

Feasibility study (I stage) of CO₂ geological storage by ECBM techniques in the Sulcis coal province (SW Sardinia, Italy)

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Abstract

An ECBM feasibility study started for the *Sulcis Coal Province* (SW Sardinia, Italy): available geochemical, structural-geology, stratigraphic and reservoir engineering considerations as well as the newly gathered experimental data are discussed, including fluid geochemistry (major and minor elements, dissolved gases, C and He isotopic ratios) of different strata/reservoir, coal composition and experimental data on CO₂/CH₄ adsorption on coal. A MapInfo GIS structure was built up including stratigraphic, geo-structural, hydro-geochemical, coal-compositional and environmental-impact information as well as the CO₂ sources location and typology. Though preliminary, these data highlight both the positive and negative features of the *Sulcis Coal Province* with respect to the exploitation of the ECBM technique. CO₂ geological storage and CH₄ production potentials in *Sulcis* have been roughly evaluated as a whole, in the frame of the Sardinia region CO₂ sources, including the coal-fired power plants, both existent and foreseen (hundreds of millions of tonnes of CO₂ are possible to be stored underground in the next decades). The most important objective of this phase I of the project is the selection of the best *Sulcis* ECBM test-pilot site, which will be followed by the choice of a site for scale up (Phase II-2007) and possibly by future full scale implementation within a network type of project (Phase III-2008).

Keywords: ECBM potential, *Sulcis Coal Province*, fluid geochemistry, coal composition

Introduction

The potential storage of CO₂ in Italy has never been fully evaluated [1,2,3,4] but we are convinced that a general Italian survey could be supported by running in parallel specific feasibility studies in “operative” test sites addressed to ECBM, EOR or EGR exploitation. Soon after the first encouraging scientific results (i.e. Allison Unit, USA, [5,6,7,8]) some pilot-test projects and feasibility studies have been initiated worldwide [5 and references therein]. In Italy, significant coal reserves are not present with the exception of the *Sulcis Coal Province* (Sardinia), which is not yet exhausted. The Sulcis region occupies the South-Western end of Sardinia. The project about which we report has the main objective to evaluate the ECBM technique exploitation throughout the *Sulcis Coal Province* as a whole (more than 1400 Km² wide totally divided in 725 Km² in-shore and 730 Km² off-shore), starting from the

sectors actually mined by Carbosulcis S.p.A, in the frame of the ongoing coal mining concession of 550 Km². The *Sulcis Coal Province* is N-S oriented, limited westward by the sea and the coal strata are deepening westward into the sea. Beside the final objective of CO₂ storage, the project aims initially at producing CH₄ as an economically attractive driver, possibly starting by adopting standard CBM techniques. Afterwards, it is scheduled to start injection of CO₂ or, if possible, of the flue-gas itself, which will come from a coal-fired power plant (with a composition of about 17% CO₂, 3.5% O₂, 75 % N₂, 1% Ar, 3.5% H₂, as expected for the *Sulcis SU3* nearest power plant). Around 10⁸ tons of coal are foreseen to be usable for ECBM exploitation in the *Sulcis Coal Province*.

Results

The specific work done or in progress throughout *the Sulcis Coal Province* up to date in the frame of this Phase I of the project is (Fig 1):

- **thorough analysis** of the information provided by Carbosulcis S.p.A and collection of literature data on CBM, ECBM and the Sulcis Coal Province; data integration for fluid geochemistry, coal composition, structural geology, stratigraphic and reservoir engineering;
- **coal composition characterization** in terms of proximal analyses i.e., macerals, vitrinite reflectance (Table 1), porosity, humidity, calorific values, and other data relevant for ECBM feasibility assessment;
- **fluid geochemistry characterization** at different levels: surface and underground aquifers (major and minor elements, dissolved gases, Fig. 2, and isotopic ratios of C and He) in the circulating fluids and geochemical modelling (ongoing);
- design and build-up of a **desorption device** and of experiments (USBM Direct Method, Fig. 3) to evaluate the desorption rate and quality of gas spontaneously released from cores of the Sulcis coal;
- experimental study of the adsorption of CO₂/CH₄ (Fig. 4) by a **gravimetric method** to evaluate the adsorption capacity of the coal seam (Pini et al., see this volume);
- building of a **GIS database** using the PC based Mapinfo software throughout the *Sulcis Coal Province*, with all the CBM and ECBM pertinent “layers” (including industrial CO₂ sources), which is compatible with other EC “CO₂ storage” GIS databases, such as the GETSCO EC project (Fig.1).
- first screening of the documents useful for **the evaluation of Environmental Impact Assessment** (EIA as VIA in Italy) throughout the Sulcis area, on the basis of the existent laws and directives. The discussion of this aspect is beyond the scope of this paper;

Parameters	Vitrinite Reflectance	Maceral group composition (mmf)		
		vitrinite	inertinite	liptinite
Sample	\bar{R}_v , %	vol%	vol%	vol%
Seam-1	0.67	93	7	0
Seam-2	0.67	89	0	11
Seam-3	0.68	85	3	12
Seam-4	0.67	82	0	18
Seam-5	0.67	100	0	0
Seam-10	0.70	89	0	11

Table 1 Characterization of the Sulcis coals sampled on March, 2005 at – 400 m in the Monte Sinni coal mine.

- final preliminary **evaluation of CBM reserves and CO₂-ECBM storage potential** (Table 2) including the hints about the post-ECBM exploitation CO₂ geological storage potential, mapping the extent of the “Miliolitico” limestone formation (Fig. 5).

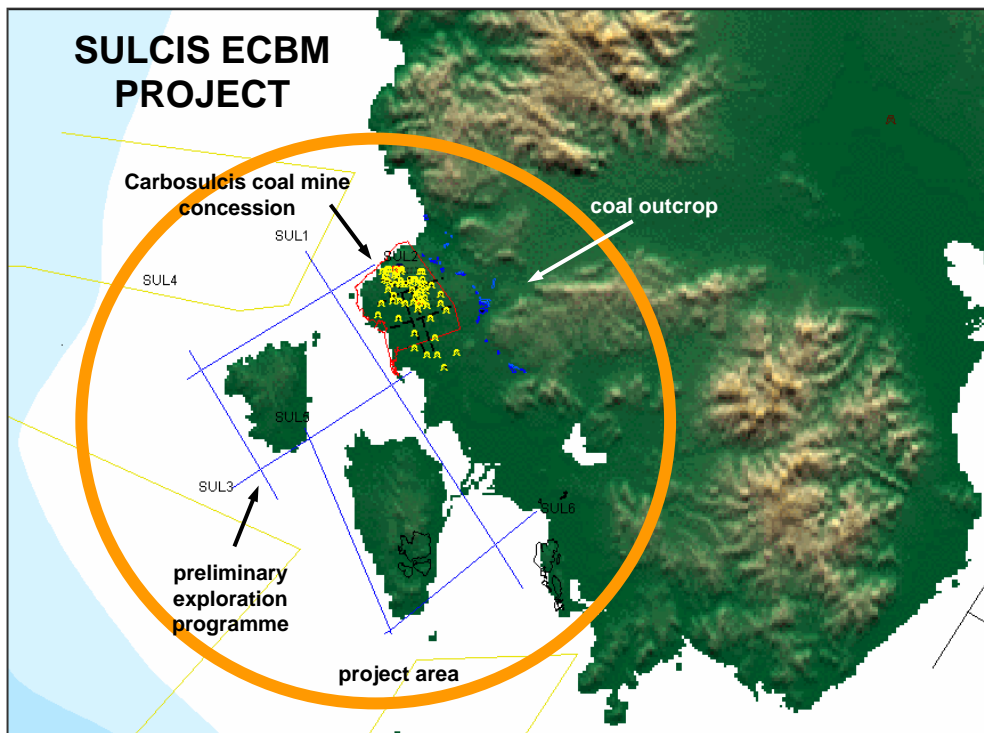
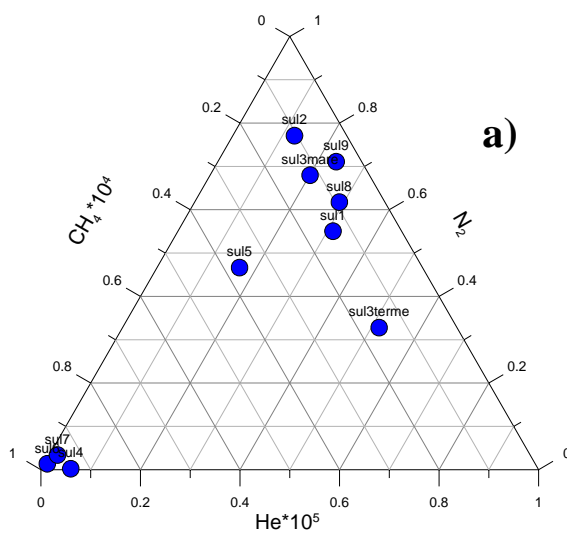


Figure 1 Extract from the ECBM *Sulcis* GIS performed by IES S.r.l and INGV. The GIS database includes geo-referenced geology, structural geology, hydrogeology, stratigraphy, fluid geochemistry, stratigraphic wells, geophysical data, tectonics as well as the CO₂ industrial sources and environmentally critical sites.



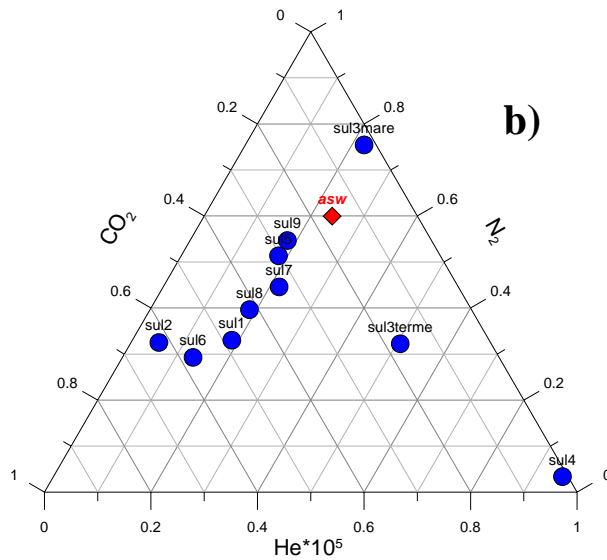


Figure 2 Triangular diagrams of the *Sulcis* groundwater dissolved gases (June 2005 survey): a) CH₄-N₂-He diagram, b) CO₂-N₂-He diagram.

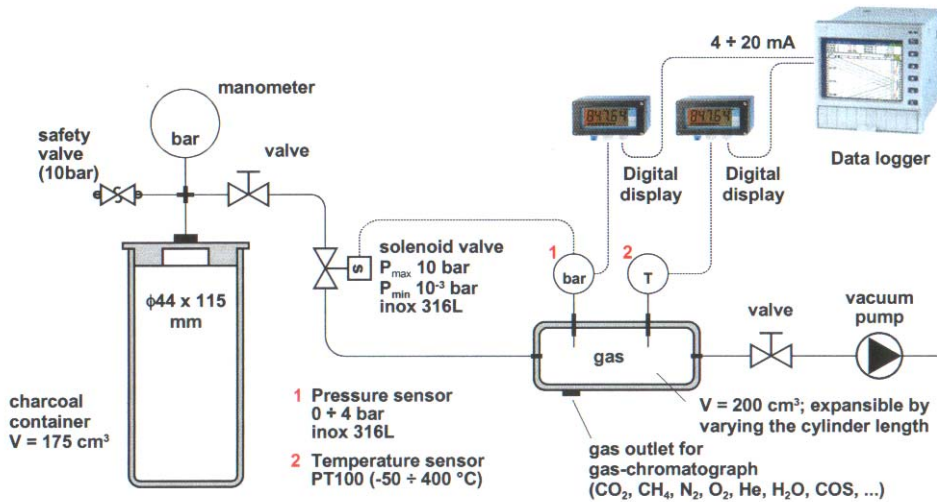


Figure 3 INGV design to measure the methane de-sorption quality, quantity and rate to characterize the Sulcis coal for CBM and ECBM techniques. 50 bar of pressure is reached for a coal sample of around 50 cc volume.

	Onshore	Offshore	Total
Estimated producible gas by CBM (million m³)	6700	4500	11200
Estimated producible gas by ECBM (million m³)	5300	3500	8800
Estimated total producible methane (million m³)	12000	8000	20000
CO₂ storage capacity under ECBM (million ton)	40	30	70
CO₂ storage capacity beyond ECBM (million ton)	110	90	200
Total CO₂ storage capacity (million ton)	150	120	270

Table 2 Preliminary calculation of CBM and ECBM methane reserves and of CO₂ storage capacity in the Sulcis deep coal basin, on the basis of the available data.

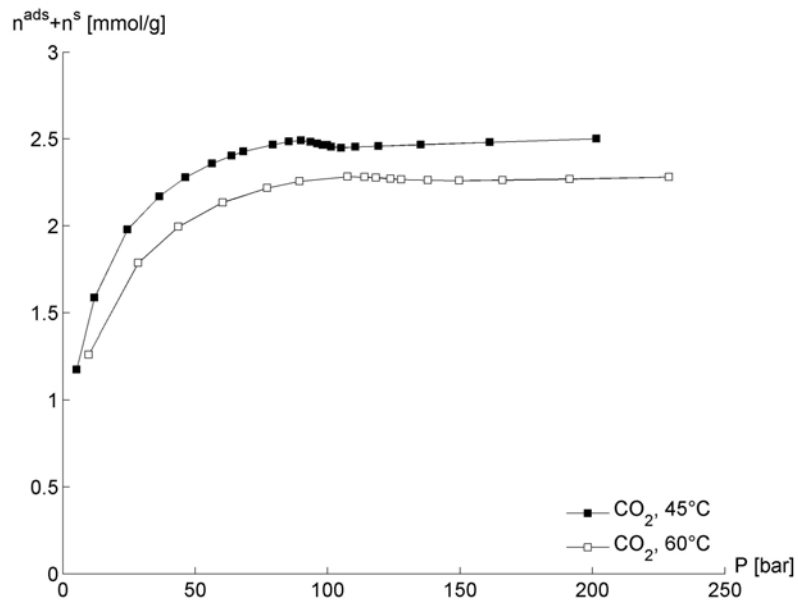


Figure 4 CO₂ capacity of the Sulcis coal powdered at 0.25-0.35 mm as a function of pressure (see [9] and Pini et al. in this volume for all the details about these data).



Figure 5 Sulcis coal stratification (Produttivo Formation): alternation of coal strata and carbonaceous-clays, above the “Miliolitico Limestone Formation”, under the coal strata, seat of the SUL 4 groundwater sample.

Conclusions

- At the moment, the known litho-stratigraphy, the fluid geochemistry and the coal composition data indicate that there is potential for both CBM production and CO₂ geological storage in the Sulcis area. In particular, the prevalent Na-Cl fluid geochemistry (Van Voast, 2005, and references therein) of the circulating groundwater is compatible with the possibility of finding methane in the deep coal beds (-800 ≈ -1500 m), as seen in the USA CBM producing basins.
- The important E-W S.Antioco fault represents the southern limit of the Sulcis Tertiary coal basin and of the possible associated ECBM area. Along this fault, highly radioactive thermal groundwater comes

to the surface (up to 2200 Bq/L, reported here for the first time in the literature), suggesting a deeply rooted fault as well as convective fluid circulation along the discontinuity.

- In the Sulcis area, high purity CO₂ industrial sources (i.e., the Sarroch refinery, or large coal power plants with CO₂ capture) are available or will be available in the future. Direct flue-gas geological storage from the existing or future power plants without CO₂ capture is theoretically possible (Gunter et al., 2004, and references therein).
- The CO₂ storage potential in the Sulcis area by using ECBM techniques is likely to be the largest of its kind in Italy. Our preliminary data indicate that the Sulcis coal can uptake CO₂ up to 10% of its weight (see also Pini et al. in this volume).
- A multiphase and multi-techniques project scenario could have a duration of 30-60 years (5-7 years dewatering and CBM, 8-25 years ECBM and the rest for CO₂ geological storage in deep coal without methane production and/or in deep saline aquifer).
- In Sulcis, the environmental aspects must be accurately taken care of, due to the tourist attraction of this part of Sardinia. The Sulphur gas species could be injected underground alongside with the CO₂.
- A Sulcis coal based Carbon Capture and Storage (CCS) project at Sulcis, of which the ECBM project would represent the integrated geological storage element, may have world-wide relevance if economic coal-fueled zero emission power generation is demonstrated, particularly considering the high sulphur content of the Sulcis coal (6%). This could serve to enlarge the coal world reserves, by admitting all the other previously unused sulphur-rich coal of the world to the power generation market.

List of References

- [1] Quattrocchi F, Bencini R, Cinti D, Galli G, Pizzino L, Voltattorni N, Navarra A. CO₂ geological sequestration in Italy: state of art and potential sites. In: Proc. XI Inter. Conf. "Water Rock Interaction" "WRI-XI", Saratoga Spring, New York, USA, June 2004; 573-576.
- [2] Quattrocchi, F., Bencini, R., Lo stoccaggio geologico della CO₂: stato dell'arte in Italia ed all'estero. *Termotecnica*, 2005; 5: 39-46.
- [3] Quattrocchi F. Lo stoccaggio geologico di CO₂: stato dell'arte e strategie. *Qualenergia*, 2006; VI (1): 23-26.
- [4] Angelone M, Gasparini C, Guerra M, Lombardi S, Pizzino L, Quattrocchi F, Sacchi E, Zuppi GM. Fluid geochemistry throughout the Sardinian Rift-Campidano Graben: fault segmentation, seismic quiescence of geochemically «active» faults and new constrains for the selection of the CO₂ storage sites. *Applied Geochemistry*, 2004; 20: 317-340.
- [5] White CM, Smith DH, Jones KL, Goodman AL, Jikich SA, LaCount RB, DuBose SB, Ozdemir E., [6] Morsi BI, Schroeder KT. Sequestration of Carbon Dioxide in Coal with Enhanced Coalbed Methane Recovery. A Review. *Energy & Fuels*, 2005; 19(3): 659-724.
- [7] Asghari K, Al-Dliwe A. Optimization of carbon dioxide sequestration and improved oil recovery in oil reservoirs. Proc. 7th Int. Conf. on Greenhouse Gas Control Technologies (GHGT-7). 2004; On web site <http://www.ghgt7.ca/>
- [8] Busch A, Gensterblum Y, Krooss B. Methane and CO₂ sorption and desorption measurements on dry Argonne premium coals: pure components and mixtures. *Inter. J. Coal Geology* 2003; 55: 205-224.
- [9] Ottiger S, Pini R, Storti G, Mazzotti M, Quattrocchi F, Bencini R, Adsorption of pure carbon dioxide and methane on dry coal from the Sulcis Coal Province (SW Sardinia, Italy). *Environmental Progress* 2006; submitted.