project cost totalled 16M. partly from a Horizon 2020 grant of 6.715M Euro.

Key References

- Calcagnile, G., and G. F. Panza (1981), The main characteristics of the lithosphere-asthenosphere system in Italy and surrounding regions, Pure Appl. Geophys., 119, 865 – 879.
- Cappetti G, Celati R, Cigni U, Squarci P, Stefani G, Taffi L (1985). Development of deep exploration in the geothermal area of Tuscany, Italy. 1985 International Symp. on Geothermal Energy, Kailna, Hawaii, Geothermal Resources Council, Davis, CA, pp 303–309
- Carmignani, L., F. A. Decandia, and P. L. Fantozzi (1994), Tertiary extensional tectonics in Tuscany (northern Apennines, Italy), Tectonophysics, 238, 295–315.
- ENEL, (2018). Two centuries of geothermal industry, an Italian first.
- Gianelli, G., Manzella, A., and Puxeddu, M., (1997). Crustal models of the geothermal areas of southern Tuscany (Italy). Tectonophysics, vol. 281, no. 3-4, pp. 221–239, 1997.
- Jolivet, L., R. Dubois, M. Fournier, B. Goffe, A. Michard, and C. Jourdan (1990), Ductile extension in Alpine Corsica, Geology, 18(10), 1007–1010.
- Kruszewski, M., and V., Wittig (2018). Review of failure modes in supercritical geothermal drilling projects Geotherm Energy (2018) 6:28
- Manzella, A., Ruggieri, G., Gianelli, G., and Puxeddu, M., (1998) Plutonic-geothermal systems of southern Tuscany: a review of the crustal models, Memorie Società Geologica Italiana, vol. 52, pp. 283–294, 1998.
- Reinsch T, Dobson P, Asanuma H, Huenges E, Poletto F, Sanjuan B., (2017). Utilizing supercritical geothermal systems: a review of past ventures and ongoing research activities. J Geotherm Energy. 5:16.
- Unwin, J., (2019). The oldest geothermal plant in the world. At look at Larderello Geothermal Energy plant in Italy, the oldest geothermal plant in the world.

Well Name	Year Drilled (planned)	Entities/ Players	Depth (targeted) Meters/Feet	Pressure (targeted) MPa / PSI	Temperature (targeted) °C / °F	Latitude WGS84	Longitude WGS84
Carboli-11	1990-1991	ENEL SPA Italy	**3,455 m** / 11,335 ft	**n/a**	**427°C** / 801°F	43.12334	10.784766
Sasso-22	1978-1979	ENEL SPA Italy & EEC	**4,092 m** / 13,425 ft	**n/a**	**>380°C** / 716°F	43.172008	10.851269
Quercenne-3	1993	ENEL SPA Italy	**2,461 m** / 8,074 ft	**n/a**	**370°C** / 698°F	43.174008	10.793433
Radicondoli 29	1996	ENEL SPA Italy	**4,850 m** / 15,912 ft	**n/a**	**382°C** / 720°F	43.201843	10.99811
San Pompeo-2-ST-2	1980-1982	ENEL SPA Italy & EEC	**1,280-2,935 m** / 4,199-9,629 ft	**8.6 MPa** / 1,247 PSI	**n/a**	43.139341	10.816267
San Pompeo-2-ST-1	1980-1982	ENEL SPA Italy & EEC	**2,600-2,937 m** / 8,530-9,636 ft	**4.0 MPa** / 580 PSI	**450°C** / 842°F	43.139341	10.816267
San Pompeo-2	1980-1982	ENEL SPA Italy & EEC	**2,966 m** / 9,731 ft	**>24 MPa** / 3,481 PSI	**>400°C** / 752°F	43.139341	10.816267
Venelle-02	2017	ENEL Green Power, E.ON Energy, CNR, CAU, SINTEF	**2,909 m** / 9,544 ft	**30 MPa** / 4,351 PSI	**515°C** / 959°F	43.153674	10.793766

Clean Air Task Force (CATF) is a global nonprofit organization working to safeguard against the worst impacts of climate change by catalyzing the rapid development and deployment of low-carbon energy and other climate-protecting technologies.

CATF's Superhot Rock Energy team is a group of scientists, industry practitioners, and policy experts dedicated to decarbonizing the energy sector through superhot rock energy. Our goal is to achieve demonstration and commercialization of superhot rock energy anywhere in the world, providing affordable access to the largest untapped energy source on the planet.

This factsheet is part of a CATF project mapping regions of the world where superhot rock energy has high potential. Learn more, and see all of our factsheets, at catf.us/shrmap/