

## BAROSSA VALLEY FROST FORECASTING

by E.A. Mizon. B.Sc.

### 1. TOPOGRAPHY OF AREA:

The valley extends roughly from north-east to south-west at an elevation of 800 to 1,000 feet above sea level and is bounded on the south-east by a range rising to 1,800 feet over parts of the southern end and averaging an elevation of 1,400 feet. A lower range with peaks to 1,200 feet forms the north-western boundary. The valley has a width of approximately 3 miles with approximately 7 miles between the ridges on either side.

Figure I is an approximate topographic map of the area.

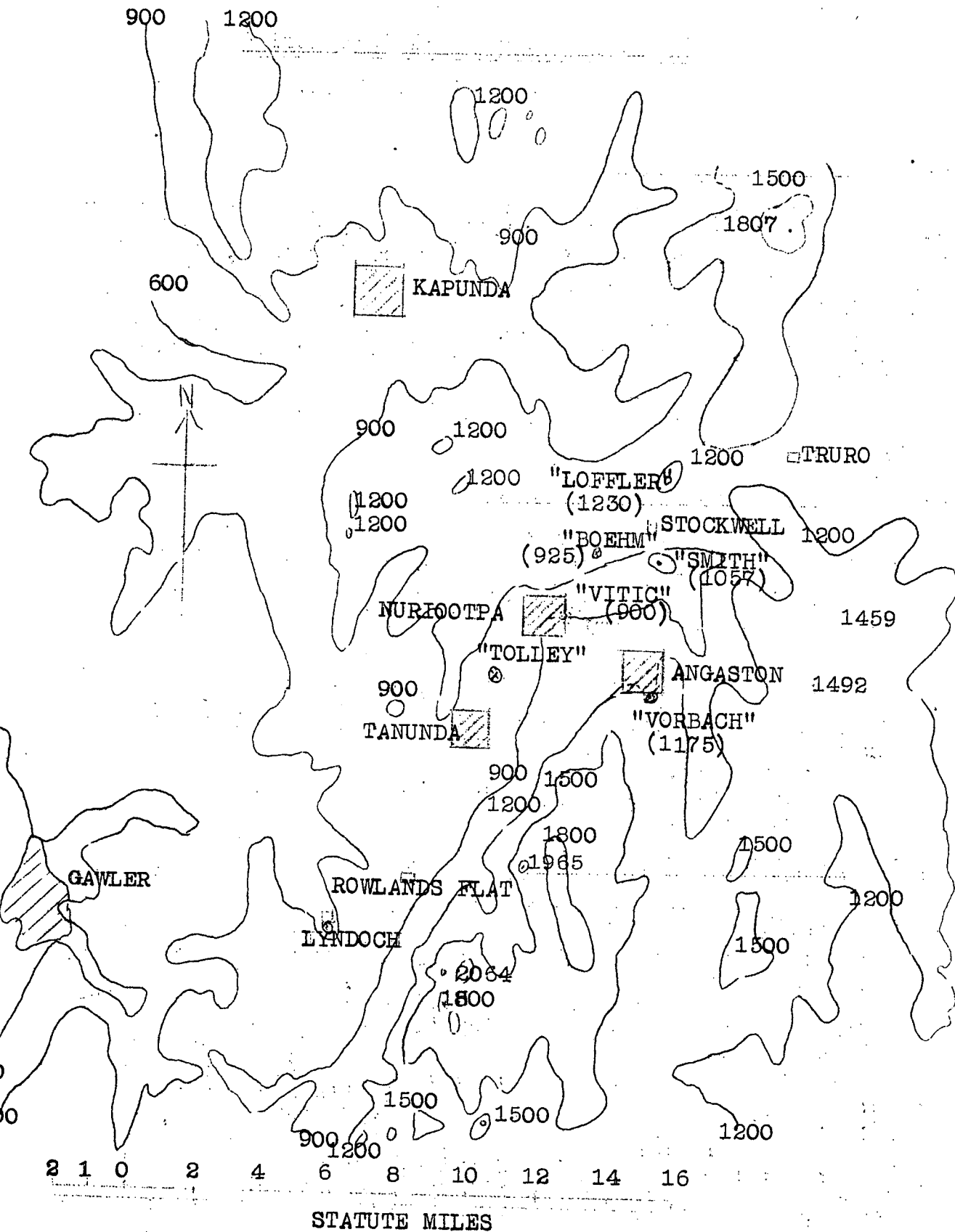
### 2. FROST FORECASTING PROBLEM:

It has been observed on a number of occasions that frost formation was prevented when conditions seemed ideal for frost occurrence, by the onset of a light north-easterly wind of sufficient strength to cause enough mixing in the low layers to arrest the temperature fall. Unfortunately no observations are available of the actual wind strength on these occasions. If the wind does not set in until just prior to the temperature reaching the frost point, the growers may incur considerable costs by calling out labour for lighting pots, and labour costs in these times constitute a large proportion of burning expenditure. It is economically desirable therefore that the forecasting of these occurrences be placed on as sound a basis as possible.

### 3. PRELIMINARY INVESTIGATION:

As a first attempt to discover the processes occurring in this region, the standard temperature reporting network was expanded during the 1950 season by installing reference and minimum thermometers at elevated positions. Obtaining the co-operation of farmers whose properties were considered suitable for the purpose proved difficult, but two sites were finally selected. The first of these was to the north of Stockwell on the property of Mr. F.W. Loffler (1230 ft. above M.S.L.) and the second to the east of Light's Pass at the home of Mr. K. Smith, a teacher at the Nuriootpa High School. In addition, Messrs. L.R. Senior and M. Kreig, two former members of the R.A.A.F. Meteorological Service, agreed to carry out pilot balloon flights at the Nuriootpa High School late each afternoon. Unfortunately the record was broken due to loss of hydrogen at one period.

The instruments used were standard reference and minimum thermometers exposed in 3-sided boxes, open at the



**Figure.1. Barossa Valley and Surroundings.**  
 (See article by E.A.Mizon, page 8.)

bottom, erected at normal vine height with the open face oriented south.

The 1950 season was remarkable in that on 19 occasions during September and October minimum temperatures of 35 or less were recorded at vine height at the Nuriootpa Viticultural Station, but only 3 of these were 32 degrees or less, while no occasions of temperatures below 31 degrees occurred.

The analysis of days with minima of 35 degrees or less during the past three seasons at the Viticultural Station is given in Table I.

Table I

Minimum Temperatures - Viticultural Station

Year	35	34	33	32	31	30	29	28	Total
1950	5	7	4	1	2				19
1949	3	2				4	3	3	15
1948	2	5		4	3				14

The 1950 season was not a very good one from a frost investigation viewpoint, particularly as complete returns were only available from the additional stations from 23rd September onwards and 7 of the above occasions occurred before that date.

Analysis of the temperature data gave no definite result, except that the total cooling from late afternoon to minimum at both valley sites and elevated sites were not significantly different, whereas the elevated sites, being on west facing slopes, averaged 5 degrees higher than valley sites at approximately 4.30 p.m. on afternoons preceding the occurrence of minima of 35 degrees or less in the valley. The value 35 degrees was chosen to ensure that the cases investigated were those on which reasonable risk of frost occurrence may have been expected.

The following statistical analyses were applied to the 1950 data, but gave no reliable forecasting rules. In each case only those days when basic requirements of clear skies or only few clouds and light winds (less than 10 m.p.h.) were satisfied in late afternoon were included in the analyses.

- (1) Regression of total cooling from 4.30 p.m. to minimum against dew point depression for all occasions.
- (2) Regressions as in (1) for classified wind directions (west to south, south to east, etc.).

The scatter was so great that in some cases the calculated regression coefficients were negative i.e. the greater the dew point depression the less the total cooling.

#### 4. CALCULATED KATABATIC WIND EFFECTS:

##### (1) Bjerknes Circulation Theorem

A formula has been developed by R. Wenger [1] which admits of numerical verification. Starting from the theorem of V. Bjerknes that the rate of increase of circulation along any closed curve is equal to the number of isobaric-isosteric unit solenoids comprised within the curve, Wenger establishes the relation -

$$\frac{d}{dt} \int u ds = R. \Delta T. \log_e \frac{p_0}{p}$$

where

$u$  = velocity of circulation along path element  $ds$ .

$R$  = gas constant ( $2.9 \times 10^6$  ergs/gram).

$\Delta T$  = difference between temperature of hillside and free atmosphere at the same level.

$p_0, p$  = pressures of the isobaric surfaces passing through place of observation and crest of hill respectively.

(average values of 981 and 963 millibars used for valley at Nuriootpa (900 ft. above M.S.L.) and average height of 1400 feet on hills from which any katabatic wind likely to originate.)

Taking  $\bar{u}$  as mean velocity of circulation

$$\bar{u} \frac{ds}{dt} = R. \Delta T. \log_e \frac{p_0}{p}$$

which is approximately

$$\begin{aligned} \bar{u}^2 &= R. \Delta T. \log_e \frac{p_0}{p} \\ &= 2.9 \times 1.39 \times 10^4. \Delta T. \\ &= \underline{4.03 \times 10^4 \times \Delta T.} \end{aligned}$$

For a critical speed of 3 m.p.h. ( $1.34 \times 10^2$  cm/sec.) which is probably sufficient to cause turbulent mixing and hence retard temperature fall

$$\Delta T = \frac{1.34^2}{4.03} = .45^\circ\text{C} \approx 1^\circ\text{F.}$$

The analysis of the valley and elevated station reports indicate that it would be necessary for an inversion of the order of 12°F/1000 feet to exist over the valley proper before this critical wind speed would become established purely from katabatic effects.

It is estimated that in many cases the value of  $\Delta T = 2^{\circ}\text{C}$  could be expected in this region.

This value gives -

$$\bar{u} = 6.4 \text{ m.p.h.}$$

## (2) Jeffrey's Treatment as Antitriptic Wind

Following the treatment of a katabatic wind as an antitriptic wind, as outlined by Jeffreys [2] and using the following parameters.

$$\lambda = 2.29 \times 10^{-4} \text{ }^{\circ}\text{C/cm.} \quad (\text{departure of lapse rate from D.A.L.R.})$$

$$k = 10^4 \text{ cm}^2/\text{sec.} \quad (\text{frictional coeff.})$$

$$l = 3 \times 10^{-2} \quad (\text{direction cosine of slope})$$

$$\alpha = 3.66 \times 10^{-3} \quad (\text{coeff. of expansion of air})$$

$$A = 2^{\circ}\text{C} \quad (\text{difference between temperature in free air and on hillside}).$$

we obtain a value of

$$\underline{u = 4.75 \text{ m.p.h.}}$$

In the absence of actual vertical temperature soundings and wind observations in this area the above calculated values which are reasonably consistent must be taken as indicative of the degree of katabatic wind to be expected under these conditions in the absence of any general circulation. As the orientation of the valley favours air drainage from north-east to south-west, any initial east to south-east katabatic wind will be turned to an east to north-east flow after it leaves the main slope.

Further, any general east to north-east gradient flow will be funneled through the Truro Gap and winds above prevailing gradient values can be expected in the valley, apart from local katabatic winds.

5. SYNOPTIC SURVEY OF 1948, 1949 and 1950 FROST SEASONS:

Table 2 is an analysis of Viticultural Station minima below 36 classified by gradient wind directions and speeds during the 1948, 1949 and 1950 seasons. The frequency figures to the left of the slant in each case refer to winds of 10 m.p.h. or less and those to the right of the slant to gradients over 10 m.p.h. The gradient values were determined in most cases from the 1100Z and 1600Z pilot balloon observations at Parafield. As this station is itself subject to local north-easterly winds under good radiation conditions, reference was made to the synoptic charts for those occasions when east to north components predominated in the Parafield upper winds to ensure that these were indeed representative directions.

The entry against 29° under N may possibly have been classified as calm since the Parafield 1600Z gradient wind was 010° 9 knots and a sharp ridge crossed the area during the night.

Table 2

Min Temp.	N	NE	E	SE	S	SW	W	NW	C
35	3/0	1/0			0/2	1/0	0/1	1/0	1
34		1/0	1/1		0/1	3/4	1/1		1
33		0/1				0/2	0/1		
32				1/0	2/0	0/1			1
31				1/0	1/1		0/1		1
30				1/0	2/0		1/0		
29	1/0				0/1	0/1			
28	0/1				1/1				
Totals	4/1	2/1	1/1	3/0	6/6	4/8	2/4	1/0	4
Totals / 32	1/1			3/0	6/3	0/2	1/1		2

The following facts are revealed by the above table -

- (1) Of the frost temperatures recorded, 90% occurred with calms or gradients between S.E. and W.
- (2) On 35% of occasions of frost temperatures the gradient wind exceeded 10 m.p.h. and in all but one case was opposed to normal katabatic flow.
- (3) Severe frosts ( 30°F) are most likely with gradients between S. and S.W. but may occur even with northerlies This will be covered more fully below.

The high frequency with which low temperatures are attained with gradient winds between S. and S.W. indicates that the katabatic values calculated in the preceding section are reasonable, and in fact, that even stronger katabatic winds are to be expected at times.

The case of a minimum temperature of 28°F with a northerly gradient warrants special investigation.

On this occasion, 16th-17th September, 1949, a cold, very dry air mass (dew points 25°-30°) had been brought over the area late on 15th September, (see Figure 2) and the trailing edge of the associated polar front was orientated N.E.-S.W. across the Barossa Valley the following evening. The air ahead of this front was also rather dry, but the available reports indicate a considerable dew point gradient away from the front in this warmer air, the frontal zone having become rather broad by this time in this region. By 10 p.m. the temperature at vine height over parts of the valley had fallen to 35°F - at which time some alarm thermometers operated - and by 0345 C.S.T. on the 17th the temperature at the Viticultural Station was 29°F (vine height) and 50 pots were lit. At this time the wind was a very light N.W. At 0435 C.S.T. the wind veered to N.E. (speed not recorded) and the temperature rose to 33°F within a few minutes. It appears therefore that the front was lying just south of the valley during most of this period and the N.W. gradient was sufficient to neutralise the natural katabatic wind to be expected under the extreme radiation conditions prevailing. It will be noted from the anti-cyclonic centre positions marked on fig. 3 that a north-eastward movement of the pressure centre occurred between 1730 C.S.T. 16th and 0530 C.S.T. 17th. This development resulted in a north-westward surge of the frontal surface and the establishment of a N.E. gradient over the Barossa Valley early on 17th, the wind resulting in sufficient turbulence to produce a 5°F. temperature rise.

This situation emphasises the difficulty of forecasting frost occurrences even with markedly dry air masses. Had the front been located even a few miles further northward it is most likely that frost temperatures would not have been reached

in the Barossa Valley on this occasion, due to early establishment of N.E. winds of appreciable strength.

Figure 4 is a reproduction of portion of the thermograph and anemometer records for Adelaide during this period which illustrate the marked effect of winds over 5 m.p.h. on the rate of cooling. The speed curves are the upper and lower limits of the gustiness range.

## 6. CONCLUSIONS:

- (1) The topography of the area favours the development of katabatic winds of 5 to 10 m.p.h. under conditions of strong surface inversions. These originate on the slopes as E. to S.E. winds but are turned into E. to N.E. winds in the centre of the valley.
- (2) Except for a limited area east and north of Angaston (outside the main vine areas) light easterly gradients having southerly components are not effective in the production of surface winds in the valley, due to the absence of suitable orientated gaps through the main range.
- (3) Easterly gradients having northerly components are effective, even though light, funneling occurring through the Truro Gap.
- (4) Statistical or semi-statistical means of forecasting frost in this area are unreliable, particularly when based on late afternoon conditions. The major factors vitiating these aids are -
  - (i) Changes in air mass, particularly the arrival of "polar" outbreaks.
  - (ii) Small changes in gradient direction around east.
- (5) An extension of the present investigation is desirable but will require -
  - (i) Temperature soundings in the valley and over the slopes during suitable nights.
  - (ii) The installation of several suitable anemometers to obtain records of direction and speed and thus map the air flow.
  - (iii) The installation of thermographs at at least two stations; in the valley and on the slopes.

LIST OF REFERENCES

- [1] S. ATMANATHAN - Scientific Notes, India Meteorological Department. Vol. IV. No. 40, pp.113-114.
- [2] H. JEFFREYS - Q.J.R.M.S., Vol. 48, 1922, pp.42-46.
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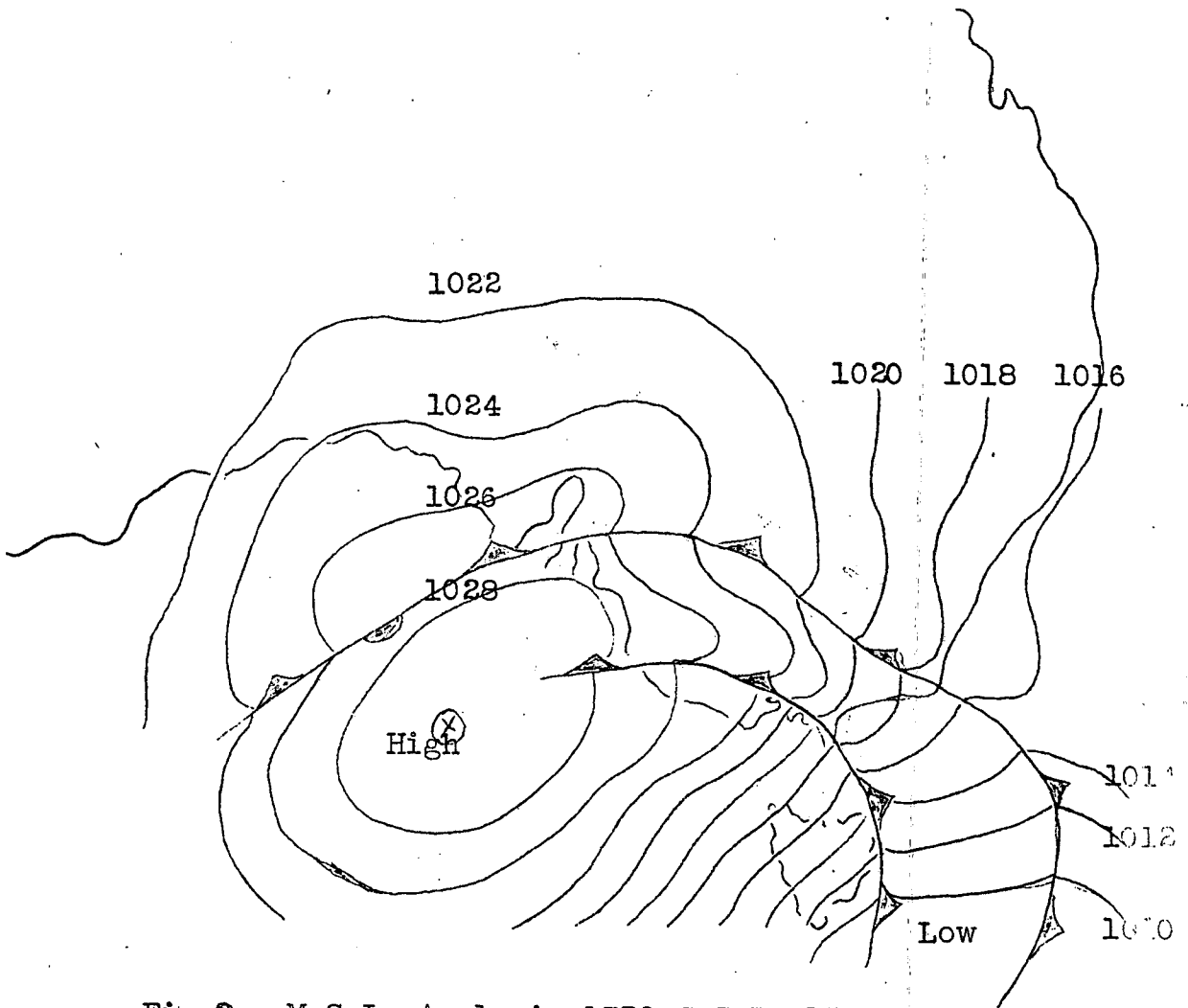
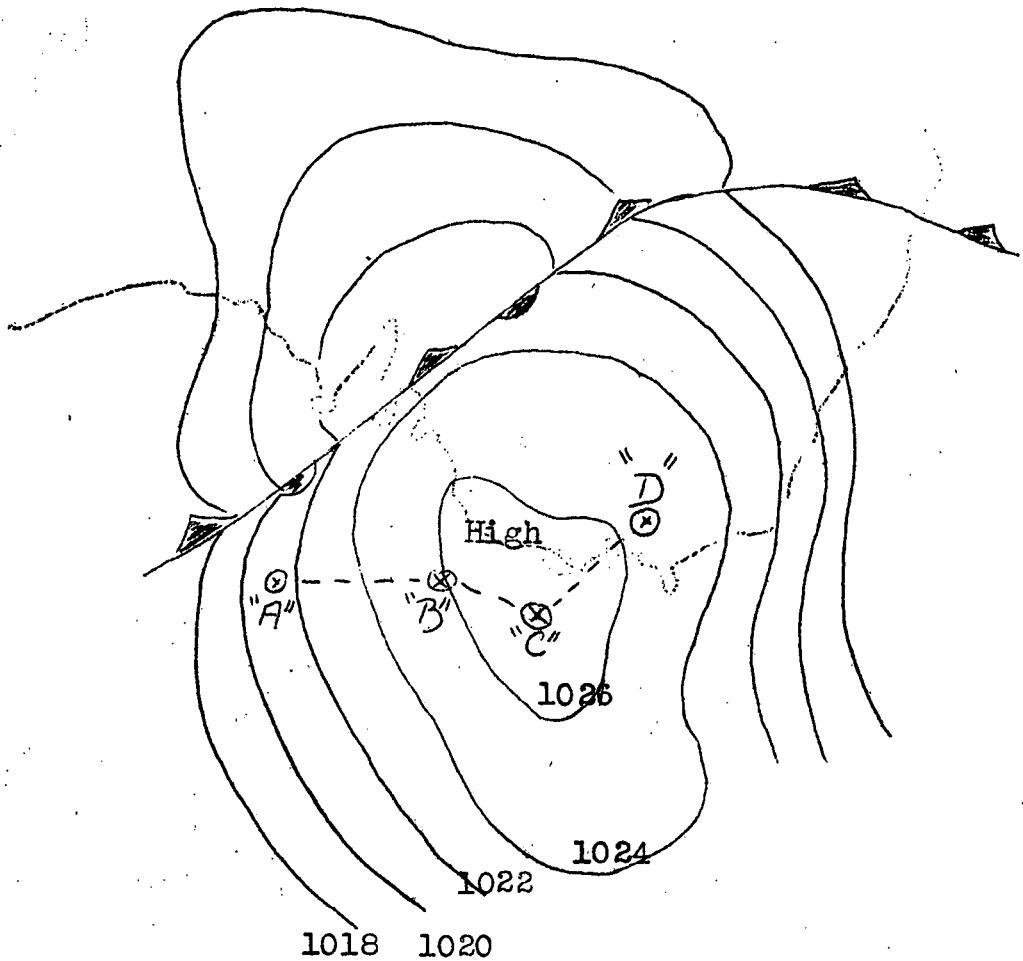


Fig.2.--M.S.L. Analysis 1730 C.S.T. 15-9-49

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Positions of Anti-cyclonic Centre-

- "A" --- 1730 C.S.T. 15-9-49.
- "B" --- 0530 C.S.T. 16-9-49.
- "C" --- 1730 C.S.T. 16-9-49.
- "D" --- 0530 C.S.T. 17-9-49.

Fig.3.-----M.S.L. Analysis 1730 C.S.T. 16-9-49.