Thermal Wave ('Thermo-Onda') Soaring in Italy and Argentina

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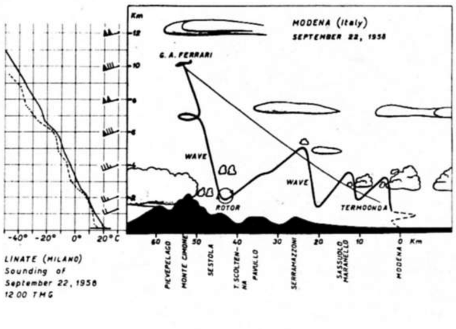
Following the suggestions of Dr. Kuettner, the chairman of the cientific Section of OSTIV, I conducted a systematic inquiry among the Italian glider pilots during the first six months of this year. I also organized three round-table discussions, two at Rome and one at Varese, with the object of gaining more information on wave phenomena associated with thermal phenomena.

The main argument treated was that of wave situations of either orographic or other origin and their coexistence with phenomena of thermal instability. Particular attention was given to the cumulus clouds with vertical wind shear having a climb on the upwind side of the clouds, but only insofar as it served to establish the most convenient technique to be used when flying on the outside of convective clouds.

The structure and the dynamics of these particular occurrences, in which the convective currents of thermal origin rising from the ground merge at a higher altitude with the wave formations, are not yet completely known to the pilots, many of whom, though having utilized these situations, have not always succeeded in interpreting them.

In Italy, the well-known pilot Guido Antonio Ferrari has been focusing his attention on these phenomena since 1955. The following year, at the International Congress of OSTIV in St-Yan (France), he presented his first technical report on this subject, in which the term termo-onda appeared for the first time. Unfortunately, Ferrari did not have the chance to discuss his report at the Congress, because of an unfortunate off-the-field landing with his glider which forced him to abandon the World Championship and return to Italy. However, he continued his investigation, with numerous flights, observations, and much research. In this specific aera he completed hundreds of hours soaring time and, among other things, in 1958 established the Italian record for the highest altitude above sea level 10,030 m and the highest gained altitude 9,031 m, records still unbroken (fig. 1).

Fig. 1



At the International Scientific Congress on Jet streams and Undulating Air Currents held at Turin in June 1959 Ferrari was present with still more findings on the subject of termo-onda. He referred to the observations made in the Paduan Valley (Northern Italy) and in the Apennine regions of Central Italy in the course of some of his more significant soaring flights in the conditions which we have mentioned. He also expounded the technique used by him to get the most advantage from each of these typical situations. To explain the procedure he used a simple model which very effectively illustrated the technique. Very few of the foreign pilots and meteorologists present at the congress in Turin understood the importance of the experiments and research conducted by Ferrari in this field; this is also due to the fact that at this congress his findings were presented and published only in Italian.

Nevertheless, in Italy, the term termo-onda gradually became more widespread and today fifteen years after its coining, it is commonly used by those who wish to indicate those conditions in which wave phenomena coexist with the phenomena of thermal convective instability. I have had the chance to make interesting observations on these phenomena, especially from the meteorological point of view. I even made investigative flights with and without a motor, first in Argentina (1952–1955) in the valley of La Cruz located in the mountain region of the Sierra de Cordoba; then in Italy (1956–1970) in the valley of Rieti, in the Central Apennines.

Such observations agree with the flight experiences of Ferrari and a group of pilots of the Military Section of Gliding headed by Col. Mantelli. They also agree with later experiments conducted by a group of sporting glider pilots of Central Italy and particularly by Ferruccio Piludu. These observations are further confirmed by the experiences of the Italian glider pilots who in the past ten years have participated in the National Championships in the Apennine region of Rieti, where the National Center of Glider flying of the Aero Club of Italy is located and where termo-onda situations are present very frequently.

To present these observations and experiments in sufficient depth and with scientific precision and to illustrate all the phenomena associated with them would take too much time. Therefore, I will merely summarize the principles which govern the phenomena, as it has been possible to formulate them, using the findings of the experiments conducted by the Italian glider pilots up to now.

(1) With the term termo-onda Ferrari, from 1955 on, intended to indicate those particular conditions in which the coexistence of wave phenomena with the phenomena of thermal convective instability, gives rise to situations which present characteristics different from pure waves and pure thermal currents and which in order to be utilized in soaring require a special technique.

(2) The thermodynamic conditions which characterize the situations of termo-onda are the following:

(a) Wind which strikes a mountain ridge even of moderate altitude. The velocity of the wind increases gradually with the height, reaching a velocity of 20–25 Kts., and sometimes even more, in the strata affected by the wave movements.

(b) The temperature gradient is adiabatic, from the ground to the altitude where there are wave movements.

(3) For the conditions of termo-onda to be produced it is not necessary that the wave movements be stationary or persistant; even less is it necessary that they should be in atmospheric stratifications of great thickness.

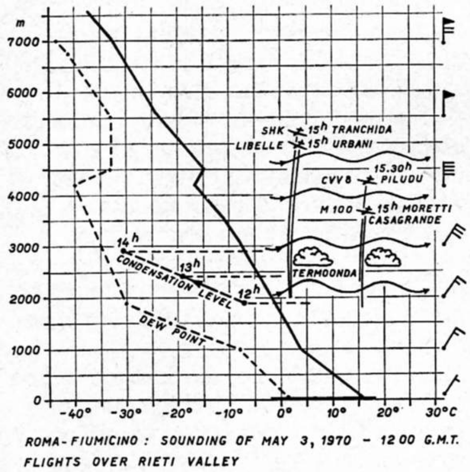
(4) Termo-onda exists even when there are unstable waves and pulsating wave motion.

(5) In the situation of termo-onda, thermal convective activity originating on the ground is normally organized by wave movements, that is, the ascending thermal currents merge at higher altitudes with the ascending part of the wave, whereas the descending currents originate in the zone corresponding to the descending part of the wave.

(6) If these wave phenomena and thermal phenomena occur in masses of dry air, they pass completely unnoticed, but if the air is sufficiently humid, the phenomena become visible by the formation of cumulus or strato-cumulus clouds whose appearance, size, and form depend on various factors.

(7) Unstable wave pulsations of orographic origin produce isolated cumu-

lus clouds of varying vertical development. These clouds are moved by the wind. The thermodynamic conditions favorable for the formation of such cumulus clouds are a wind which strikes an obstacle with a certail force, thermal instability, and the presence of sufficient humidity in the air.
The longer or shorter duration of these clouds associated with pulsating waves whose length never exceeds 2 km depends on the humidity in the surrounding air and the influx of humid air by an eventual ascending thermal current which comes from the surface of the land. Normally, however, the life of these clouds is very short.
(8) The situations of termo-onda, of great interest to soaring, are produced during the summer downwind from the mountain barriers, in conditions of very strong winds at flying altitude. These can easily be identified when the air is sufficiently humid and permits the formation of cumulus or strato-cumulus clouds.
(9) The bands of termo-onda whether made up of isolated cumulus clouds alligned in the direction of the wind, or whether made up of true street of connected cumulus and strato-cumulus clouds parallel or transverse to the wind, are produced along a narrow strip affected by more intense wave phenomena, because they originate in correspondence with the higher mountains more favorably exposed to the wind, or in resonance with the waves produces by the preceding orographic obstacles.
(10) It is interesting to note that the two aforementioned types of streets of cumulus clouds produced by the termo-onda always originate two or three wave lengths from the mountain, in contrast with the cumulus roll clouds which instead are formed under the first, second, and even third wave, that is, in the immediate downwind zone.
(11) When the wave movements do not extend to the upper strata of the atmosphere and do not assume the unmistacable characteristics of the large stationary wave formations, the isolated cumulus clouds produced by the termo-onda, unlike the connected chain of cumulus clouds, are formed even in the immediate downwind zone.
(12) There are three typical situations in which the termo-onda is produced, precisely the following:
(a) Situations characterized by isolated cumulus clouds which, though assuming notable proportions at times, never do merge but align themselves in the downwind zone at a certain distance one from the other.
(b) Situations characterized by bands of cumulus and strato-cumulus clouds forming connected chains of clouds transversly to the wind.
(c) Situations in which the bands of cumulus and strato-cumulus clouds are parallel to the wind.
These are now discussed in turn.



ROMA-FIUMICINO : SOUNDING OF MAY 3, 1970 - 12 00 G.M.T.
FLIGHTS OVER RIETI VALLEY

Fig. 2

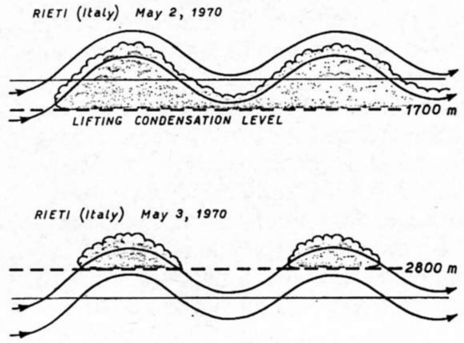
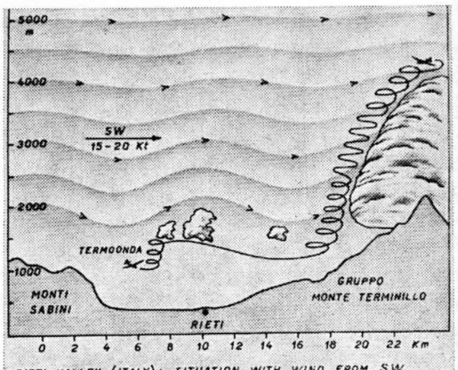


Fig. 3

A. Isolated Cumulus Clouds

Of the three types of situations in which the termo-onda is produced, the one which is more frequently present is characterized by the formation of isolated cumulus clouds. The reason for this, among others, is that it constitutes the initial and final phase of the situations in which the chains of the strato-cumulus clouds are parallel to the wind.
The necessary conditions for the formation of isolated cumulus clouds that will last all day is the presence of a not excessive humidity in the air. In such a case, the base altitude of condensation is always higher than that encountered in the situations of the chains of strato-cumulus clouds parallel to the wind.
In the valley of Rieti, such a situation is present more frequently with winds from the NE that are associated with a circulation of air of Balkan origin, cold and relatively dry. In such a case the cumulus clouds of the termo-onda originate on the crest of the waves and never succeed in joining together to form one continuous chain, though they often reach great proportions.
This typical situation occurred in the regions of Central Italy on May 3, 1970, and is illustrated in the thermodynamic diagram based on radio soundings of the Rome-Fiumicino Regional Meteorological Center taken at 12.00/Z, and presented in figure 2.
In this diagram are indicated the base altitudes of condensation of the cumulus clouds during the various hours of the afternoon, and the height attained by the pilots who took advantage of conditions on that day, in different parts of the valley.
It is important to point out that on the preceding day, May 2, 1970, the same thermodynamic conditions existed. However, the air mass which was striking the Apennine range was humid and, as a result, the base altitude of condensation of the cumulus cloud formations was lower; so much so that in certain areas the cumulus clouds managed to join together to form little chains (fig. 3).
Regarding the technique for utilizing the ascending currents associated with these cumulus clouds, it should be pointed out immediately that the lift is not beneath the clouds but ahead of them and upwind from them. In this zone, occasionally, little wisps of cumulus clouds are formed, produced by the currents rising from the ground, currents which merge with the wave movements higher up producing at that point a certain turbulence and an increase in the velocity of the ascending current.
To maintain the climb, the pilot must spiral upwind from the cumulus cloud, riding with the wind. When the climb



RIETI VALLEY (ITALY): SITUATION WITH WIND FROM SW

Fig. 4

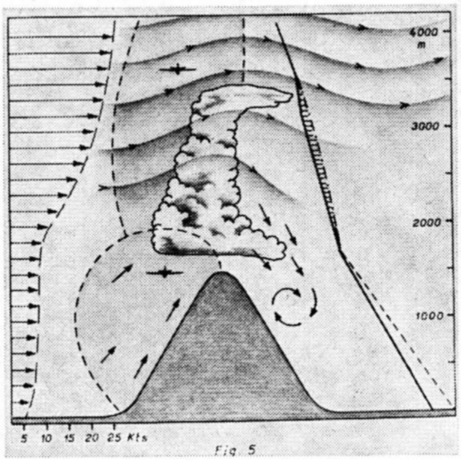


Fig. 5

indicated by the rate-of-climb indicator begins to decrease, it is best to stop making spirals and to head against the wind toward the clear area, and not let oneself be fooled by the presence of overhead cumulus clouds or by the fact that the residual rise under them is still appreciable. Otherwise, continuing with the wind, one will end up in the down-drought of the termo-onda, out of which one can get out only at the price of a notable loss in altitude.
The flight against the wind toward the clearing should continue until the rate-of-climb indicator registers a notable decrease in climb. Then, one is back in the initial zone, where the formation of the wisps of cumulus clouds will be seen and where, therefore, the spiral flight can be resumed.
Having reached the front part of the base of condensation of the cumulus clouds, one should stay upwind in line with the cumulus cloud formations, spiraling or flying parallel on the outside of the clouds, as though over a mountain slope. In this way, one passes from a thermal current to a thermal-wave flow, reaching and surpassing the tops of the cumulus clouds, outside of the clouds.
When the vertical wind shear is moderate, the best lifts is close to the clouds, so that at times, to climb more rapidly it is preferable to spiral by weaving in and out of the clouds.
The isolated cumulus clouds of the termo-onda may be arranged in parallel lines either transversly to the wind or parallel to it. When one mountain ridge is downwind from another, as is the case in the valley of Rieti, and a wave flow is in resonance with the second obstacle, the conditions of soaring are enhanced by the orographically forced rising of the lower strata of air and the flight becomes extremely easy. These conditions are present on the mountains of Sabina with the winds from the North East; whereas, with the winds from the South West or West they form along the group of hills of Mt. Terminillo. Figures 4 and 5 clearly illustrate the phenomenon.

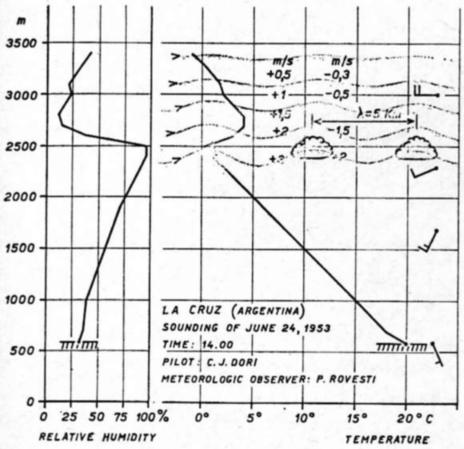


Fig. 6

B. Bands of Cumulus Clouds Transversly to the Wind

When a mountain ridge is favorably exposed to the wind and its height and orographic configuration are of a certain uniformity, the phenomena of termo-onda extend along the bands of cumulus clouds transversly to the wind whose length depends on the following orographic conditions.
It is easy to understand that the process of formation of these bands is identical to that of the isolated cumulus clouds of the termo-onda. Therefore, also for the bands transversly to the wind, it is necessary that the air be not excessively humid, otherwise very quickly the bands will join to form patches of strato-cumulus clouds.
I had the chance to study these conditions in Argentina, in the Valley of La Cruz (Cordoba), where from 1952 to 1956 the Argentinian Institute of Gliding had its headquarters. This phenomenon was encountered with winds from the South East on the surface, shifting gradually toward the west at


BANDS OF CUMULUS CLOUDS OVER THE PADUAN VALLEY (ITALY)
Fig. 8

higher altitudes. Figures 6 and 7 represent one of these situations, studied in the course of an aerological sounding taken with a light sailplane equipped with an electrical psychrometer. The five bands of cumulus clouds shown in figure 7 were 5 km apart, and had an average length of 20 km. Their base of condensation was 1,775 m above the ground and their vertical development did not exceed 300 m. The temperature gradient of the atmosphere was adiabatic from the ground to the base of condensation. The clouds were bounded above by a definite thermal inversion, under which the relative humidity was notable; whereas, on the ground it was only 32%.
The thermal convective activity was not very great. Nevertheless, the updrafts merged at higher altitudes upwind to the bands of cumulus clouds and at this point of the bands, they swelled up, and the updrafts were notably re-enforced and the turbulence increased.
Figure 7 indicates among other things the values of the vertical velocities registered during the sounding. From the same figure, it is possible to see how even these bands were formed at a distance of a variety of wave lengths from the Sierra de Comechingones which was generating them.
In Italy there are characteristic and imposing examples of bands of cumulus clouds of termo-onda transversly to the wind, especially in the Paduan Valley. Ferrari and various other pilots made use of these conditions many times in their flights (fig. 8).
The technique for the utilization of these bands is just as simple as the one suggested for the cumulus clouds of termo-onda. It is a matter of getting oneself in the band, having the best updraft near the upwind border of the band and to fly parallel to it. Since the drift of the wind is notable, one should be careful not to let oneself be driven by the wind into the downdraft of the termo-onda which, as it is easy to understand, is found beneath the back-center part of the cumulus band.
In distance flights it is possible to proceed rapidly, maintaining the same al-

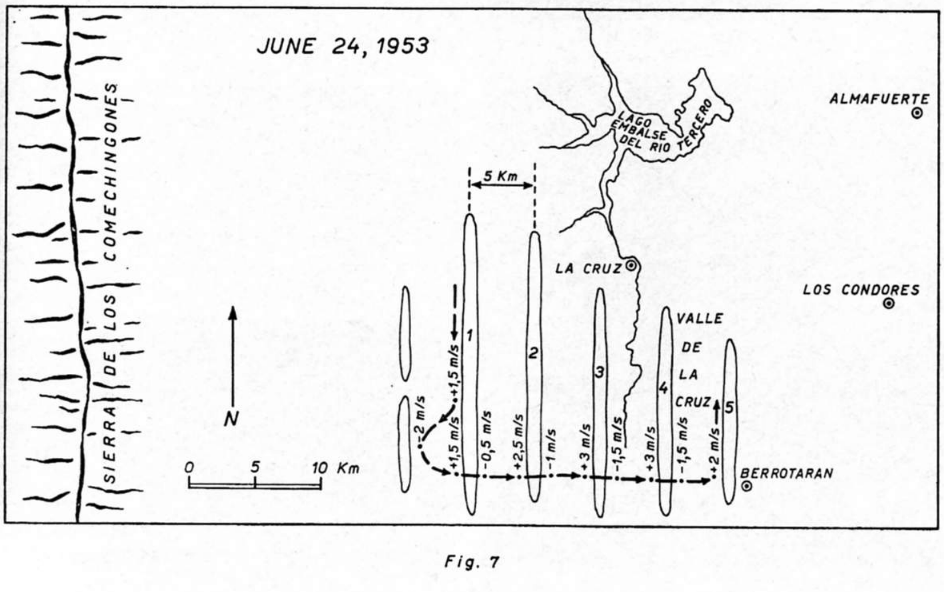
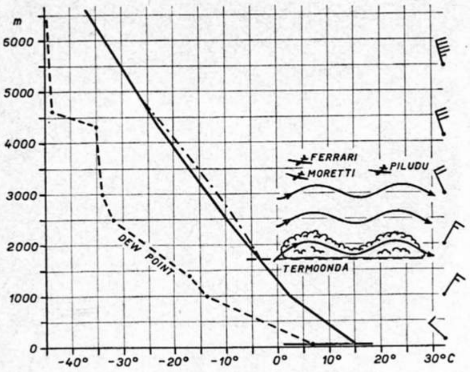


Fig. 7



ROMA-FIUMICINO: SOUNDING OF MAY 2, 1970 - 1200 G.M.T.
FLIGHTS OVER RIETI VALLEY

Fig. 9

titude without spiraling. If, instead, one wishes to gain maximum altitude, one should stay upwind from the band, following it as though it were a mountain slope.

C. Bands of Cumulus or Strato-Cumulus Clouds Parallel to the Wind

The formation process of these bands, which assume the aspect of real streets of clouds, is initially the same as that of the isolated cumulus clouds. However, their base altitude of condensation is normally lower, because the masses of air which favour the formation of these bands, are always quite humid.

A typical example of these conditions, shown in principal in figure 3, is illustrated in the thermodynamic diagram of figure 9, based on the previously mentioned radio soundings of 12.00/Z of Rome-Fiumicino on May 2, 1970. In it are also reported the altitude of the cumulus clouds present that day in the Valley of Rieti and the altitudes reached by the different pilots who took advantage of these situations.

In the summertime, when the humidity is not so great, these bands look like real streets only in the hours of greatest thermoconvective activity, that is, of the greatest insolation. The process of formation begins at about 10.30 with the appearance of a series of moving wisps of cumulus clouds, lined up parallel to the wind. These cloud wisps group together at certain points producing isolated clouds of a cumulus nature. Their duration is brief, however. In fact, all at once they will break up only to regroup shortly after, having joined up with other wisps, thus producing another cumulus cloud always in the same place.

The rhythm of formation and dissolution of such clouds becomes more frequent. As the hourspass, and the thermoconvective activity increases, the sky becomes more populated with cumulus clouds, which continue to develop and spread out until they join other clouds to form bands of cumulus and strato-cumulus clouds parallel to the direction of the wind (fig. 10). The width of these bands of clouds depends on the width of the atmospheric bands affected by the wave phenomenon.

The cloud bands utilized by the Italian pilots downwind from the Apennines of Central Italy, in the pre-alpine regions and in those of the Paduan Valley in northern Italy, normally are 3 to 4 km wide and a few tens of kilometers long. The base of condensation is 1,500—1,800 m and the maximum altitude 3,000—4,000 m. When the air is very humid and unstable, there may also be formed, along the band, isolated cumulo-nimbus clouds which produce storm situations and abundant precipitation. In such cases, for ten minutes and even more, the thermoconvective activity ceases completely. After this, the band of cumulus clouds is reproduced quite rapidly. Looking at these bands longitudinally, they appear to be marked transversely by light and dark stripes, about 1 to 2 km apart, depending on the length of the wave (2—4 km).

The updraft under the bands continues practically along the whole length of it. Nevertheless, upwind from the dark stripes, where the band is thicker, the updraft is greater. At times, therefore, it is better to take advantage of the more intense updraft, upwind from the dark stripes, flying transversely to the band, and following a zig-zag course. In this way, it is possible to travel notable distances even against the wind.

On both sides of the bands, that is, in the clearing there are strong downdrafts. The pilot must remember this when he intends to leave the cloud band.

(13) Wave phenomena and that of termo-onda can be produced as a result of a convergence or divergence of a mass of air channeled into a valley. In such case the variations of the static pressure, which is encountered on the horizontal plane in the zones of convergence and divergence of the air masses, make the stable strata that might be present oscillate at a certain height along the longitudinal axis of the valley.

Figure 11 synthesizes the phenomenon in a winter situation; whereas, figure 12 represents the same phenomenon in a summer situation. In the latter case, the wind drives the warm air out of the valley which, when it reaches the plains, rises along the front established by the cooler air already present there. In this way the warm air rises up to the level of the thermal inversion, where it joins with the wave movements, re-enforcing them.

This phenomenon was also studied in Argentina in the zone between the valleys of Calamuchita and La Cruz, in the region of the Sierras de Cordoba. Figure 13 shows the three formations of cumulus clouds associated directly with a wave movement generated in the zone of divergence in the valley of Calamuchita with the wind from the North-East.

Fig. 10

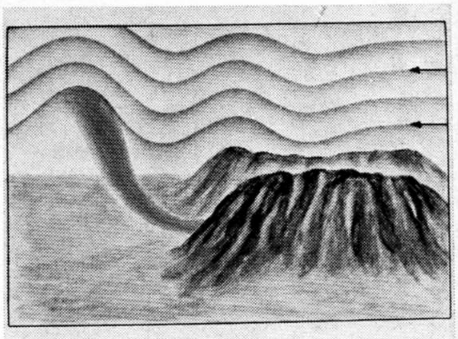


Fig. 12

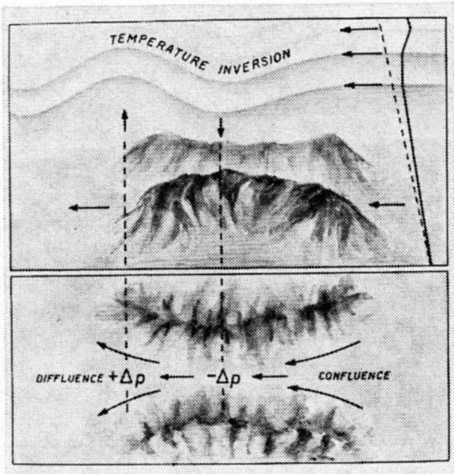


Fig. 11

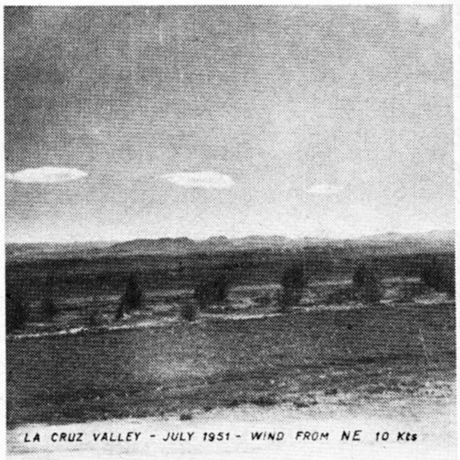


Fig. 13