Geothermics, Vol. 6, pp. 163–174.
Pergamon Press Ltd. 1978. Printed in Great Britain.

0375–6505 77 0701–0163 $02.00/0

CO_2 DISTRIBUTION IN THE ATMOSPHERE AND NOISE SURVEY AFTER BLOW-OUT IN ALFINA 1 WELL, NORTHERN LATIUM, ITALY*

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Abstract—A water-dominated geothermal reservoir, with a gas cap (mainly CO_2) on the reservoir roof, was individuated in Torre Alfina zone, northern Latium, about 30 km south-east of Monte Amiata.

The first exploratory well (Alfina 1), drilled in 1973, blew-out spontaneously so that no production casing could be inserted.

After well shut-in several surface gas manifestations appeared which were considered of some risk to the environment.

This paper describes the methods used to determine the degree of pollution and the total area involved.

The study of the gas dispersion in the atmosphere, the noise resulting from production, and the meteorological conditions in the area, was used in drawing up a disposal plant project; this plant will be assembled on future wells as a safety measure where large quantities of fluids are involved.

INTRODUCTION

Some geothermal areas are characterized by a certain degree of natural pollution caused by surface manifestations such as fumaroles, thermal springs, etc. However, it cannot be denied that industrial exploitation of these areas, by considerably increasing the quantity of fluid produced, may cause changes or variations in the natural biological equilibria.

Up to now very little has been known on the effects of pollution; exploitation of geothermal fields is a rather new and limited phenomenon and it is only recently that our ecological conscience has been wakened. Although the pollutant effects of industrial exploitation are normally felt in the long term, there are particular conditions in which this problem has a more immediate effect on the environment. For example, there are geothermal fields that produce naturally contaminating fluids, either because of their saline content in the liquid phase or their constituents in the gas phase.

This situation becomes particularly critical when exploration begins in a new field where some doubt still exists as to the type of fluid in the reservoir.

Torre Alfina zone can be taken as an example of what has just been said (Fig. 1).

In this zone, in northern Latium about 30 km south-east of Monte Amiata, a water-dominated geothermal field was individuated having a gas cap (mainly CO_2) on the roof of the reservoir.

After the first exploratory well was drilled gas began escaping to the surface so that its chemical composition had to be examined and a systematic survey made of the degree of environmental pollution.

WELL HISTORY

The first exploratory well (Alfina 1) was drilled in correspondence to a small outcrop of trachybasaltic lava. After crossing about 20 m of volcanites it met the flysch formation of the cap rock, consisting of alternations of shales, marls and limestones. On 7th June 1973, having reached

*This paper was presented at the Simposio Internacional Sobre La Energia Geotermica en America Latina, Guatemala, 18–23 October, 1976.

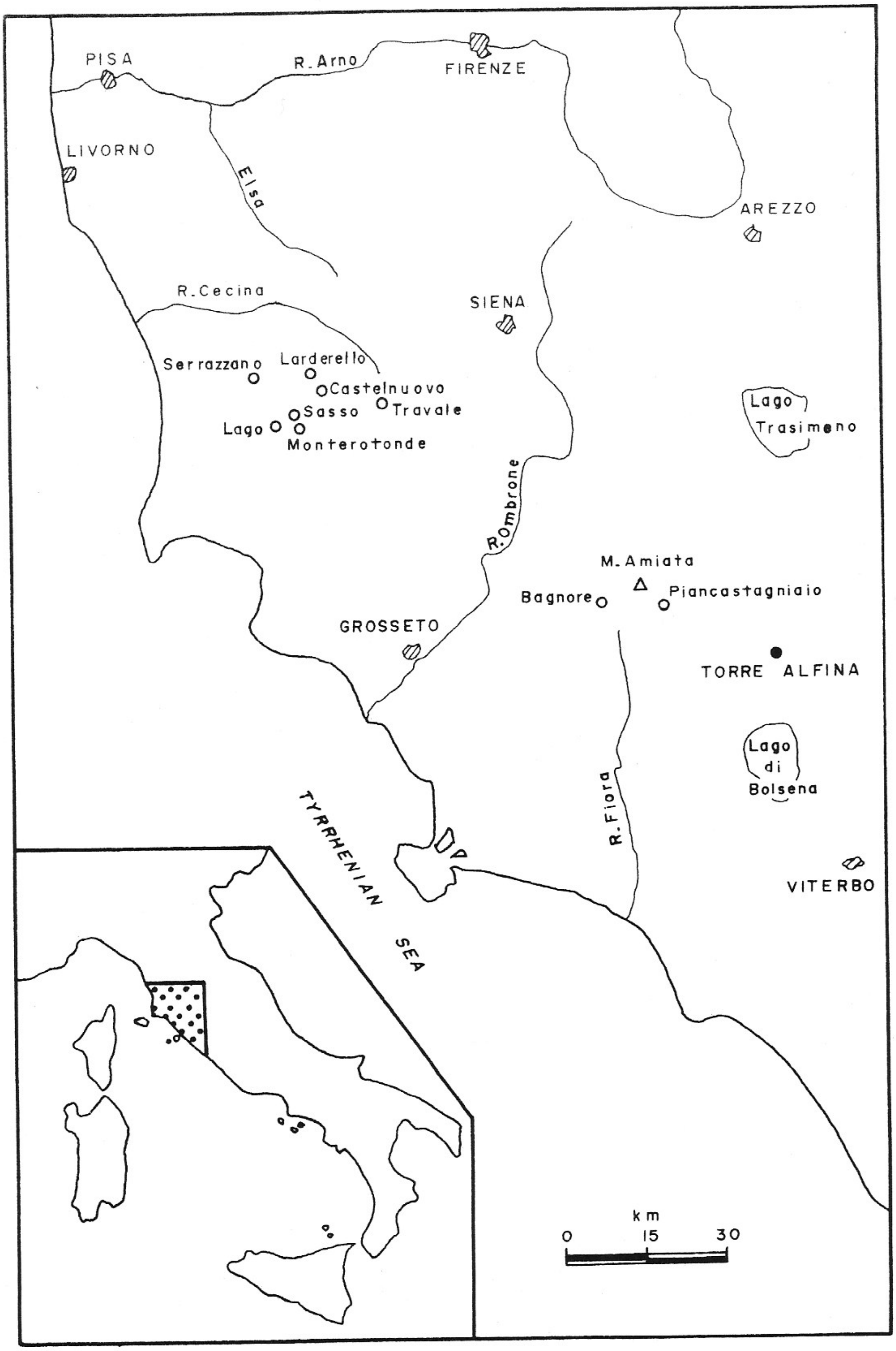


Fig. 1. Location of Torre Alfina geothermal area.

663 m depth near the reservoir roof, it blew out spontaneously, producing over 300 t/h of fluid made up almost entirely of gas.

The unexpected and uncontrolled blow-out of the well meant that the production casing could not be lowered so that the well was left uncovered except for the first 100 m cased previously. Because of the high degree of pollution, the relative risks and high noise-level involved, the well was shut-in after discharging to the atmosphere more than 25,000 tons of gas; well-head pressure in this phase rose to 33 ata, then decreasing sharply to 29 ata when shut-in was almost complete. Some hours after shut-in several gas escapes were noted in the area surrounding the well, increasing in number within a short time. At the same time well-head pressure decreased sharply once again to reach a value of 24 ata. The appearance of the surface manifestations was a result of the lack of production casing and of the lithology of the cover formation.

After well shut-in the pressurized gas found an escape route upwards through the permeable horizons in the flysch and, due to the high permeability of the volcanic cover, could reach the surface (Fig. 2).

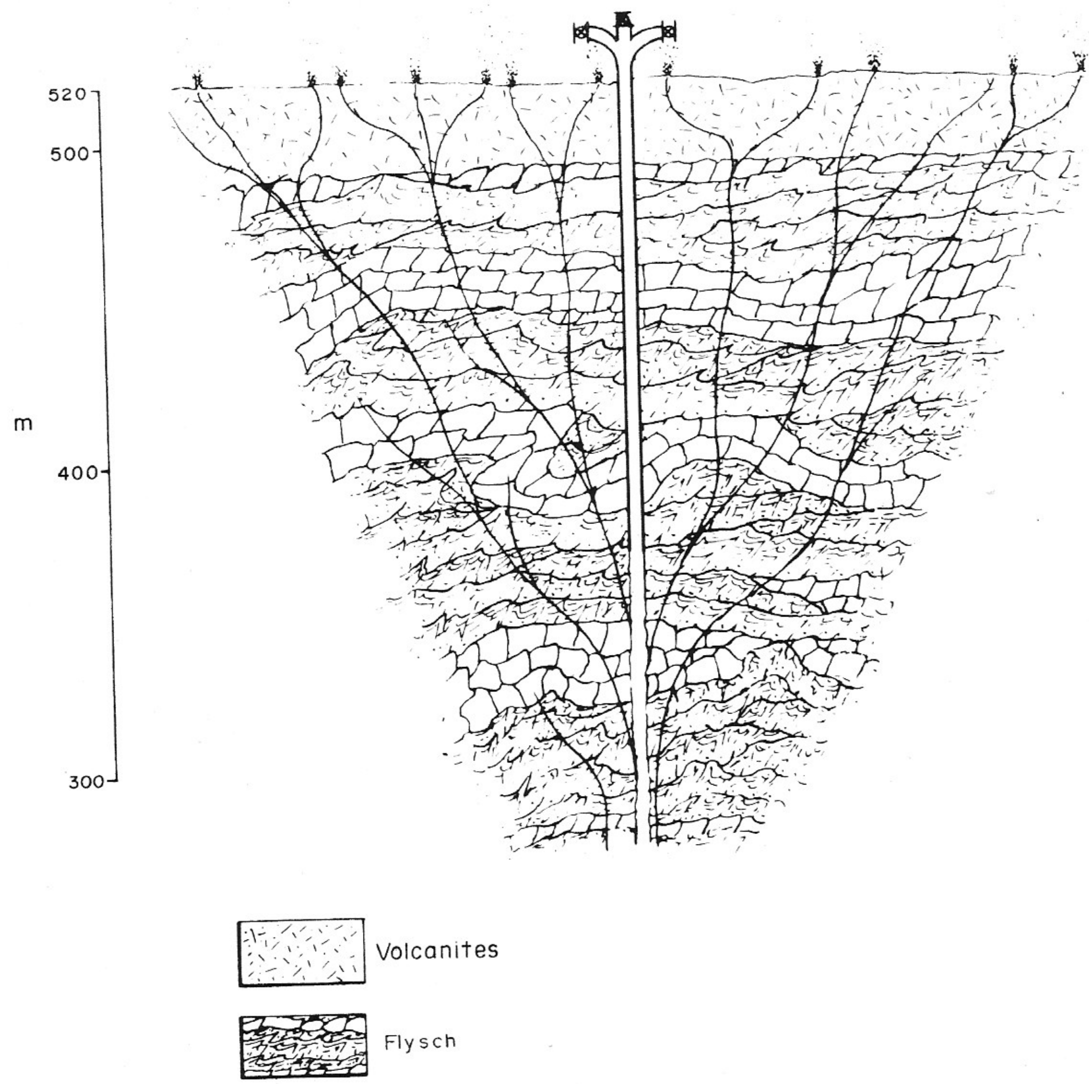


Fig. 2. Sketch of gas blowing-up around the Alfina 1 well.

Although the chemical analyses* ascertained that no poisonous constituents existed in the gaseous mixture, the presence of large amounts of CO_2 was of some danger to the rig technicians and to the inhabitants of the nearby cottages.

This situation led to the decision to cement the well completely for safety reasons. At the end of this operation well-head pressure reached 6 ata and the gas manifestations disappeared in some places, remaining slightly active in others. In order to reduce the concentration of CO_2 at ground-

*Average analysis of gas produced in Alfina 1 well (values given in % in volume): $CO_2 = 98{\cdot}55$; $CH_4 = 0{\cdot}15$; $N_2 = 1{\cdot}30$, $H_2S < 0{\cdot}001$.

level an attempt was made to concentrate the gas from all the manifestations in a few points and then discharge it at great height. Three boreholes were drilled for this purpose at depths of 16, 13 and 10 m respectively, thus creating preferential routes for the gas produced from the volcanic formation.

Only one of these three boreholes was successful, causing the disappearance of the nearby manifestations, whereas the other two gave no satisfactory results.

Due to the persistence of these surface manifestations some systematic analyses were made of the CO_2 concentration in the atmosphere, in view of the possible accumulation of gas in the morphologically depressed zones and in particular meteorological conditions.

This survey had two objectives:

(a) to delineate the area with a CO_2 concentration exceeding the acceptance value (5000 ppm) in every meteorological condition;

(b) to study gas dispersion in the atmosphere: the results of this study would then be used in designing disposal plants for later wells, thus ensuring maximum safety conditions during large-scale fluid production.

SURVEY METHOD AND DATA COLLECTED

The survey covered all the area containing the manifestations and a surrounding area of more than 250 m diameter around Alfina 1 well, over a total period of 53 days.

After an initial experimental sampling, 34 stations were selected for regular gas sampling over about 4 weeks.

Immediately after this phase the number of stations was reduced to 11 of the more important ones and sampling continued for another 3 weeks. The CO_2 concentration values were measured twice daily, between 6.00 and 9.00 a.m. and 6.00 and 9.00 p.m. at fixed distances of 10 and 80 cm from ground-level.

The apparatus used was a Dräger gas detector, consisting of a pump and CO_2 detector tubes which permit an immediate read-off of the concentration (% in volume).

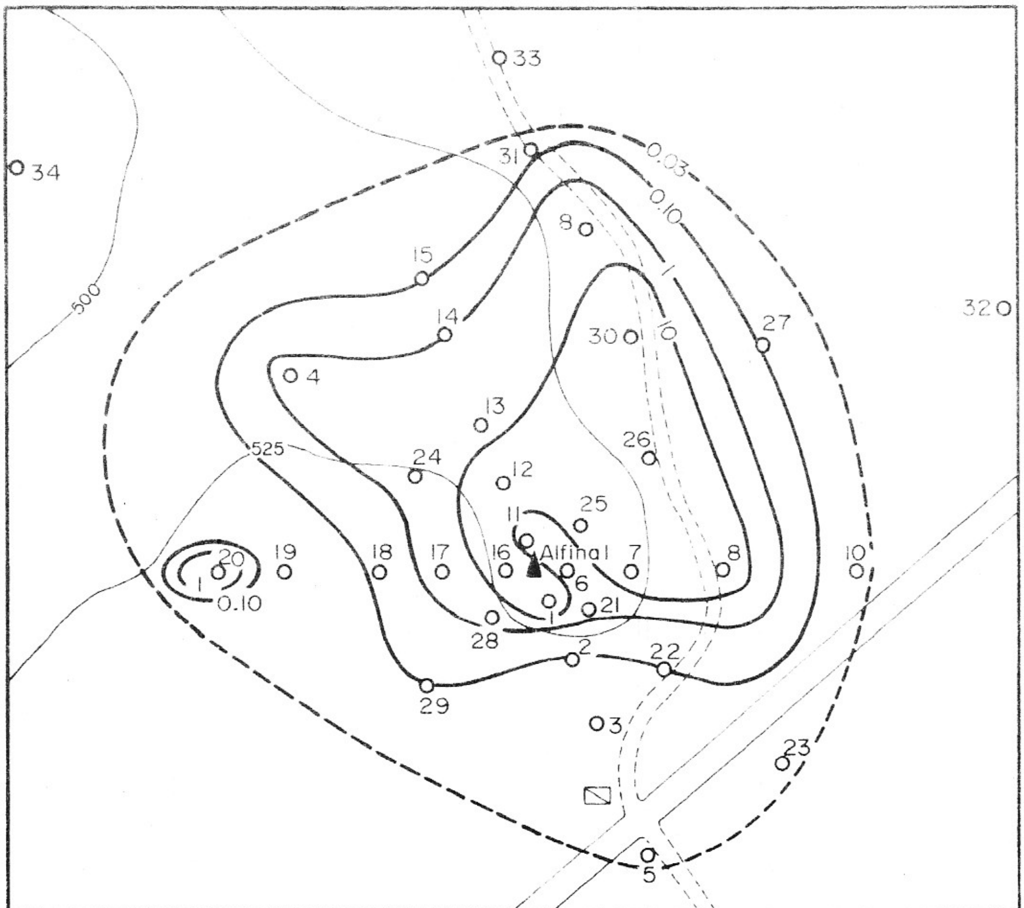
For a real evaluation of the degree of pollution in this area we had to ascertain the CO_2 content normally present in the environment. To obtain this some measurement points were selected at a considerable distance from the study area. Air samples were taken in different meteorological conditions which, after laboratory analysis using a steam phase chromatograph, gave a range of concentrations between 0·036 and 0·050% in volume. These values correspond to the natural atmospheric ones.

At the same time as the CO_2 systematic measurements were being made, a series of meteorological data was collected, including those on wind velocity and direction, atmospheric thermal gradient, thermoigrographical and barographic recordings. These data were used to check whether and how much the variations in atmospheric physical parameters influence the trend of the CO_2 concentration in the study zone, especially as regards time and space variations.

EXAMINATION OF RESULTS

As already mentioned in the previous paragraph, 4 daily samples were taken in the area around Alfina 1 well throughout the whole period of the gas leakage. Maps were then drawn of the CO_2 distribution for each possible meteorological condition.

Figures 3, 4 and 5 represent some examples of the CO_2 distribution in the most frequently occurring meteorological conditions. An examination of these figures shows that the gas concentration is always higher at 10 cm from ground level, independent of sampling time or atmospheric conditions. This is easily explained if we consider that the gas discharge pressure was



Average meteorological conditions							
Wind		Temperature	Barometric pressure	Relative humidity	Thermal gradient	Conditions of	
Direct	Vel. m/sec	°C	mm Hg	%	2-10m GL	Soil	Sky
	0	14	713	73	+0.08	Damp	Variab.

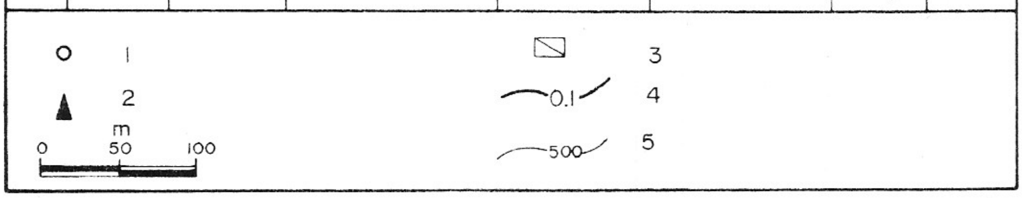


Fig. 3(a). CO_2 distribution 10 cm from ground-level around Alfina 1 well. (Measured on 28 July, 1973 from 7.00 to 9.00 a.m.) 1. CO_2 measurement station. 2. Alfina 1 well. 3. Meteorological station. 4. CO_2 concentration curve (% by vol.). 5. Elevation a.s.l. (m).

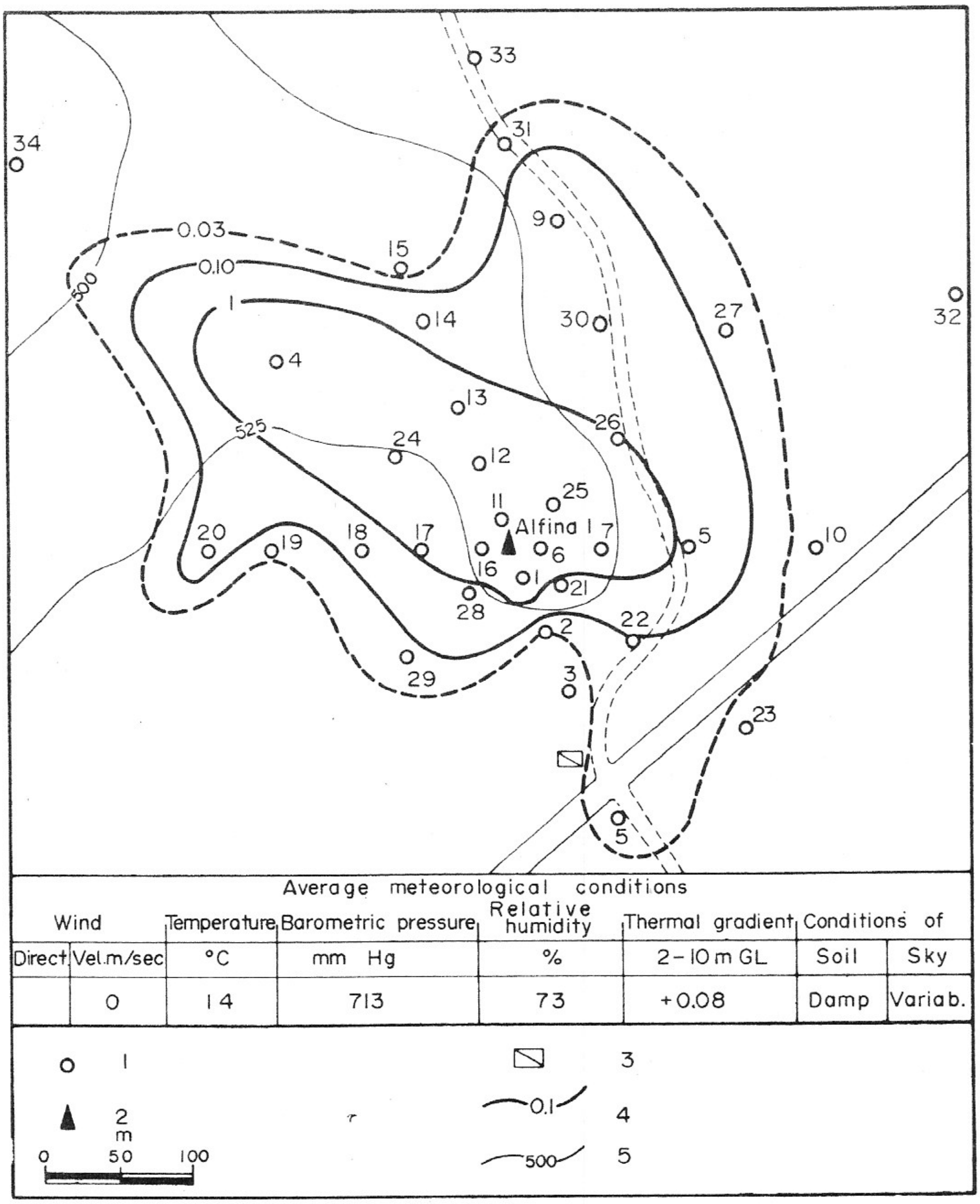
negligible and therefore the density difference between air and CO_2 was the determining factor.

Of the atmospheric agents, the wind plays an important part in distributing the CO_2 concentration. In fact, although it has the greatest effect at 80 cm above ground-level, a percentage variation in the CO_2 content is more noticeable at lower levels.

In this regard it is interesting to note that the gas manifestations began during a summer period characterized by some of the most unfavourable atmospheric conditions as, for example, uniformly high pressures with weak wind force (maximum velocity 4 m/s) or none at all (Fig. 6).

Consequently, winds of such a small force are almost completely hindered in their action by the morphology of the zone. In fact, the isoconcentration curves, especially at the lowest levels, normally present a trend equal to that of the morphology and not to wind direction (Figs. 3 and 4).

Generally, however, the wind has the effect of diluting the CO_2 concentrations and spreads the gas over wider areas than are affected in static air conditions. Thus the zones with a low CO_2



Average meteorological conditions							
Wind		Temperature	Barometric pressure	Relative humidity	Thermal gradient	Conditions of	
Direct	Vel.m/sec	°C	mm Hg	%	2–10 m GL	Soil	Sky
	0	14	713	73	+0.08	Damp	Variab.

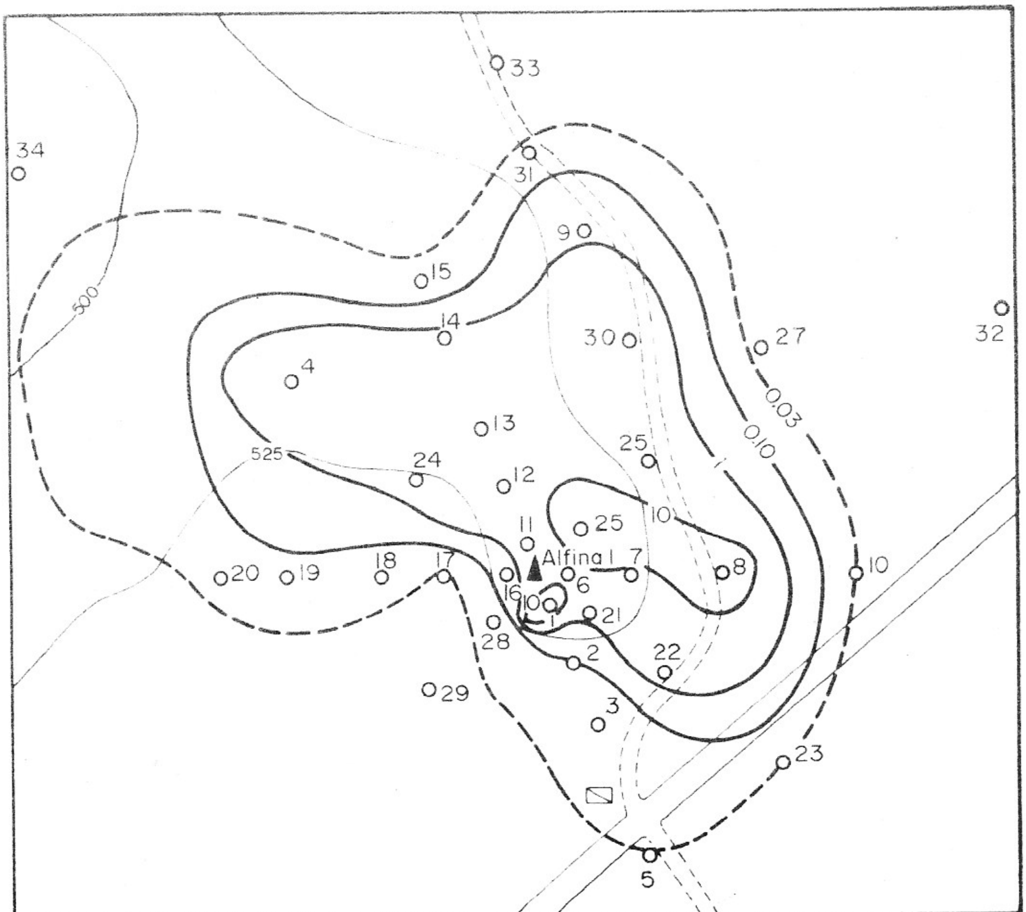
Fig. 3(b). CO_2 distribution 80 cm from ground-level around Alfina 1 well. (Measured on 28 July, 1973 from 7.00 to 9.00 a.m.) For explanation of legend see Fig. 3(a).

concentration become more extensive and those with a high concentration become smaller. The effect is even greater the stronger the wind force in play.

Another observation comes from the particular atmospheric conditions usually found in the morning between 6.00 and 7.30 a.m.: no wind, great humidity, rather low temperature. In this case, the CO_2 which is at a general standstill, accumulates in spots that are topographically more depressed and sheltered and especially near the gas escape points where it reaches concentrations of more than 40% in volume.

Figure 3(a) shows an example of this situation relative to 10 cm from ground-level; the highest concentrations were measured at stations No. 1, 7, 8, 12, 16, 25, 26 and 30. These stations are almost all escape points as well.

A survey made on the different measuring stations (Fig. 7) shows that the amount of gas dispersed in the atmosphere tends to decrease with time, resulting in a gradual reduction of the areas with a high CO_2 concentration, as can be seen by comparing Figs. 3, 4 and 5.



Average meteorological conditions							
Wind		Temperature	Barometric pressure	Relative humidity	Thermal gradient	Conditions of	
Direct	Vel.m/sec	°C	mm Hg	%	2-10m GL	Soil	Sky
N	3	15	714	65	+0.05	Dry	Clear

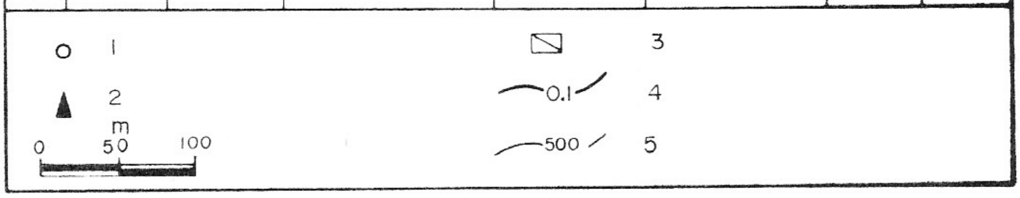


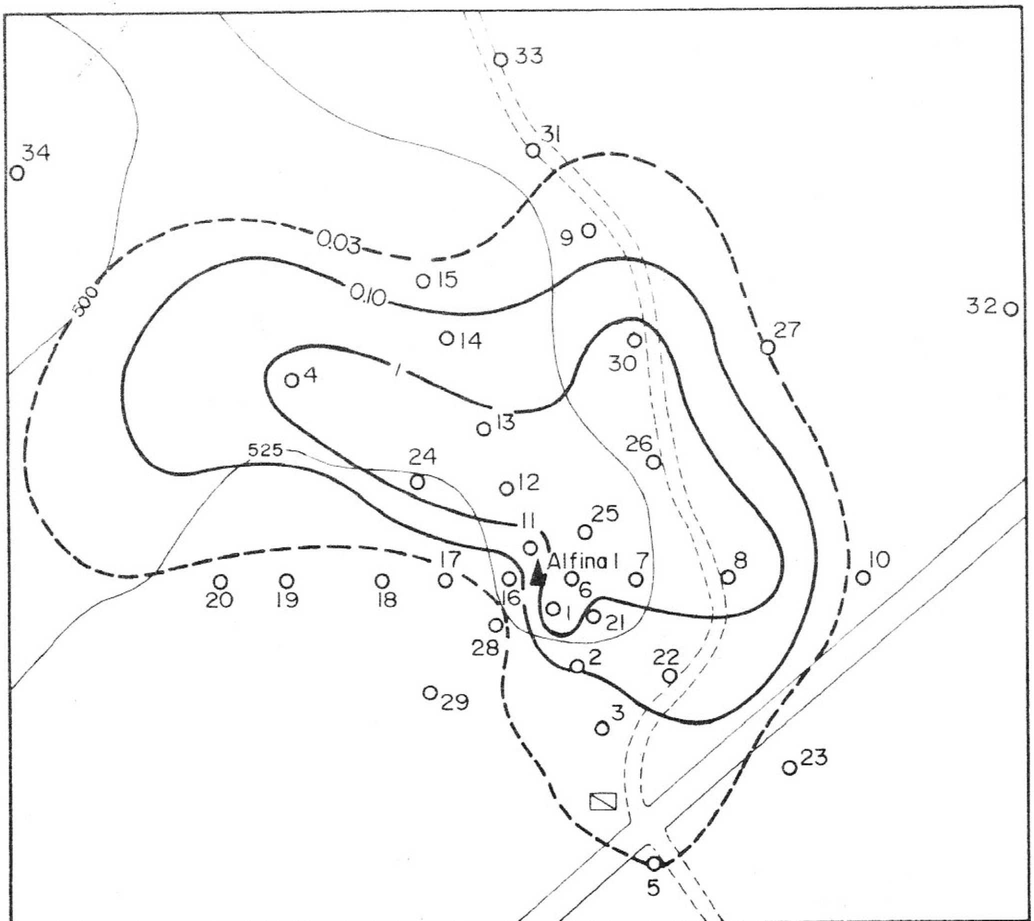
Fig. 4(a). CO_2 distribution 10 cm from ground-level around Alfina 1 well. (Measured on 31 July, 1973 from 6.00 to 8.40 a.m.) For explanation of legend see Fig. 3(a).

NOISE SURVEY

When large quantities of fluid (especially gas) are produced in geothermal wells considerable problems arise with regard to noise. This problem had, of necessity, to be solved in view of the programme to continue exploration in Alfina geothermal area. A noise survey was therefore required as the basis of a project for the silencer plants.

During the period between blow-out in Alfina 1 well and its shut-in, a series of noise measurements were made using an industrial MSA noise meter, type 965, with immediate read-off and capable of detecting noise level in dB (from 70 to 140).

After this first survey a study was made of the noise pressure levels per octave band in dB and dBA in different production conditions. To be more exact, the noise measurements were made with fluid flow-rates of 80, 200 and 280 t/h in points near the well and in the surrounding areas,



Average meteorological conditions							
Wind		Temperature	Barometric pressure	Thermal humidity	Thermal gradient	Conditions	
Direct	Vel m/sec	°C	mm Hg	%	2-10m GL	Soil	Sky
N	3	15	714	65	+0.05	Dry	Clear

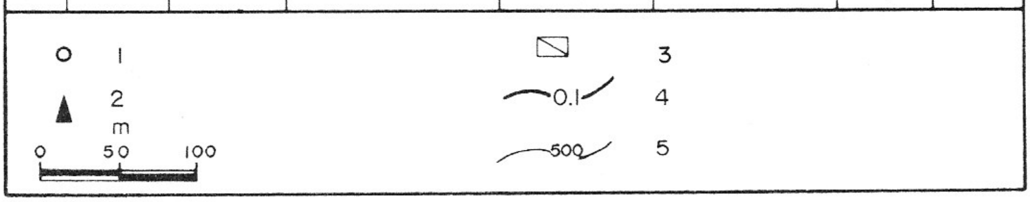


Fig. 4(b). CO_2 distribution 80 cm from ground-level around Alfina 1 well. (Measured on 31 July, 1973 from 6.00 to 8.40 a.m.) For explanation of legend see Fig. 3(a).

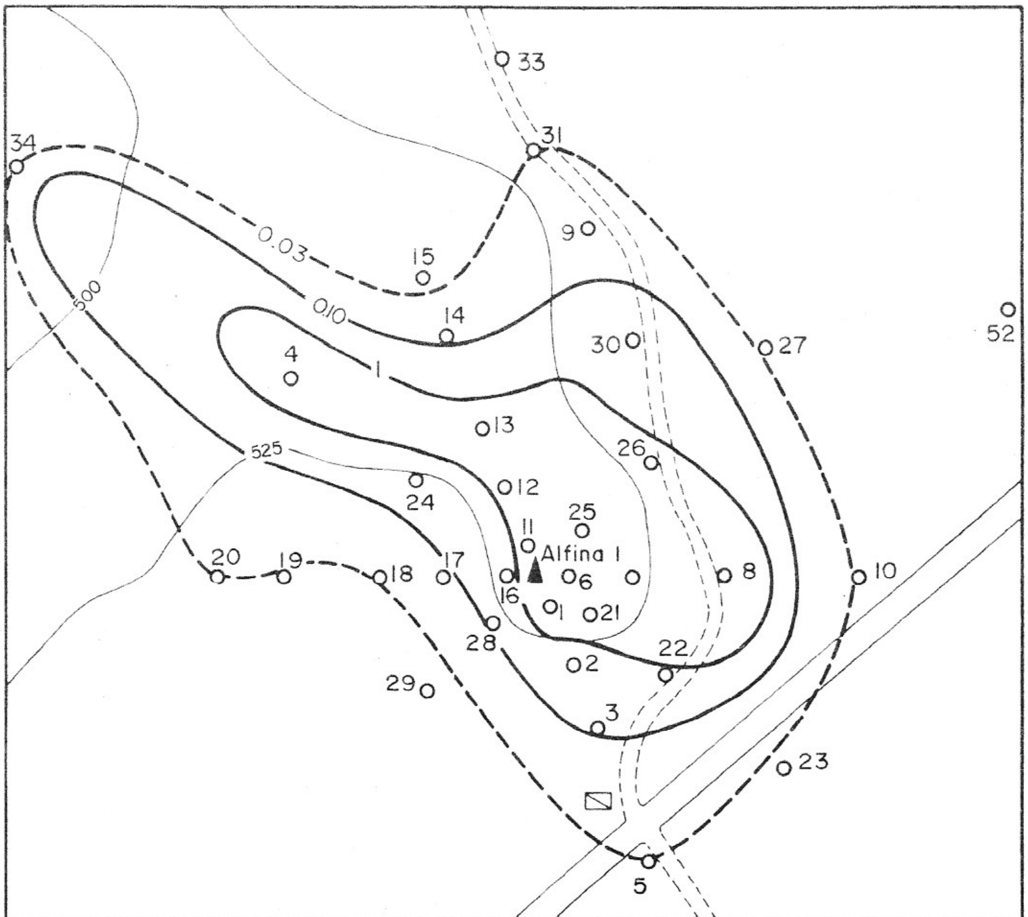
with particular attention paid to residential zones. Finally, after well shut-in the area background noise could be measured.

Figure 8 gives a diagram of the noise pressure level distribution as a function of its frequency with a flow-rate of 80 t/h.

The apparatus used in this second survey was a Bruel-Kjär precision noise meter for impulse measurements, type 2209.

CONCLUSIONS

The uncontrolled blow-out of Alfina 1 well caused environmental problems connected with gas leakage and high noise levels.



Average meteorological conditions							
Wind		Temperature	Barometric pressure	Relative humidity	Thermal gradient	Conditions of	
Direct	Vel.m/sec	°C	mm Hg	%	2-10m GL	Soil	Sky
	0	17.5	721	74	+0.15	Dry	Clear

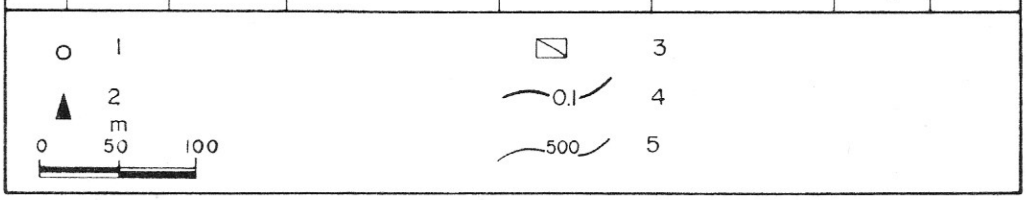


Fig. 5(a). CO_2 distribution 10 cm from ground-level around Alfina 1 well. (Measured on 7 September, 1973 from 6.00 to 7.30 a.m.) For explanation of legend see Fig. 3(a).

The problem, where the gas was concerned, became more complicated when the manifestations appeared in the area surrounding the well.

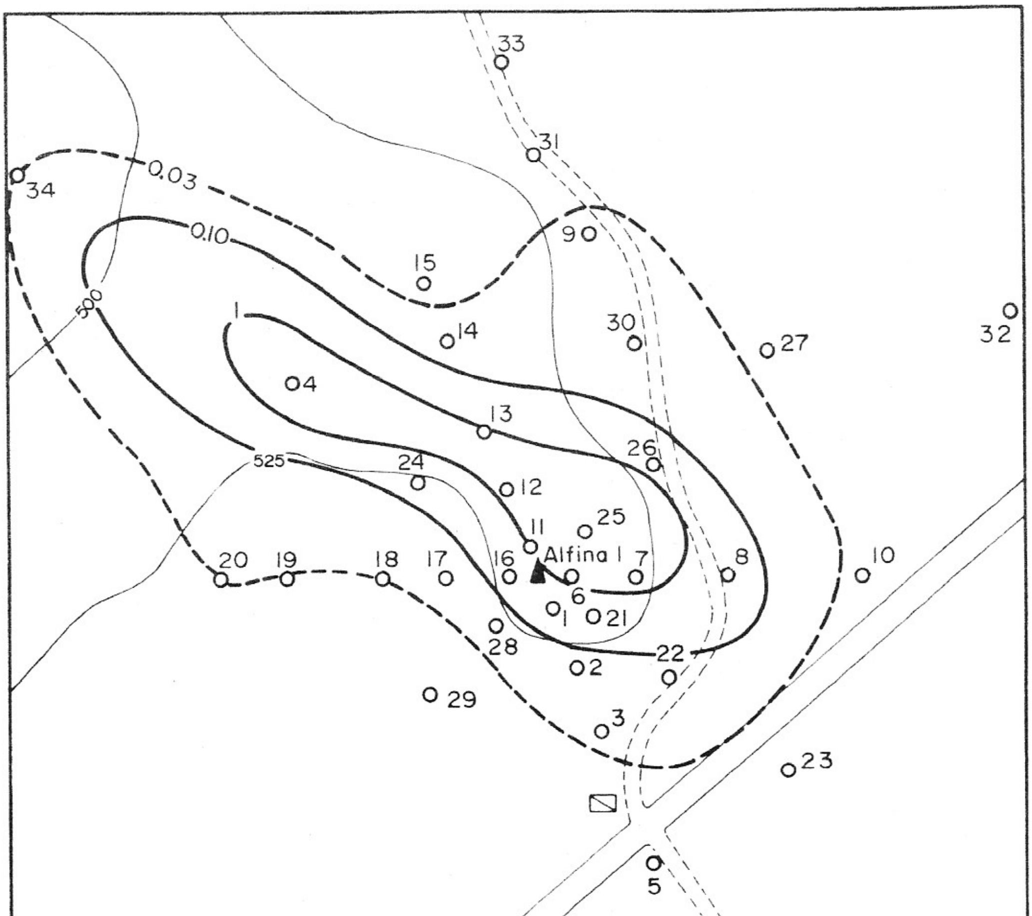
The study programme was mainly directed at keeping the CO_2 concentration within safety limits for men and beasts. A more detailed ecological survey was not required as the gas emanations disappeared after about 2 months.

A longer and more detailed study was carried out, on the other hand, on the meteorological conditions in the zone. From this study we obtained the so-called ≪parking level≫ at which the gas from later wells should be dispersed ideally to obtain immediate dilution in the air with no ground fall-out.

The data from the noise survey were used in the silencer project.

The results of all these surveys were used in designing the first disposal plant, comprising a 40 m high chimney, coupled to two Stopson silencers.

With this plant a later well, Alfina 1 Bis, was able to produce continuously for more than 1 month, ensuring maximum safety conditions for the environment. A chemical and noise test at a flow-rate of 280 t/h proved that no gas fell on the ground and that the noise was reduced by 10 dB (scale A) at 30 m from well-head and by about 20 dB (Scale A) 450 m away.



Average meteorological conditions

Wind		Temperature	Barometric pressure	Relative humidity	Thermal gradient	Conditions of	
Direct	Vel m/sec	°C	mm Hg	%	2-10 m GL	Soil	Sky
	0	17.5	721	74	+0.15	Dry	Clear

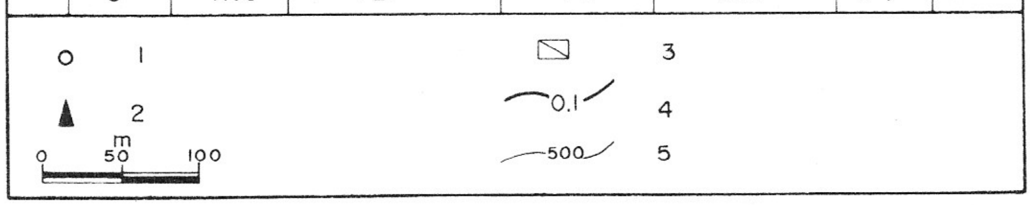


Fig. 5(b). CO_2 distribution 80 cm from ground-level around Alfina 1 well. (Measured on 7 September, 1973 from 6.00 to 7.30 a.m.) For explanation of legend see Fig. 3(a).

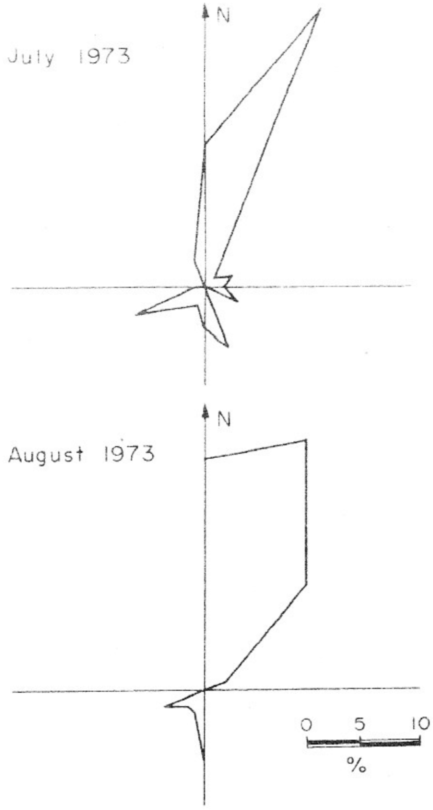


Fig. 6. Wind frequency in 16 directions in % of the number of daily recordings. (The missing % means there was no wind at all.)

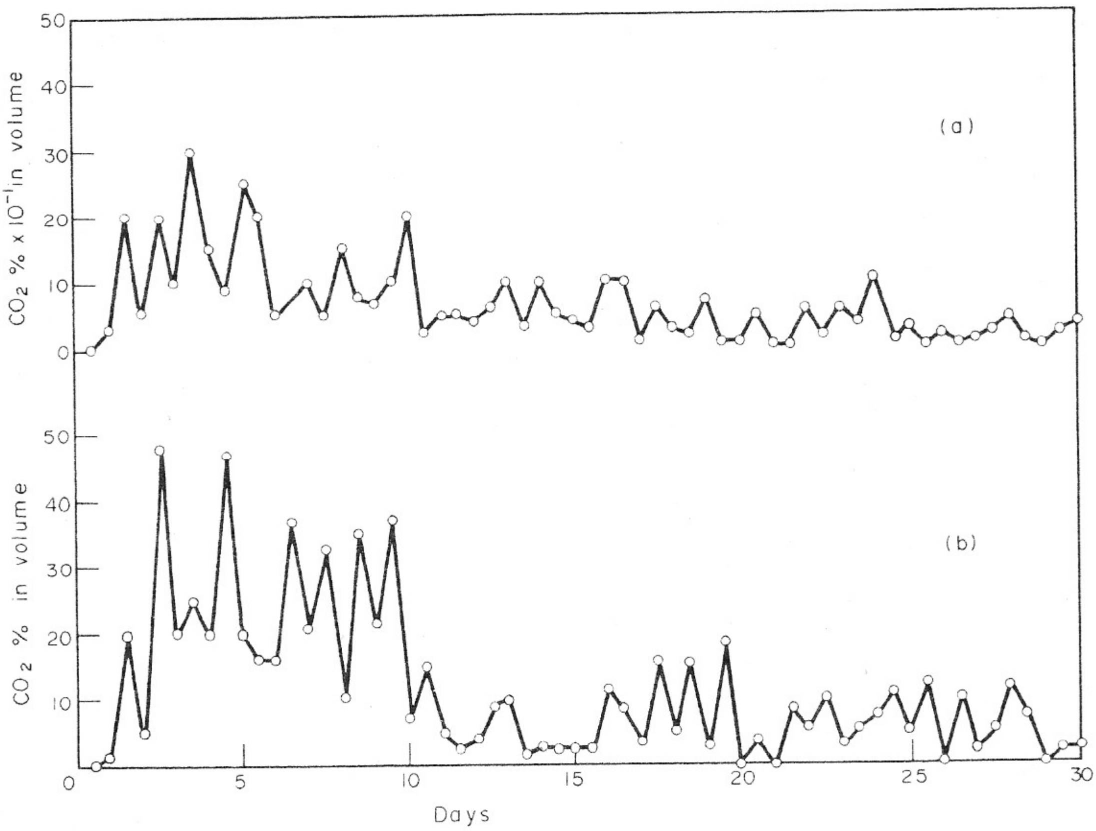


Fig. 7. Trend of CO_2 concentration vs time, measured at No. 8 station, 80 cm (A) and 10 cm (B) from ground-level.

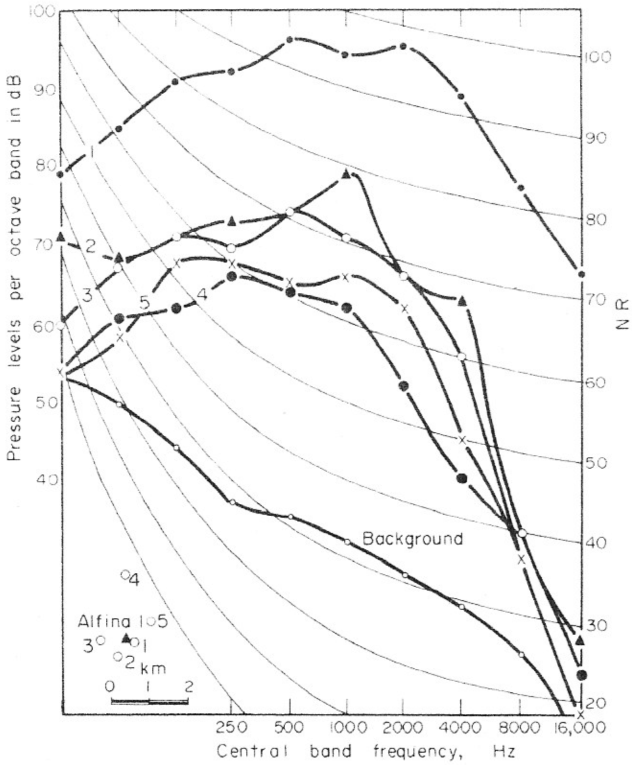


Fig. 8. Pressure levels per octave band in dB as a function of frequency, with wind gusts of 2–2·5 m/s in a N.E. direction and well flow-rate of 80 t/h. (This Figure also shows location of measurement points.)

REFERENCES

Cataldi, R. and Rendina, M. (1973) Recent discovery of a new geothermal field in Italy: Alfina. *Geothermics* **2,** 3–4, 106–116.

Strauss, W., Ed. (1971) *Air Pollution Control,* part 1.

Strauss, W., Ed. (1972) *Air Pollution Control,* part 2.