ENVIRONMENTAL AISK IN DIRECT GEOTHERMAL APPLICATIONS

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ABSTRACT

Resource access,utility and environmental impact are the nain economic ard legal aspects which control geothermal direct applications. Risk,smaller in low- opposed to high-temperature development,is present mainly as "environmental risk" related to the nature of the major component in geothermal fluids,i.e. water,as a composite dynamic system to be controlled physico-chemically and as a resource to be defined in energetic or non-energetic priorities economically and legally. Reference is made to the Italian geothermal karst system Abano and Sciacca.with different environmental issues .

KEYWORDS

Direct applications,environmental risk,karst systems,vulnerability,hazard,element at risk

INTRODUCTION

The new energy philosophy,with environmental emphasis on renewable resources,stresses the importance of direct geotherral uses thanks to various ancillary benefits acd to the abundance and ubiquity of low-temperature thermal waters.

The concern with the environment,a *key* preoccupation in research an6 legislation, affects also the direct geothermal development and ths socioeconomic assessment of the environmental impact remains a "must"to explain what is wrong with the system that does not allow the geoheat to go forward in some areas .

The review of the Italian case histories Abano and Sciacca suggest under- and overrating of the environmental risk as well as uncomplete matching of regulations and technologies, reulting in economic and legal controversy .

ENVIRONMENTAL RISK IS GEOTHERMAL DIRECT USE

The concept of geological risk,when environmentally extended from natural. events to human activities, should stick to agreed refecences and this applies also to the environmental risk in geothermal direct applications because of the hazard-risk relationship in heat extractiun associated with water recovery

According to the UNESCO definition .risk is assumed as possibility of a loss or damage for human life and assets as well as for activity and production capacity,while hazard is the probability for a ruinous event to occur in a given lapse ,the so called "return time". In the casc of fluid recsvery or equivalent exploitation focussed at hest extraction,the expected induced events ,like pollution,seismicity and subsidence, have no specific return timc and this is conceivable only as a return to primary conditions before the impact,

Through hazard and through vulnerability(a measure of the portion of value in danger because of the eventual ruinous event) the risk is proportional to the element at risk,i.e.its value in the system which has to hear the event,as suggested by the general equation

$$R - E \times H \times V$$

where E is the element at risk,H is the hazard and V is vulnerability.

While insurers and planners are interested in risk,project makers and engineers are responsible for vulnerability and geoscientists for hazard,possibly the most difficult item *ui* be assessed in the risk evaluation because of still lacking scientific and statistical information about induced pollution,seismicity and subsidence .

GEOTHERMAL SYSTEMS AND GEOLOGICAL SETTING

Both Abano and Sciacca geothermal system are related tu carbonate more or less karstified formations,thereby suggesting their dafinition as geothermal karst systems.

Limestones and dolomites of different age represent important reservoir rocks for fluids of economic interest(hydrocarbons, thermal waters but standard water above all) anc this interest is stressed as case histories by the coexistence of geothermal and petroleum research with related deep drilling (Ficarolo 1 and S.Angelo Pieve di Sacco 1,depth about 2000 m a5 well as Legnaro depth 4989 m in the area around Abano; Sciacca 1,depth 2829 m in the Sciacca area itself) to check the Mesozoic carbonate basement .

The information from deep petroleum drilling, so far not exploited fully, may probably help in a better geothermal understanding of both areas, in the framework of "deep controlling shallow" conditions and situations .

The geothermal system,ideally an association of hydro- and thermodynamic conditions and processes enabling a non-static heat accumulation ,may be viewed in fact as a convective thermal cell,warmer than the surrounding rock mass, which concentrates and accumulates heat in a reservoir , provided an impervious cover favours hart conservation ,

To assess the potential for low-temperature geothermal resources in regional thermal environments , a knowledge of temperature gradients to depths of about 2 km is normally required; regional variations in temperature gradient reflect in fact regional variations in heat flow, thermal conductivity ,or both , and result in some uncertainties,where the deep gradient data derived from near-surface data are not checked at depth . In hard fractured reservoirs more emphasis should also be attached to zonation for a better formation evaluation.

All this means to study base level for drainage, amount and type of recharge and above all the structure of the geothermal convective cell,without forgetting the thickness of the host karstified carbonate rock , the impervious-ness of tie cover and the eventual presence of on heating source .

Thanks alsu to preferential permeability pathways (enhancing circulation but also pollution), the vertically developing convective cell, warmer than the surrounding rock mass and apparently proportional in its dimensions to the thickness of the carbonate sequence , represents ihe key for a sound assessment of the geothermal potential ; in the Abano basin the 70-86° C water temperatures decrease more or less gradually from centre to periphery but are almost constant at depth inside the thermal area(average 78.5° C at 780 m depth in the Sissalunga well, the deepest in the basin).

The only apparently anomalous "temperature hook",resulting from active hydrothermoconvection in thick carbonate sequences, shows more pronounced where impervious sedimentary cover or self sealing favour heat accumulation; tte eventually associated ground or perched water tables may produce intensive "wind channel"or "chimney" air circulation,as in the case of "stufe"di San Calogero at Sciacca, reported by Sommaruga (1954)and illustrated by figures 1 arid 2.

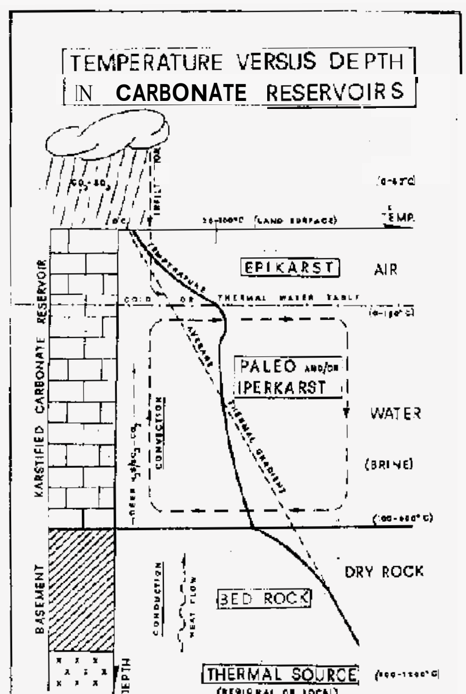


Fig.1

ABASO

The Abano thermal basin, between Padova and Ferrara in North Italy, has been famous since ancient times thanks tu curative hot springs.

Upper Jurassic to Lower Oligocene marine sediments outcrop in the Euganean Hills and probably Triassic dolomites have been found by a 1814 m deep well near Arquà Petrarca; the volcaniic rocks in the area belong to two magmatic events(Eocene basalts and Oligocene rhyolites) but the non-volcanic origin for the Abano thermill waters has been established(Piccoli et al;. 1976). The geothermal fluids, now being produced by increasingly deep wells in the Euganei district have in fact a primary carbonate source in the Prealpine watershed and, by moving at depth over a more than 50 km distance, reach the Abano-Montegrotto-Galzignano area .

In the Euganei thermal district, the most important Italian and possibly European spa area with over 3 million-per-year attendances, the creation of a control system, covering licence granting, water level measurement and consumption, resulted also in an inventory of wells (230 out of abuut 400 so far drilled), classified according to depth, head pressure losses, productivity ana water temperature; the previously mentioned temperature decrease from centre tu periphery but constancy at depth may be inferred by the abundant information issued by Comprensorio, the official control body, or published by its experts(Dainese and Schiesaro)

The originally springing waters ,later produced from Quaternary thermal aquifers are now being produced increasingly trom the deeper Biancone, an Upper Jurassic to Lower Cretacic limestone formation more than 200 m thick.

Studies have been carried out(Ballestrazzi et al.,1991)to control subsidence by local reinjection of effluents hilt remote reinjection/ recharge should also be envisaged in the periphery of the hydrothermal basin(Lesmo, 1982). No special water balance has apparently been established for the global hydrothermal basin.

In the earlier times , the heat from the springinging thermal water was extracted in the pit where an array of coils or radiators was immerged in the circulating fluid for heating and domesti purposes; presently the heat pit is replaced by metal plate or shell and tube heat exchangers but a conventional boiler may be exceptionally present for back-up purposes. A further step in *the* environmentally focussed production and conservation of the geothermal resource has to be seen in the suggested installation of the so called inverte in the production well to balance production and congumption exactly(Schiesaro , 1991).

The environmental concern is illustrated at best by the evolution of the exploitation technology, i.e. ponds and tunnels for water tapping in the 19th century, Norton wells arid deeper percussion drilling later, restricted flow for the single well, abandonment of gas/air lifting in 1965 iafter a severe soil collapse in a spa area , resulting from joint impact of air arid aggressive waters on a poorly cemented steel production column).

More costly but cnvironmentally reliable well completion [bigger diameter rasing in the alluvial sediments down tu the limestone basament) in limestone, Instead of sands, can prevent from mixing of polluting shallow waters; well completion in the carbonate formation Biancone and pollution preventing reverse circulation (allowing drilling also whcn water is present and preventing the fluid absorption induced by direct circulation in the limestones) represent other development in the environment safeguard bur an equivalent environmental attention has *so* farnot be paid to the effluents .

The "environmental" remains as vulumetry of the existing 130 hotels(equivalent to some tens thousand standard flats), as requested geothermal flow(about 3600 cu.m/hour in the peak season, temperature 65-87" C,, salinty 2.5-6 gr/1 from about 220 wells averaging *300-400* m in depth) but mainly as volume of the effluents (2000-3000 cu.m/hour); these effluents are released on the surface in an area of about 23 sq;km at a temperature around *35-45'* C, without any attention for a more integrated energy use and lor the unsaturated zone ,a pollution carrier to the underlying thermal aquifers including Biancone with its eventual convective cell

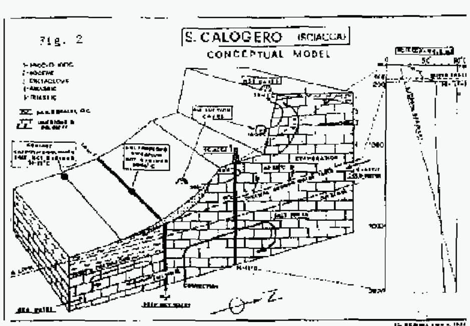
SCIACCA BASIN

In the arcn of Sciacca,a Sicilian spa centre on the South-western coast,,surface thermal shows(springs aiid vapours) are known from ancient times .

The local thermal basin,roughly 11-12 sq.Km at its bottom(Pratelli and Schiesaro,1987)corresponds to a structural "high" in the carbonate platform, located at the crossing between the extension of the Graham Banks -Pantelleria trend and a main negative structural axis in the Tertiary sequence . The Sciacca sedimentary sequence , as suggested by the figure 2, includes Triassic to Cretaceous dolomites arid limestones,,Cretaceous to Eocenic calcarenites and "scaglia",Oligocenic to Lower Hiocenic breccias and calcarenites, middle Miocenic sandy marls and shales, Plio-pleistocenic calcareous marls,"trubi",sandy shales .Hydrogeologically this sequence results apparently in a multi-aquifer in which the Meszoic,Oligo-to lower Miocenic and Pliocenic aquifers are separated by the Cretaceous-Eocenic and middle Miocenic aquitards(Preatelli and Schiesaro,1987).

The sulphureous overflow that springs at the 50-56° C temperature) along the southern fault of San Calogero Mount,as well as the contact carbonate-sulphate-salt hot springs(25-32° C) downhill and the hot caves(25-41° C) uphill, raise interpretation problems .In Sommaruga's conceptual model(1954)a continuous suction of cool air occurs at the base of the mountain and the exhalation of warm humid air(26-41° C temperature and 60-100 % humidity)in the hot caves uphill is controlled bv the metereological conditions (stop in suction-exhalation and even reverse flow in summer , when the outside temperature exceeds the temperature inside caves

Fig. 2



The conceptual model of Figure 2 offers also the interpretation key for the global thermal basin by correlating deep snd shallow data in the Sciacca area ,thanks to drilling .

The AGIP Sciacca 1 well(1954-55),of interest for both geothernal and petroleu research,was drilled down to a total 2827 m depth(2627m b.s.) always in the same monotonous Mesozoic(Trias) dolomite formation. It resulted a dry hole for petroleum,as opposed to drilling in the Gels aiid Ragusa areas,and it failed in finding a shale cover of geothermal interest(suggested by a good conductivity level in electric survcv data) but it proved a huge information source about an hydrothermal basin and related geothermal system. The absence of an imperviocs cover, replaced by ground or perched aquifers (brackish waters according to the ENI information from SP and PG-GN logs in the interval 150 TO 500 m at depth in the AGIP Sciacca 1 well), explains either the surface shows(hot springs and hot caves,so called "stufe"di San Calogero) or the significant "temperature hook" at depth, below water table and sea level, suggesting an heat supply from the bottom .

The existence of a convective cell (stressed by the 63° top temperature at surface as opposed to the only 86° C bottom temperature notwithstanding geothermal gradient in the 2827 m deep Siacca 1 well) emphasizes the importance of the geothermal karst systems,where the host formation is enough thick and notwithstanding loa geothermal gradients(?-2.5" C/100 m In the Sciacca basin?.

While neglected as for geothermal potential, available for instance in hotel heating according to the Abano model, the Sciacca hydrothermal basin has proved being of industrial interest (production of artificial mineral water, suggested by Pratelli and Schiesaro, 1987) as stressed by an early research(S.O.R.I.M.,Società Ricerche Minerarie, Palermo),more recently renewed (by S.O.R.I.M. on account of S.I.T.A.S. Società Italiana Termale Abano Sciacca).Information suggests the existence of three main aquifers, a lover one("acque madri" at a 57-58° with a 1000 l/s yeld) and the intermediate and shallow ones(with lower temperatures and yelds)

APPLICATIONS AND ENVIRONMENTAL ISSUES

As suggested by the review of the Abano and Sciacca case histories, asking for a better assessment of *the environmental risk* in geothermal karst systems, decision makers and planners operate in a world of uncertainty when faced with the appropriate, sometimes alternative, use of geothermal energy.

Even in the low temperature ranges, where figure 3 suggests various direct thermal applications, land use planning and resource conservation, subsidence and seismicity, chemical and thermal pllution may have negative, not easily predictable effects, resulting in direct economic and indirect environmental costs especially in the spa areas where the health hazard: are loss negligible.

FLUID TEMPERATURE RANGES REQUESTED BY AGROZOOTECHNIC USES, FOOD INDUSTRIES AND GENERAL SERVICING

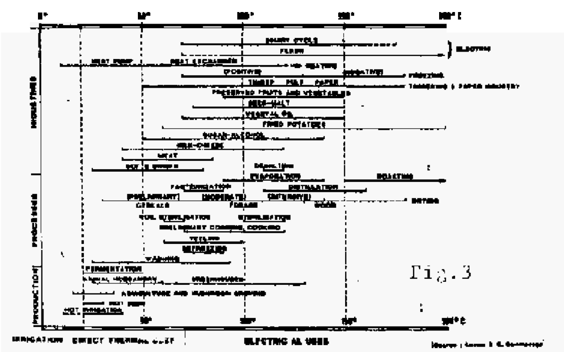


Fig.3

The geothermal system, in fact, including a subsurface reservoir and a surface plant, is a thermodynamically global entity, which cannot be impacted in a part without impacting the rest of it; this applies to the geothermal karst systems, more sensitive environrentally because of their "double porosity", to be studied and developed not only as open or closed heat-water exchange according to temperature drop and to fluid flow with or without recharge but also as quality of recoverable fluids and effluents.

Geothermal laws without a clear reference to environment, uncomplete matching of national law with evasive or lacking regional regulations, controversial matching of energetic and non-energetic uses of water (Lesmo, 1982, 1986 and 1993) may result also in questionabel choices .

CONCLUSIONS

Environment , a valuable finite asset to be used rationally and not a "res nullius" to be wasted, asks for harmonized economical, legal and technical approaches, focussed at correct geo-heat developments. This applies especially to direct geothermal applications, possible also in spa areas as district heating and rural uses provided special emphasis is given to thermal water, a quantitatively but not qualitatively resource to be protested in the difficult transition from uncontrolled economic growth to sustainable development .

Socioeconomic impact assessment is a new field of investigation covering several traditional fields of economics , sociology and political sciences but asks for complementary environmental assessment .

In front of the requested matching of ecology and related indirect environmental costs with traditional economics and related direct better known costs, the environmental geology, if integrated by econometric and tecnometric assessment, may offer a significant contribution in the qualification and quantification of costs and benefits (Buscema and Lesmo, 1979, Lesmo 1987 and 1993). The requested assessment of the environmental risk, to be based on the geological evaluation of hazard and vulnerability jointly with the economic evaluation of the natural element at risk, asks in fact for the assessment of its actual value, possible only if extended to the long term and including orientatively the added value of the resource, i.e. mineral thermal water, in its main form transitions (Lesmo, 1993 and 1994).

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