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FORECASTING TRACKS OF CYCLONES AND 24 HOUR PRESSURE CHANGE SYSTEMS; - A SUMMARY OF WORK DONE BY MÜLLER-ANNEN.

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Abstract: The following is a brief summary of two articles by Dr. H. Müller-Annen, of Hamburg, published in "Annalen der Meteorologie" 1950 and 1952. It is published in the expectation that the rules and comments will prove useful in Australian practice. The illustrations and text have been transposed so that they apply without change to the southern hemisphere.

1. FORECASTING CYCLONE TRACKS

A statistical investigation was made based on a study of 550 cyclones, excluding those which showed little movement. Numerous similar investigations have been carried out; in this case, special attention was paid to the 500 mb. surface as well as the surface level. Many years ago, the rule was established that surface depressions tend to move in the direction of the wind on the warm side. This has been called the "warm air (abbreviated to W.A.) rule", and is often valid. However, the author found many exceptions, and states that "lows move in certain circumstances with the stream in their rear, that is, in the direction of flow of the air on the cold side" This was called the "cold air (C.A.) rule."

Some significant statistical results follow:

(i) Filling depressions tend to deviate to the left, that is, to follow an anticyclonically curved path, while deepening ones tend to deviate cyclonically. Conversely, those following an anticylonically curved path are usually filling, and those following a cyclonically curved path are deepening. Many however, follow a straight path.

(ii) Comparing the cyclone tracks with the 500 mb. stream above them showed that 44 per cent deviated to the left of the upper stream and most of them lost intensity; 50% of them deviated to the right and most of them intensified while only 6 per cent followed the upper stream, all filling somewhat.

(iii) A study of the associated twenty four hour pressure change systems, used in constructing prognostic charts, showed a tendency, not very definite, for "rise" centres to intensify for "C.A." lows and "fall" centres to intensify for "W.A." lows. In the "C.A." cases there was also a tendency for "fall" centres to weaken.

(iv) Rules for the application of the "C.A." or "W.A." rule:-

(a) 24 hour surface pressure changes: If the low lies well within, or at the centre, of the associated 24 hour "fall" area, the "W.A." rule is indicated; if it lies near, or within, the following "rise" area, the "C.A." rule should be used.

(b) 24 hour height changes at 500 mbs: If the surface low lies in the upper "fall" area, the "C.A." rule applies, otherwise the "W.A." rule should be used.

(c) Reference to the 500 mb. chart shows that "W.A." movement should be expected when the upper stream is smooth, with marked zonal component, the "low" lying to the east of a shallow trough (fig. 1 and 2). The "C.A." rule may be used when the upper chart shows a marked trough (fig. 3 and 4) with considerable meridional components of flow. In this case the surface low lies near the axis of the trough. Only if the trough is markedly diffluent should deepening be anticipated.

Fig. 1. "W.A." rule.

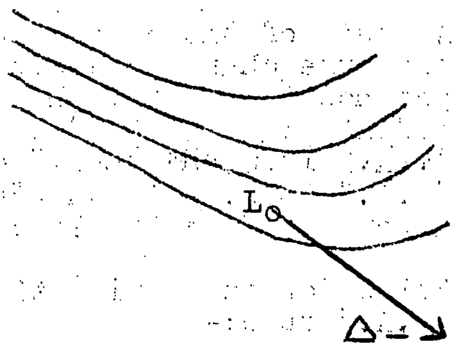

Fig. 2. "W.A." rule.

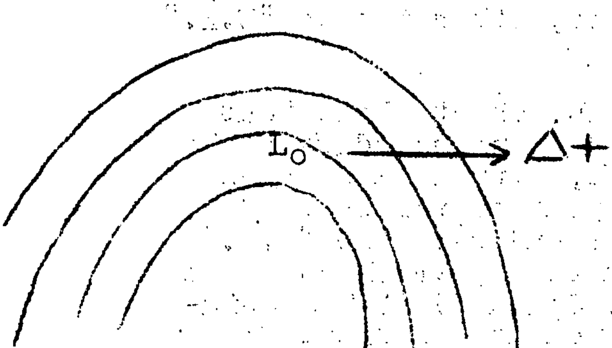

Fig. 3. "C.A." rule.
Symmetrical trough.

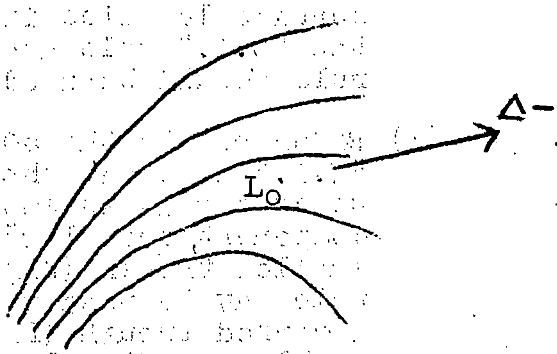

Fig. 4. "C.A." rule.
Diffluent trough.

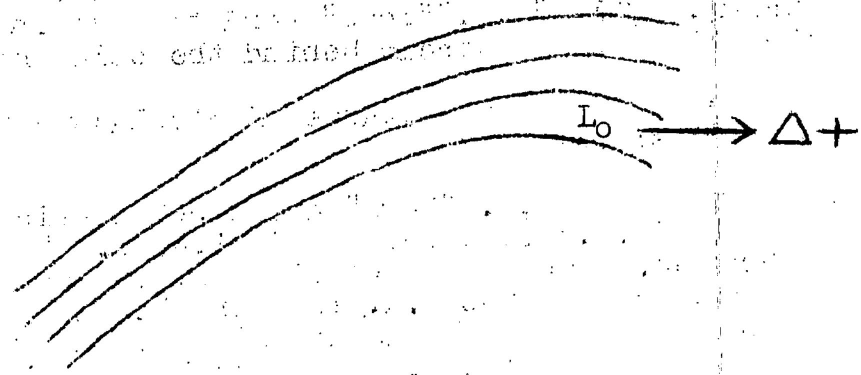

Fig. 5. "C.A." rule.
Long southwest stream
behind trough.

In figures 1-5, the full lines represent 500 mbs. isohypses, L_0 indicates the corresponding position of a surface "low", the arrow shows the direction of movement of the "low", and $\Delta+$ indicates filling, $\Delta-$ deepening.

(d) Speed and direction of the upper stream (at 500 mb.): If the upper stream is similar on the immediate forward and rear sides of the surface depression, "W.A." behaviour is indicated. If the upper stream on the two sides is markedly different, a tendency to "C.A". behaviour should be expected.

(V) Rules for the direction of displacement of surface "lows":

(a) With a long smooth upper stream (500 mbs) the low moves in the direction of this stream, slightly deviated to the right.

(b) If the low lies near an upper ridge, it moves with the stream on the west side of the ridge, i.e. generally in an eastsoutheast to south-southeast direction.

(c) If the "low" lies in an upper trough (500 mb) it tends to move in the direction of the stream over it at 500 mb, but if the streamin its rear is especially strong it will deviate somewhat to the left of the stream over it, that is, in the direction of the stream in its rear, frequently in an east to northeast direction.

(d) Using the surface flow as a criterion, "W.A" lows tend to move in the direction of the warm sector stream, while "C.A.""lows" tend to move in the direction of the stream behind the cold front.

(VI) Rules for the 24 hour distance of displacement of surface lows:

(a) In the mean C.A. "lows" moved 500 nautical miles while "W.A." lows moved 880, i.e. 1.8 times further. The stream at 500 mbs. in the mean was stronger over the W.A. lows in the ratio of 1.4 :1, although there was no significant difference at the surface. Noteworthy also is the result that, in the mean, "C.A." lows filled 6 mb. in 24 hours while "W.A." lows deepened by 14 mb. No indication of the standard deviations was given.

(b) Use of the speed of the 500 mbs. wind is not recommended. For both groups, 24 hour travel increased with increasing 500 mb. wind up to a certain critical value of the wind, and decreased with increasing wind thereafter. The same was found of surface winds. The critical value of the upper stream was so high, however, (about 90 kts.) that for most purposes one could consider that the stronger the wind aloft the greater the 24 hour travel of a "low".

(c) It is claimed that the 24 hour 1000-500 mb. thickness change gave useful results. The positive thickness change centre (i.e. centre of warming) lies to the left of the future track of the cyclone. With "C.A." "lows" the displacement will fall short of the axis of the warming area (fig. 6) while with "W.A." type "lows" it will over-shoot this axis (fig.7); for extreme cases, however, it may move parallel to this axis (fig. 8)

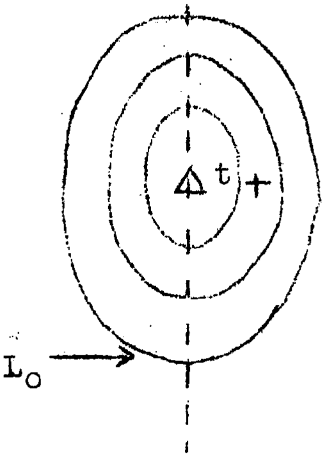

Fig. 6.

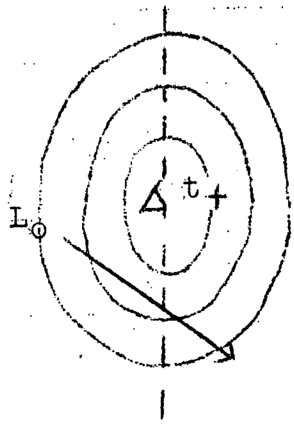

Fig. 7.

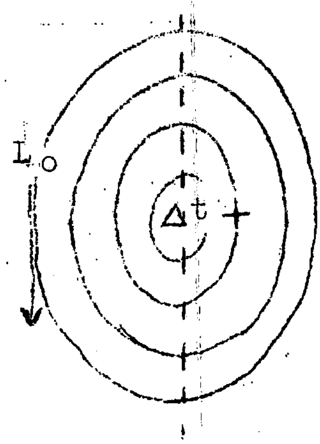

Fig. 8.

In figures 6-8, the full lines represent isopleths of 24 hour. 1000-500 mb thickness change, the broken line indicates the axis of the warming area, the arrow shows the expected displacement of the surface low L_o. In figure 7, the value of $\Delta t +$ is exceptionally high.

(d) For "C.A." lows the low tends to lie 24 hours hence in the centre of the 24 hour warming area of the 600-500 mb. layer.

(e) Guilbert- Grossman rule. (Scherhag 1948)

The "low" tends to be displaced in 24 hours to the next downstream 500 mb. ridge. This applies especially to "W.A. lows", although with a broad double upper trough underlain by two surface "lows", the more westerly "low" frequently moves in 24 hours up to the position of the other. For less pronounced C.A. "lows", the rule may hold approximately, but surface systems which are extensive or double in character may fail to move the full distance. For very pronounced "C.A." systems (sharp upper trough perhaps with a closed circulation), the surface "low" moves only a little: on the average to a position the locus of which is the surface isobar 10 mb. above the central value of the surface "low"; only with exceptionally strong gradients can the distance be as great as that represented by 20 mb.

2. FORECASTING THE DISPLACEMENT AND INTENSITY OF 24 HOUR SURFACE PRESSURE CHANGE SYSTEMS.

It was found that these systems do not in general move in the direction of the 500 mb stream over them. The following sketches illustrate the kind of movement which the 24 hour surface fall areas (F_O) (figures 9-15) and rise areas (R_O) (figures 16-24) should undergo with various situations aloft. Some of the these models have been found qualitatively very useful in the Australian area. Here △ − means "fall area intensifying", or "rise area weakening" and vice versa for △ + . Full lines represent 500 mb. contours and the arrow indicates 24 hour displacement of the surface pressure change system.

Some remarks on figures 9-24: The fall and rise areas in most cases intensify if they deviate to the right of the 500 mb. stream, and weaken if they deviate to the left. Exceptions occur when upper diffluence is present, in which case fall areas tend to intensify and rise areas to weaken, whatever their path relative to the upper stream. Rise areas located in an upper ridge also tend to weaken rapidly, (or disappear altogether) despite deviation to the right. Figures 23 and 24 show the path of a rise centre at right angles to the upper stream, but parallel to the stream in its rear, as indicated by the broken arrows.

One may think of R_O as having two components, a "dynamic" component, associated with warm air advection aloft, and a "static" component, of a secondary nature, due to cold air advection in the lower levels, and this applies also, with the necessary changes, to surface pressure fall areas. Thus F_O, R_O are composed primarily of the "dynamic" effect, modified by the "static" effect, which results in a displacement of the upper pressure change areas forward on the surface. With a long smooth upper stream, in which the systems move as small perturbations, the two effects act in concert, and the rise and fall areas succeed one another in a direction rather closely parallel to the stream aloft. This is typical of the classical polar front cyclone series, and one may confidently expect, with a quasi-stationary anticyclone, that such a series will be observed. On the other hand, a strongly curved upper stream splits the two components of pressure change; a surface pressure rise will then be the resultant of "dynamic" rise aloft, moving in the direction of the upper warm stream, i.e. generally to southeast and "static" rise near the ground, moving in the direction of the surface cold stream, i.e. generally to northeast.

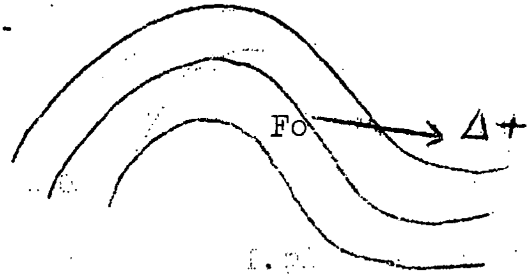

Fig. 9 (C.A)

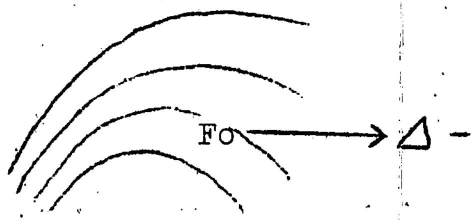

Fig.10 (C.A.) Diffluent trough

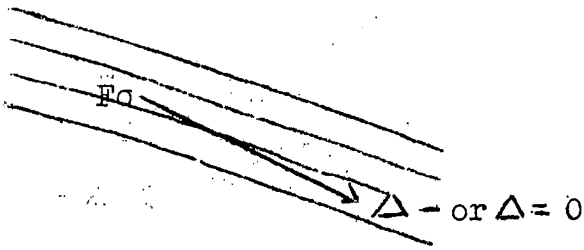

Fig. 11 (W.A.)

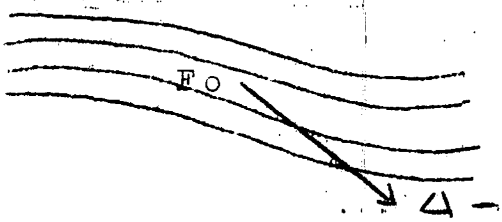

Fig.12 (W.A.) Small wave cyclones

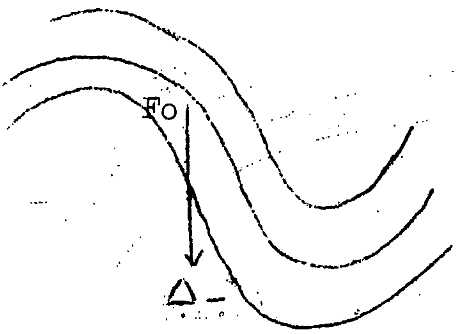

Fig.13 (W.A.) Strong ridge ahead

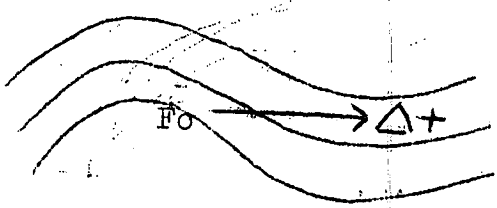

Fig.14 (C.A. and W.A.)

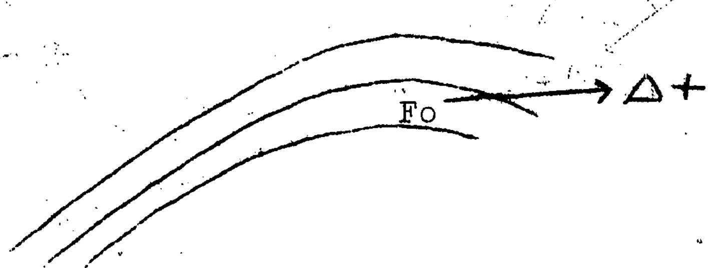

Fig. 15 (C.A.)

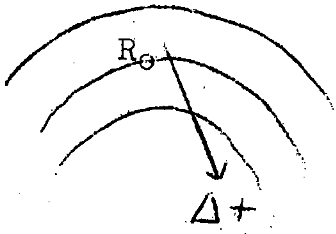

Fig.16 (C.A.)

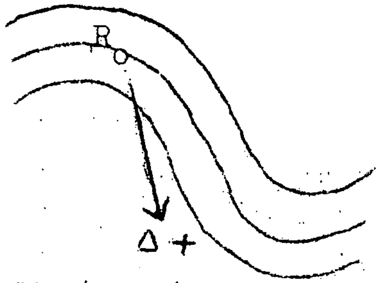

Fig.17 (C.A.) Strong ridge ahead.

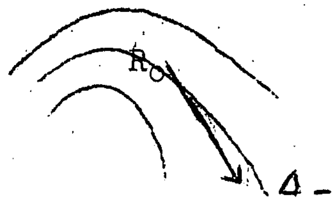

Fig.18 (Mainly W.A.) Diffluent trough.

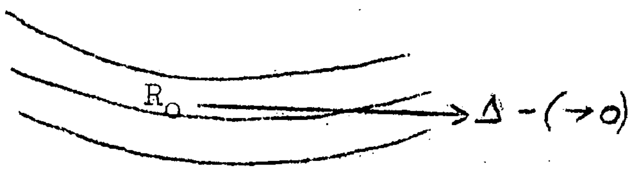

Fig.19 (C.A.)

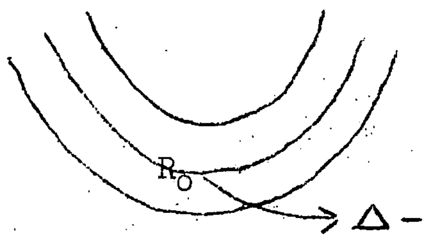

Fig. 20 (C.A.)

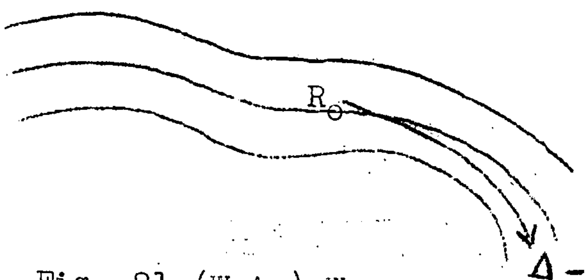

Fig. 21 (W.A.) Wave disturbance.

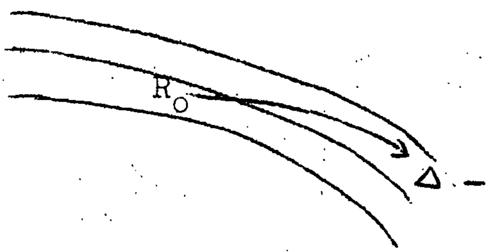

Fig. 22 (W.A.)

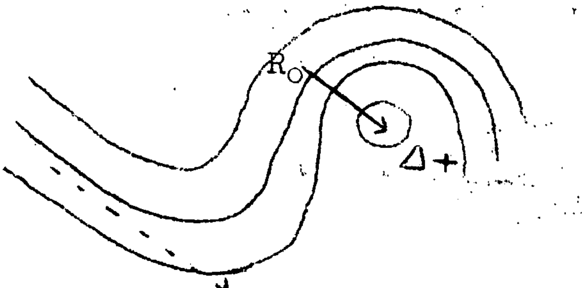

Fig. 23 (W.A.)

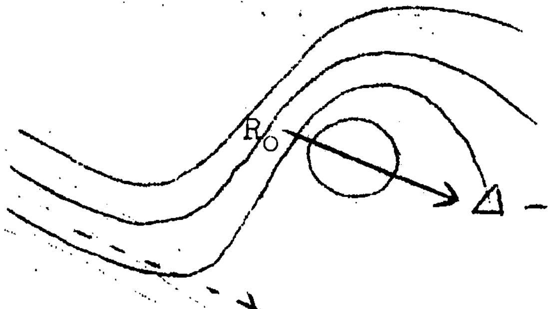

Fig. 24 (C.A. with diffluent trough).

Of the two components, the "dynamic" is the dominant, but when the two are as it were, divorced, both eventually weaken and disappear under most circumstances.

If for any reason, one trough of a series moving along in the westerly winds develops extraordinary intensity, the effect of this is felt far downstream as described by Kruhl (1950), and as indicated by Rossby's planetary wave theory.

The first effect is a strengthening of the warm stream on its forward side which results in an intensification of the downstream rise area, both on the surface and aloft. The next fall area downstream is then deviated to the left where it temporarily intensifies but eventually weakens, so that the ultimate effect is the "cutting off" and eventual elimination of the next upper trough down stream from the intense one. This is schematically illustrated in figures 25-28, where the lines represent 500 mb. contours, and Lo the surface "low".

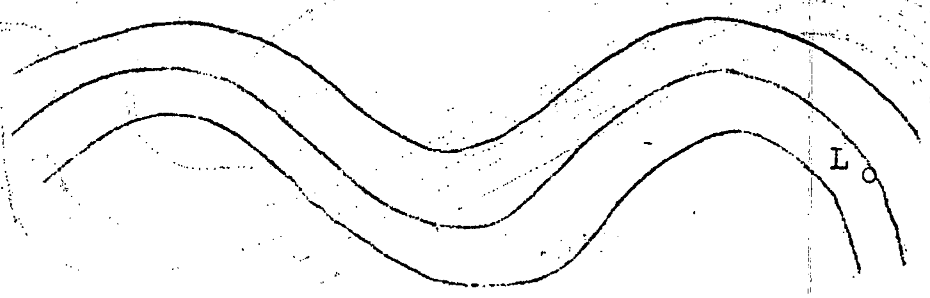

Fig. 25.

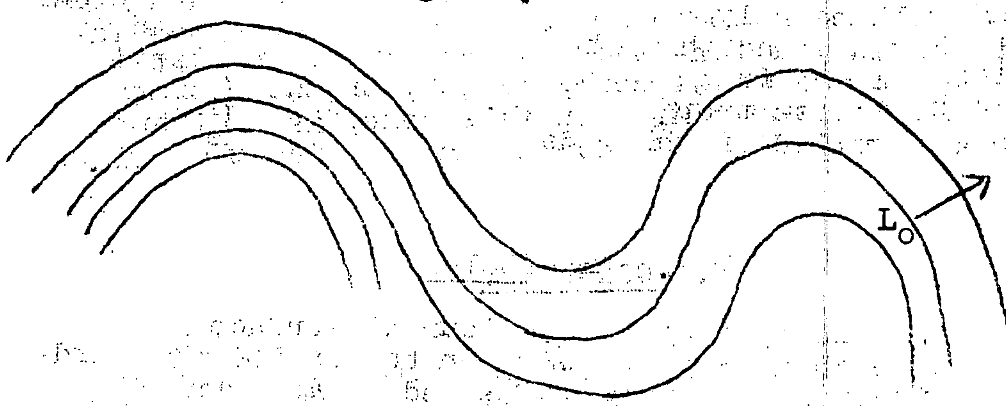

Fig. 26.

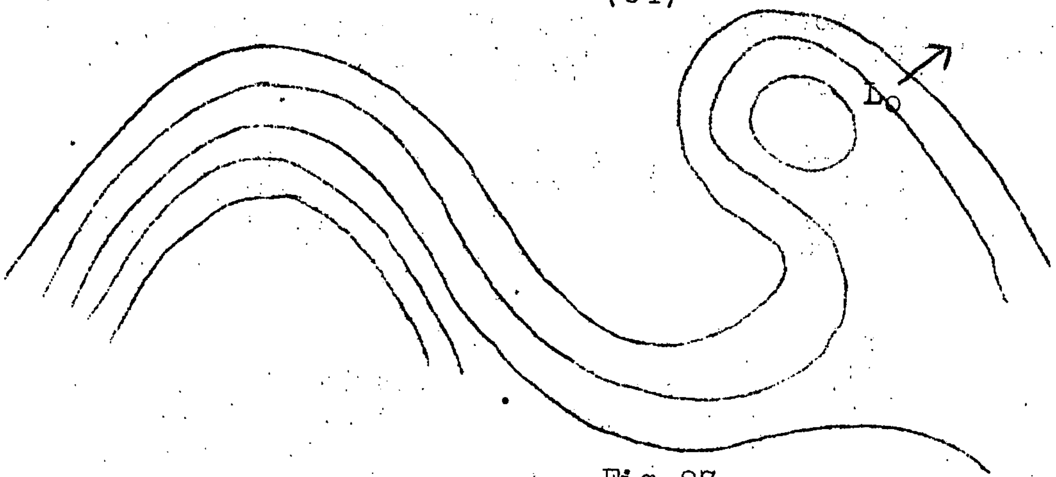

Fig.27

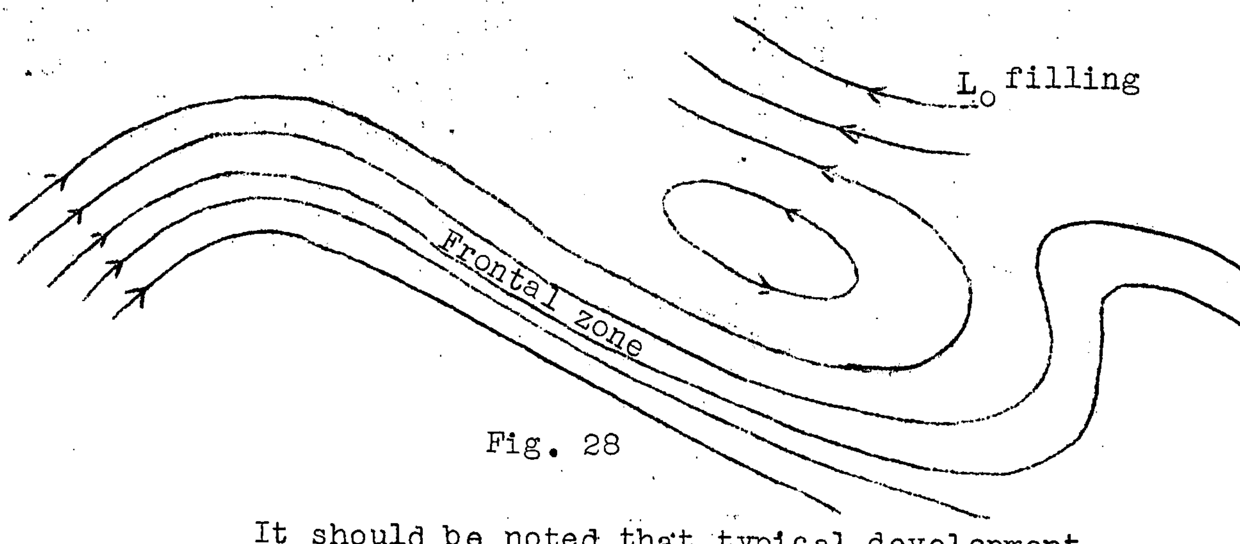

Fig. 28

It should be noted that typical development along these lines only occurs where the intense trough is quasi-stationary, and that the end product is frequently a quasi-stationary frontal zone, or jet, on the eastern side of the intense trough. In this zone, wave disturbances with a period of the order of one day are the rule.

3. CONCLUSION

The typical behaviour of surface "lows" and 24 hour pressure changes in relation to the 500 mb chart should be of interest to all concerned in the construction of prognostic surface charts. The types outlined above are clearly recognisable in the Australian area, and, although the treatment is necessarily qualitative, the application of the rules to 24 hour pressure change areas has been found frequently to give useful indications.

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