AN ATTEMPT TO CORRELATE Kh DISTRIBUTION WITH GEOLOGICAL STRUCTURE OF LARDERELLO GEOTHERMAL FIELD

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Steam production in Larderello field is obtained from fractured rocks having a very low matrix permeability.

Fractured zones are irregularly distributed and their location is one of the main objectives of present geophysical research and one of the principal problems in field exploitation. This problem has also been approached from a geological point of view in an attempt at finding the relationship between secondary permeability and the lithological and structural characteristics of the reservoir formations.

The first results, obtained by Cataldi et al. (1963), found a high ratio of productive/unproductive wells along the axes of the positive structures.

The present study of the Kh distribution in Larderello fields should permit a more detailed analysis of the different geological factors affecting the productive capacity of the reservoir formations.

Kh Distribution

Kh values were obtained for about 50 wells in Larderello area from pressure build-up analysis, using both the classical Horner method and different type-curve matches. Other methods of analysis for fractured media were also considered.

Almost the same number of values were obtained from the analysis of back-pressure curves. A comparison, possible for several wells, of the Kh values obtained from both methods shows that a good agreement exists only if skin-effect is taken into account. If not, the values given by the back-pressure curves are almost systematically higher (as much as 50 to 100%) than those given by the build-up curves.

The wells considered have a satisfactory distribution over the entire field area. In some marginal zones the majority of them are completely unproductive, due to lack of permeability, so that no tests were performed on them.

In other zones with unproductive wells, despite the fact that these have crossed permeable horizons, only a few data from injection tests are available.

The Kh distribution in these zones is not well defined.

The wells with similar transmissivity values are usually grouped together, with a few rare exceptions.

The contour lines in Figure 1 refer to Kh values taken in a geometrical progression as the curves are better defined in this way. The line corresponding to 1 Darcy-metre is not reported due to the lack of data in the marginal zones,

Comparison with Geological Structures

Figure 2 shows the elevation of the top of the formations forming the potential reservoir.

This map was obtained by geometrical interpolation between the elevations observed in the wells: the fault planes are not indicated.

From Figures 1 and 2 there is enough evidence of a correspondence between the high transmissivity zones and the structural highs, thus proving that tectonics plays a very important part in determining secondary permeability in the reservoir formations.

Other factors contribute to this permeability and they are thought to explain the observed anomalies in transmissivity distribution where this is not attributable to the structures.

Among these, lithology, lithostatic and fluid pressure must be taken into account.

Other important factors, such as dissolution and deposition, are the object of geochemical studies.

Discussion

The sequence of terrains in the Larderello zone are commonly known to be, as follows, from top to bottom:

a) the shaley cap rock formation;

b) sandstones that are irregularly distributed in the productive areas and usually separated from the lower formations by an impermeable layer of shales;

c) Competent, stratified and massive limestones distributed irregularly over the productive area;

d) alternations of dolomites and anhydrites, not always present in the productive area, quite plastic if taken as a whole;

e) a series of terrains comprising incompetent slate layers and competent quartzites.

The potential reservoir is considered to be made up of c), d) and e).

The contact between the different formations is generally tectonic and caused by mainly horizontal-type movements.

The contact zone, therefore, (and especially that between the cap rock formation and all the underlying ones) are characterized by intensive fracturing and have a high secondary permeability.

Furthermore, the whole region was subjected to compressive stress during the last phases of orogenesis thus resulting in the folding of the layers forming the potential reservoir. The permeability in the crest zone of the anticline structures may be said to have increased due to tension cracks and fissures. Cavities may also have formed along the crests due to the differential movements of the beds.

These facts may have given the greatest contribution to fracturing the upper parts of the positive structures.

Future Developments

This research will now be aimed at studying the distribution of plastic and competent layers inside formation e), the existence of overthrusts within the formations described and especially in e), and the role of the direct faults formed after folding and thrust movements. A study will also be made of fluid and lithostatic pressure.

REFERENCES

Cataldi, R.; Stefani, G.; Tongiorgi, M.: "Geology of Larderello region (Tuscany). Contribution to the study of geothermal basins." In: Nuclear Geology on Geothermal Areas. Ed: E. Tongiorgi, Laboratorio di Geologia Nucleare, Pisa, 1963, p. 235.

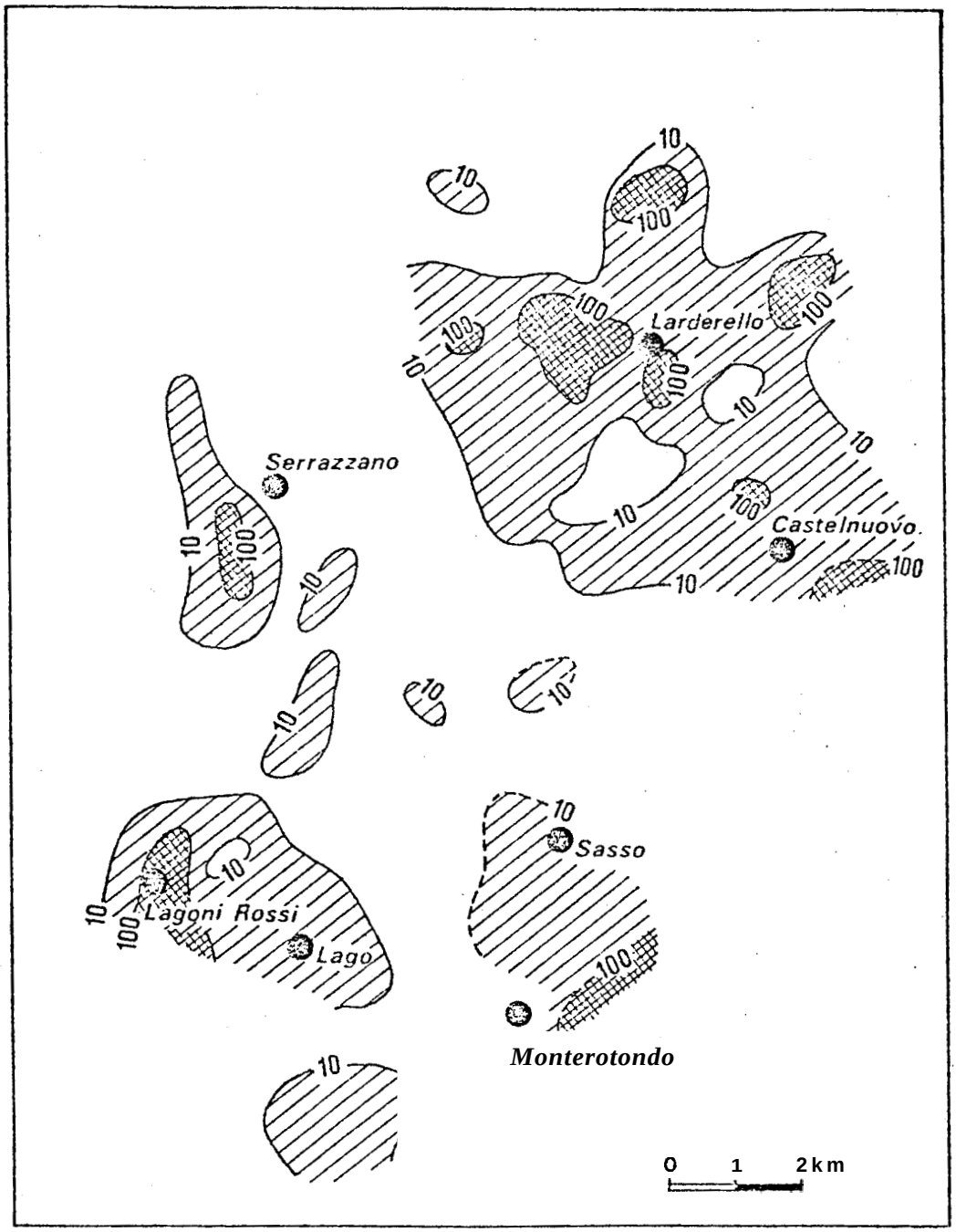

Figure 1 : kh distribution in Larderello field in Darcy-metres.

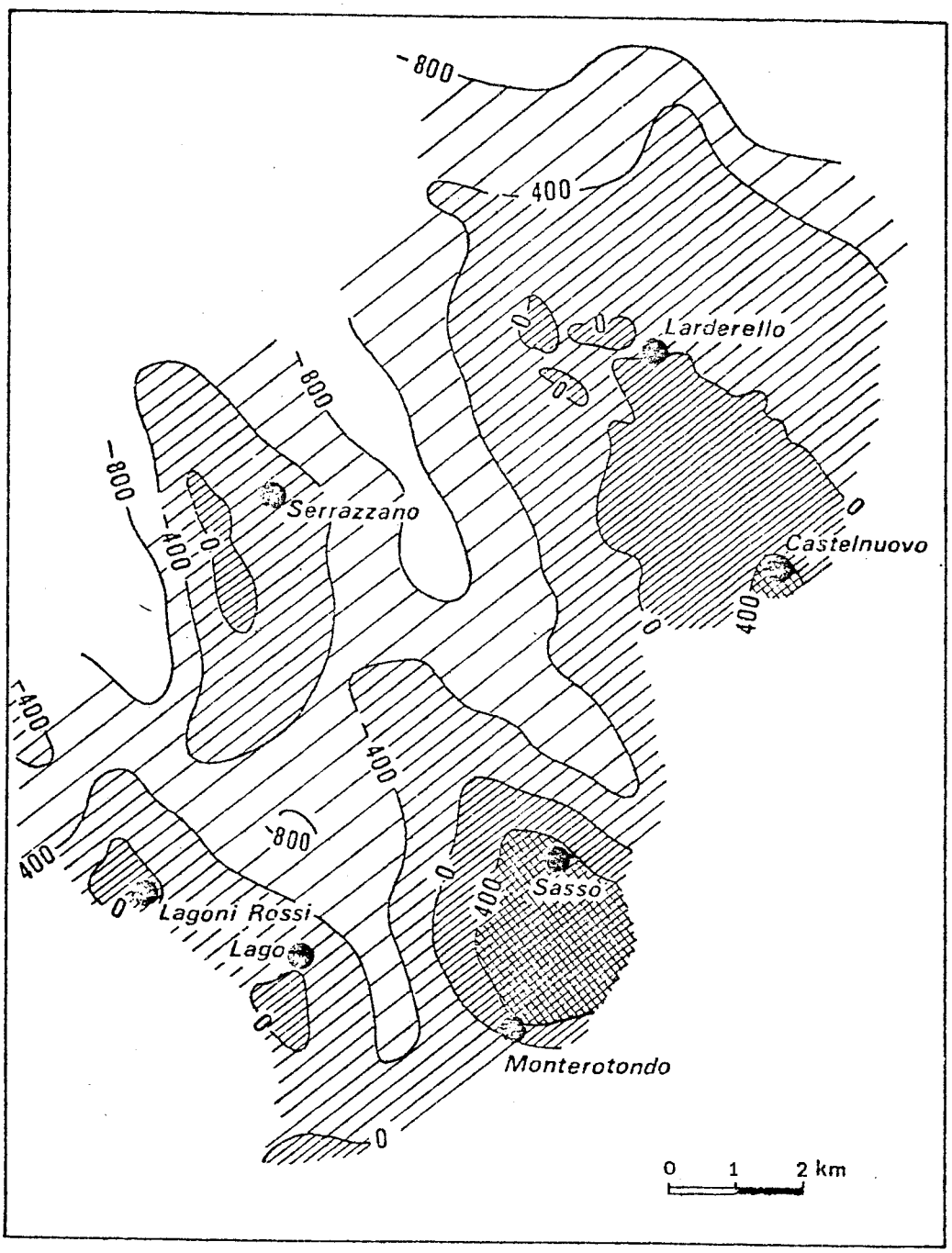

Figure 2 : Attitude of potential reservoir top in Larderello field (m a.s.l.)