CSEG JOURNAL, V. 8, NO. 1 (DEC., 1972) P. 22-40, 15 FIGS.

VIEWFIELD — A PRODUCING FOSSIL CRATER? †

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Based on present geophysical and bore hole control, the origin of the structure at Viewfield, Saskatchewan (29-7-8, W2) is best explained by invoking the theory that, following normal sedimentation for the area in question, an impact during Jura-Triassic time created a crater with a rim diameter of approximately one and one-half miles. Disturbed Mississippian limestone and dolomite (Mississippian micro-fossils identified*) is found sandwiched between Lower Watrous Red Beds (Jura-Triassic) on the periphery of the rim. Some 50-75 feet of additional Middle Devonian salt appears to be present under the rim due to plastic flow from beneath the center of the impact crater. Another 150 feet of Middle Devonian salt was removed from the crater area as the result of solution during the post impact to Lower Blairmore period. This was again followed by normal sedimentation for the area.

To date there are 23 oil wells completed in Mississippian strata along the periphery of the crater and one Devonian Birdbear completion. Several wells located on the rim had good Birdbear oil shows. Two rim wells (#1-33-7-8, W2 and #7-33-7 8, W2) had no effective porosity in the productive Mississippian Carbonate interval and were therefore abandoned.

INTRODUCTION

Since this is the Age of Aquarius (whatever that means) characterized by many people doing their own "thing", frequently bordering on the unconventional, it seems fitting that the explorationist should deviate somewhat from traditional approaches and explanations of subsurface problems encountered . As the title suggests, this is *such an attempt.*

In order to cushion the shock, perhaps a little psychological conditioning is in order. For this purpose the reader is asked to review any recent publication showing close-up photographs of the lunar surface and/or that of Mars. The references pertaining to impact craters listed at the end of this paper should also be studied at this time.

The following is a direct quotation from one of the references (Halliday and Griffin, 1966), "The study of terrestrial meteorite craters has assumed increasing astronomical importance in recent years due largely to the rapid pace of space research. The number of craters on the moon is so great that a thorough study of their nature ranks high in the program of lunar research and the photographs from the Ranger series have provided a greatly extended range of crater sizes for study. The Mariner IV photographs of Mars indicate that craters are also the most prominent feature on the Martian surface. Impact craters on earth appear relatively scarce because erosion is effective in removing the surface evidence. When the remains of old terrestrial impact craters can be located and identified, they deserve careful study since they can be subjected to many types of detailed analyses for a small fraction of the present cost of

†Presented at the C.S.E.G. Technical Meeting May 9, 1972. Manuscript received September 20, 1972.

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securing close-up photographs from other members of the solar system".

The reason for the quotation is basically two-fold. Firstly, it is intended to further impress upon the reader that the earth has been subjected to the same solar environment as the Moon and Mars and therefore has been involved in intercepting a similar frequency of foreign objects. Secondly, the writer wishes to qualify the somewhat apologetic overtone contained in the statement: "impact craters on earth appear relatively scarce because erosion is effective in removing the surface evidence." It is conceded that erosion has no doubt greatly altered impact sites and in many cases perhaps completely erased all evidence of the same; however, it is also suggested that there are numerous craters in varying degrees of preservation both at the surface and within the subsurface of the earth that have never been found and/or identified. The matter of identification cannot be over-emphasized because it is believed, in many instances, particularly when dealing with subsurface anomalies, diagnostic information is frequently lacking and although the origin of a feature may relate back to an antiquated crater, it has been sufficiently altered by the forces of nature so that we select a traditional scape-goat as the explanation.

Figure 1 is an adaptation of a figure contained in the paper "Impact Craters of the Earth and Moon", by C. S. Beals and Ian Halliday, 1965. It illustrates the distribution of impact craters formed during a terrestrial cycle of subsidence, deposition of sediments, emergence and erosion of sediments. If the cycle were to be repeated at this stage, evidence for the craters at the erosion surface would be in the form of incomplete scars, whereas those buried during a more or less continuous period of deposition should be in a relatively good state of preservation. Those phantomed in above the erosion surface, have of course, been completely oblitered.

Figure 2 shows the locations and indicates the approximate size of the craters that have been identified in Canada. The Sudbury, Ontario intrusion and the arcuate portion of the east coast of Hudson's Bay,

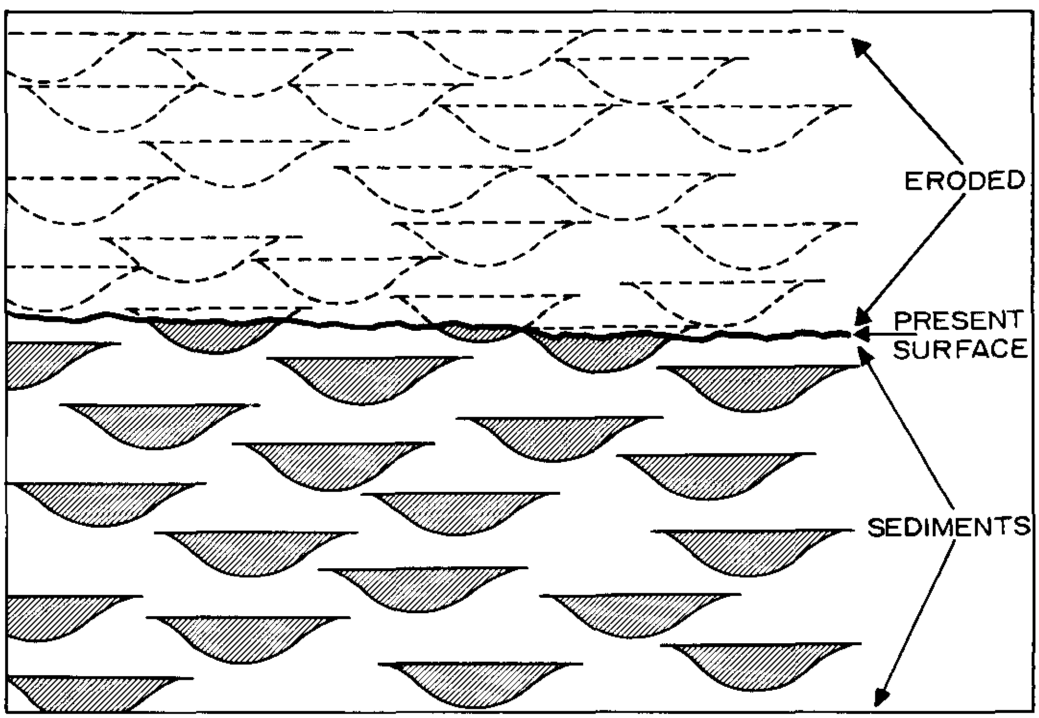

FIG. 1. Illustrates the distribution of impact craters formed during a terrestrial cycle of subsidence, deposition of sediments, emergence and erosion of sediments.

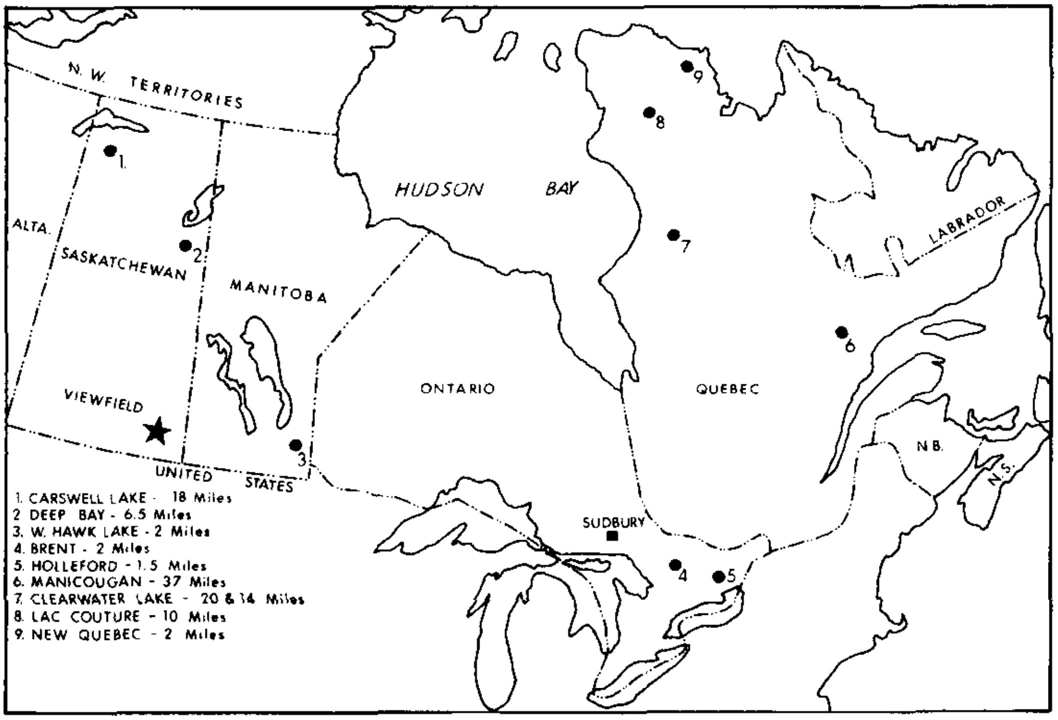

FIG. 2. Location and approximate size of impact craters identified in Canada.

are also considered to have an impact origin. The striking features about this figure are:

1. The sparse distribution of craters.
2. The confinement of the craters to the shield area of Canada, and hence the logical implication that the original leads to their discovery are at the present surface.

It has been suggested that the Lake St. Martin structure may be an impact or combination impact-eruptive feature. It has an approximate diameter of 14 miles and is located in the Lower Paleozoic subcrop belt in the Manitoba interlake region at Gypsumville. Present surface scars are indicated.

It is utterly amazing that with the amount of geophysical work and drilling conducted in the Western Canadian basin during the past twenty-five to thirty years, not a single impact crater has been officially identified within the sedimentary section and documented. The Steen River anomaly located in the shallow subsurface (605 feet) of north western Alberta may have an impact origin but requires more diagnostic information to substantiate the same.

THE VIEWFIELD CRATER

The surface elevation in the Viewfield area is approximately 2000′ A.S.L. and the terrain is typical flat prairie farmland. A shallow drainage channel trends through the location of the subsurface crater in a northwest-southeast direction.

Figure 3 illustrates seismic contours at the Second White Specks level and shows a slight circular depression encompassing Section 29. The contour interval is 0.010 sec. which represents approximately 35 feet. This configuration is also supported by the present well data.

Figure 4 represents seismic contours near the top of the Mississippian (top of the rim where applicable) using the Lower Colorado as a datum. The contour interval is 0.010 sec. which represents approximately 50 feet. The event carried across the crater area probably represents the top of the Lower Watrous rather than the Mississippian.

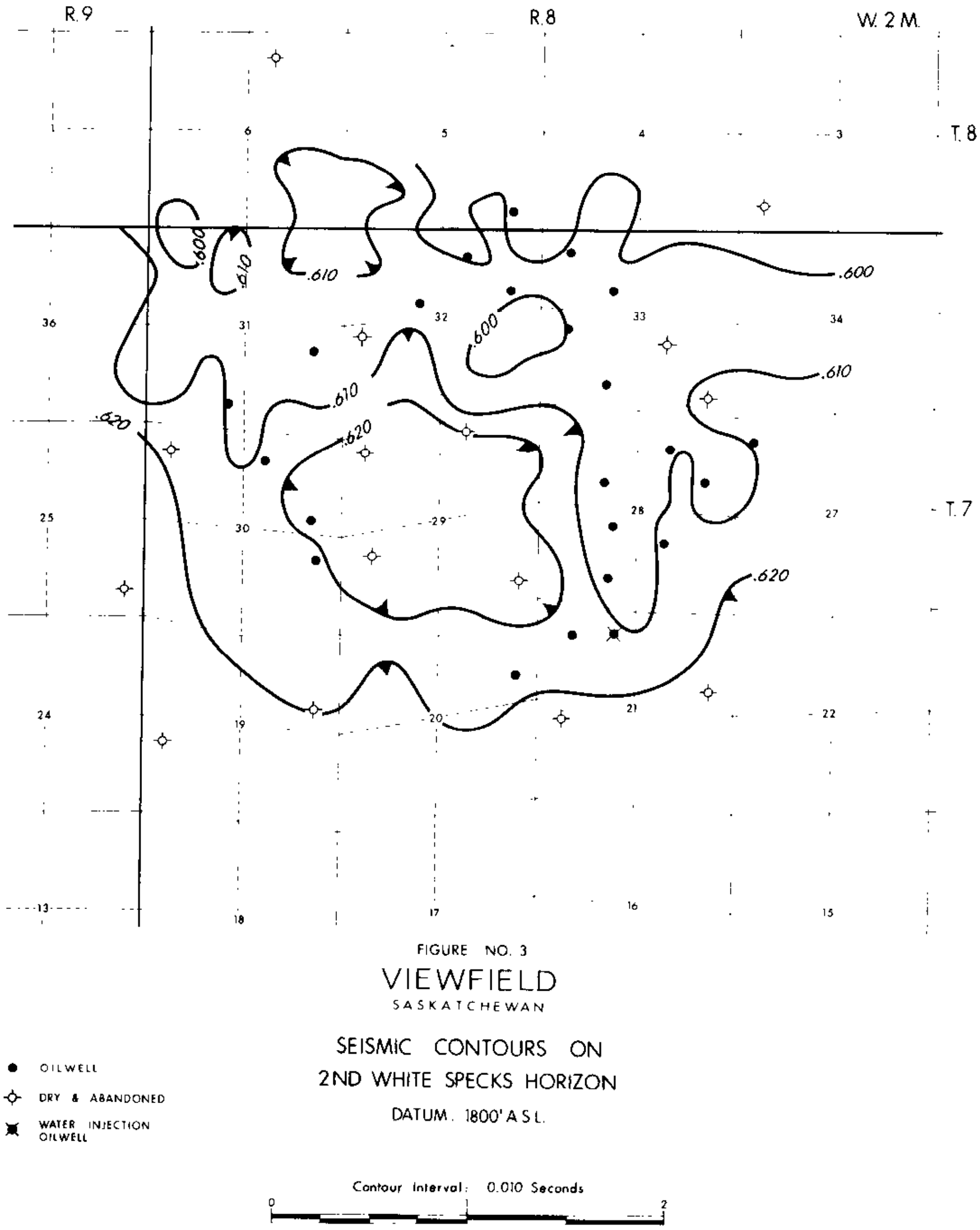

FIG. 3. Seismic contours on 2nd White Specks horizon.

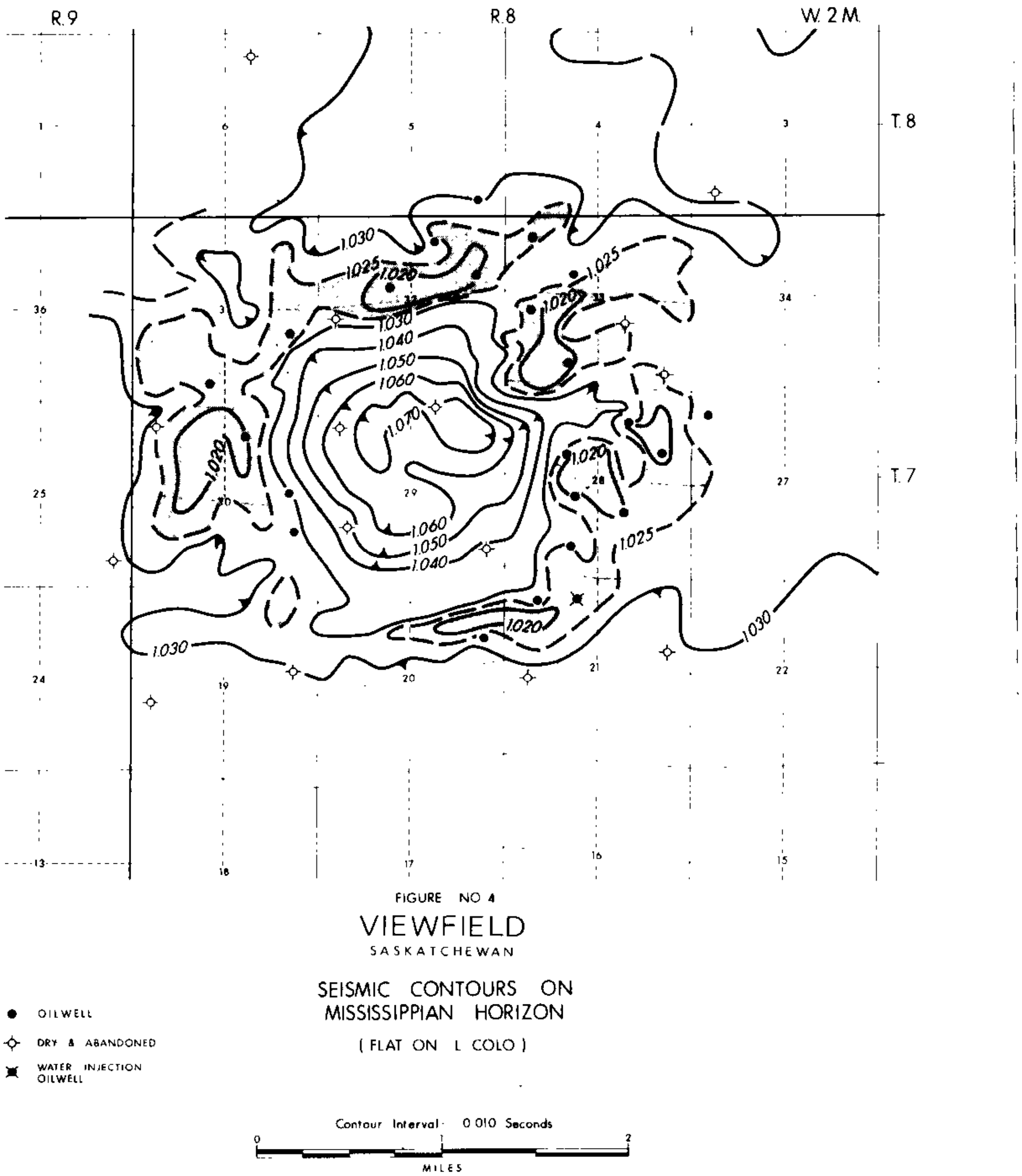

FIG. 4. Seismic contours on Mississippian horizon.

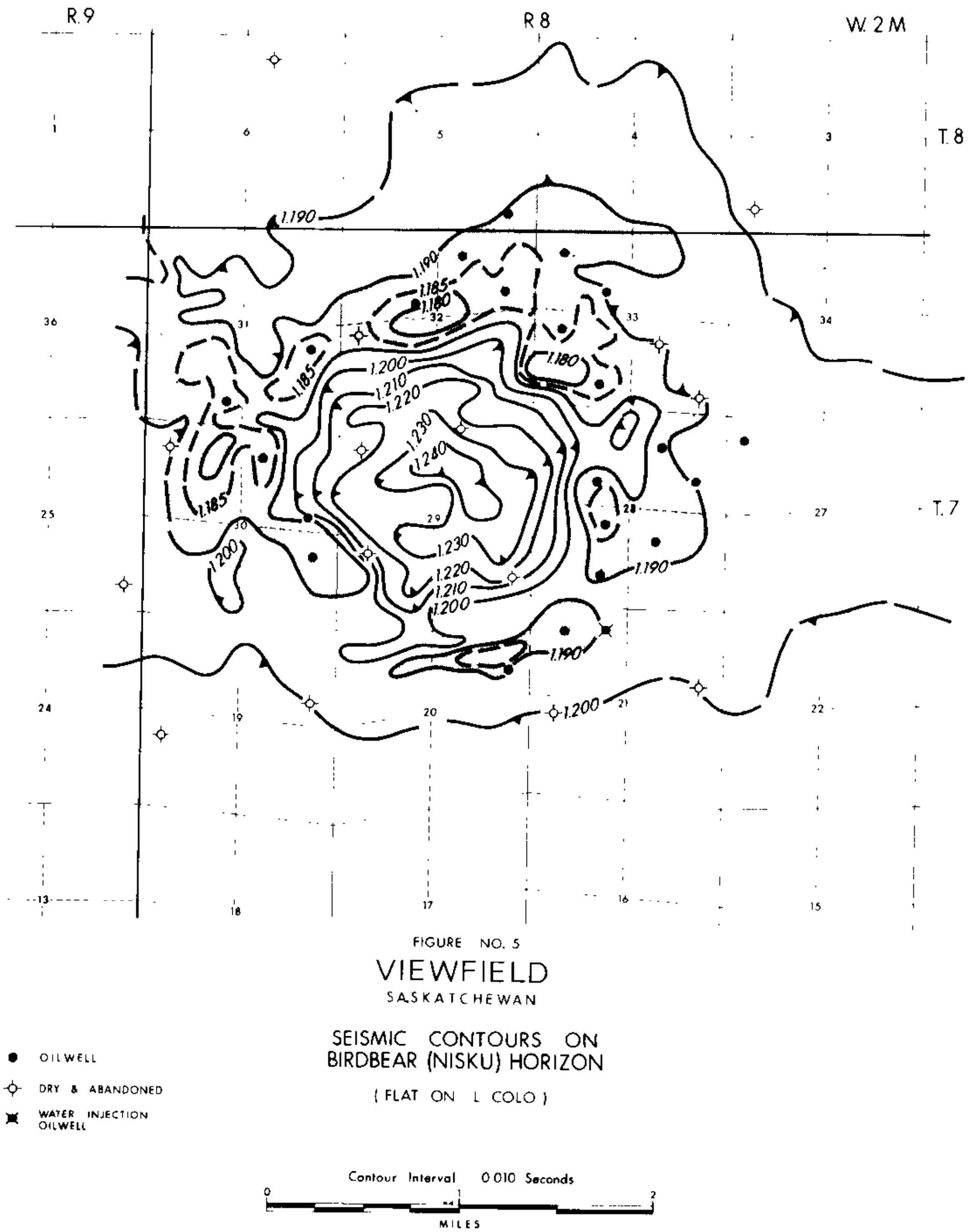

FIG. 5. Seismic contours on Birdbear (Nisku) horizon.

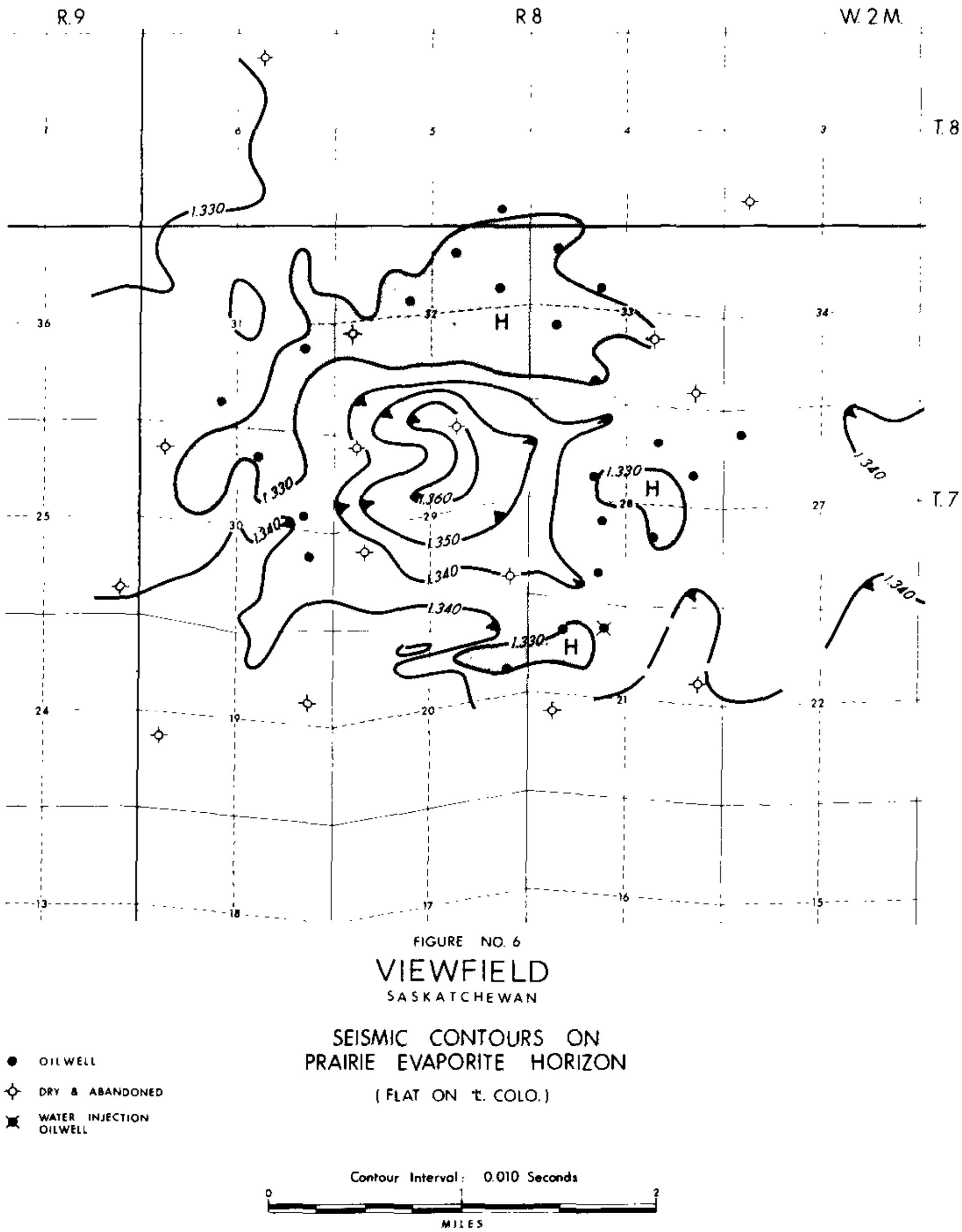

FIG. 6. Seismic contours on Prairie Evaporite horizon.

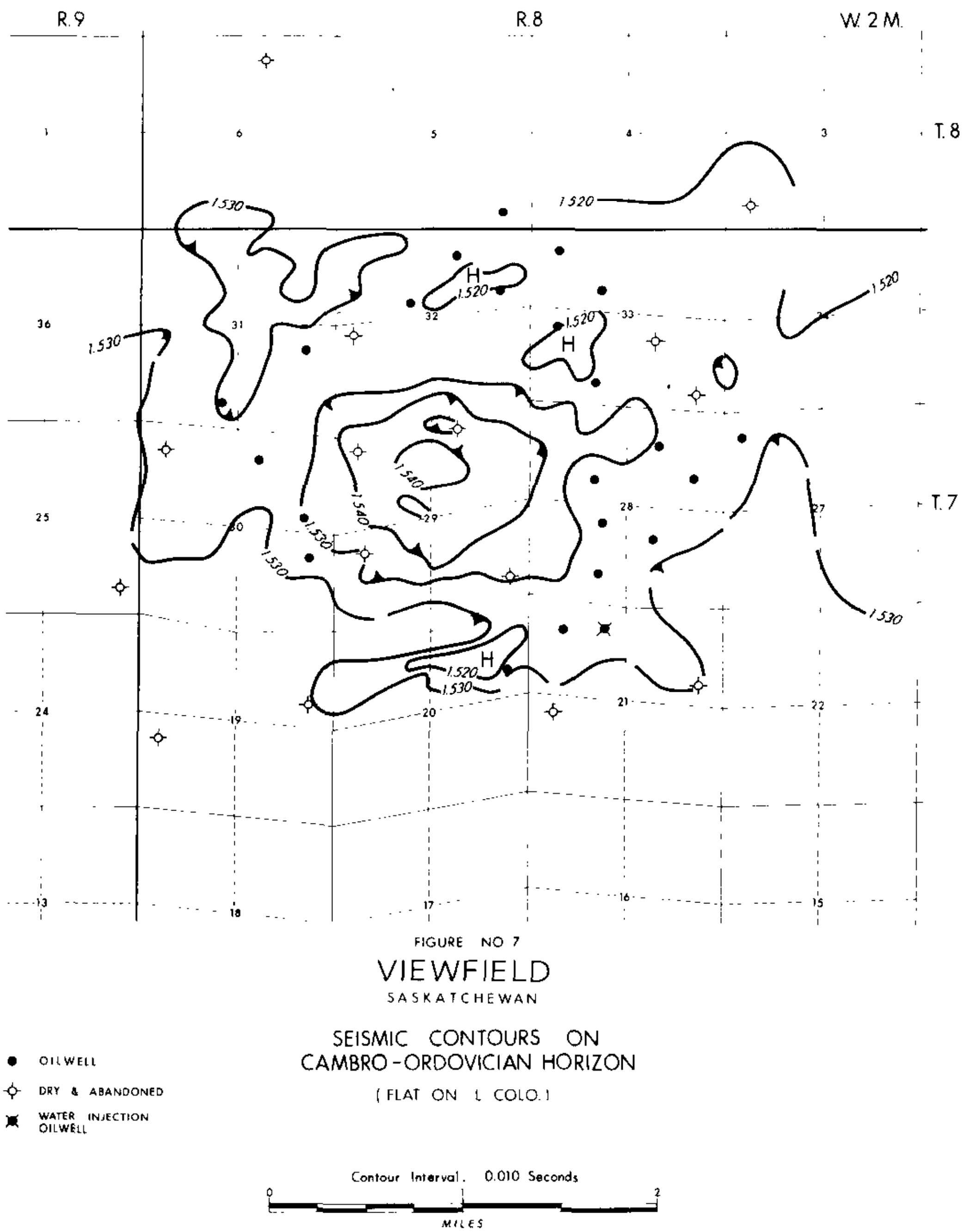

FIG. 7. Seismic contours on Cambro-Ordovician horizon.

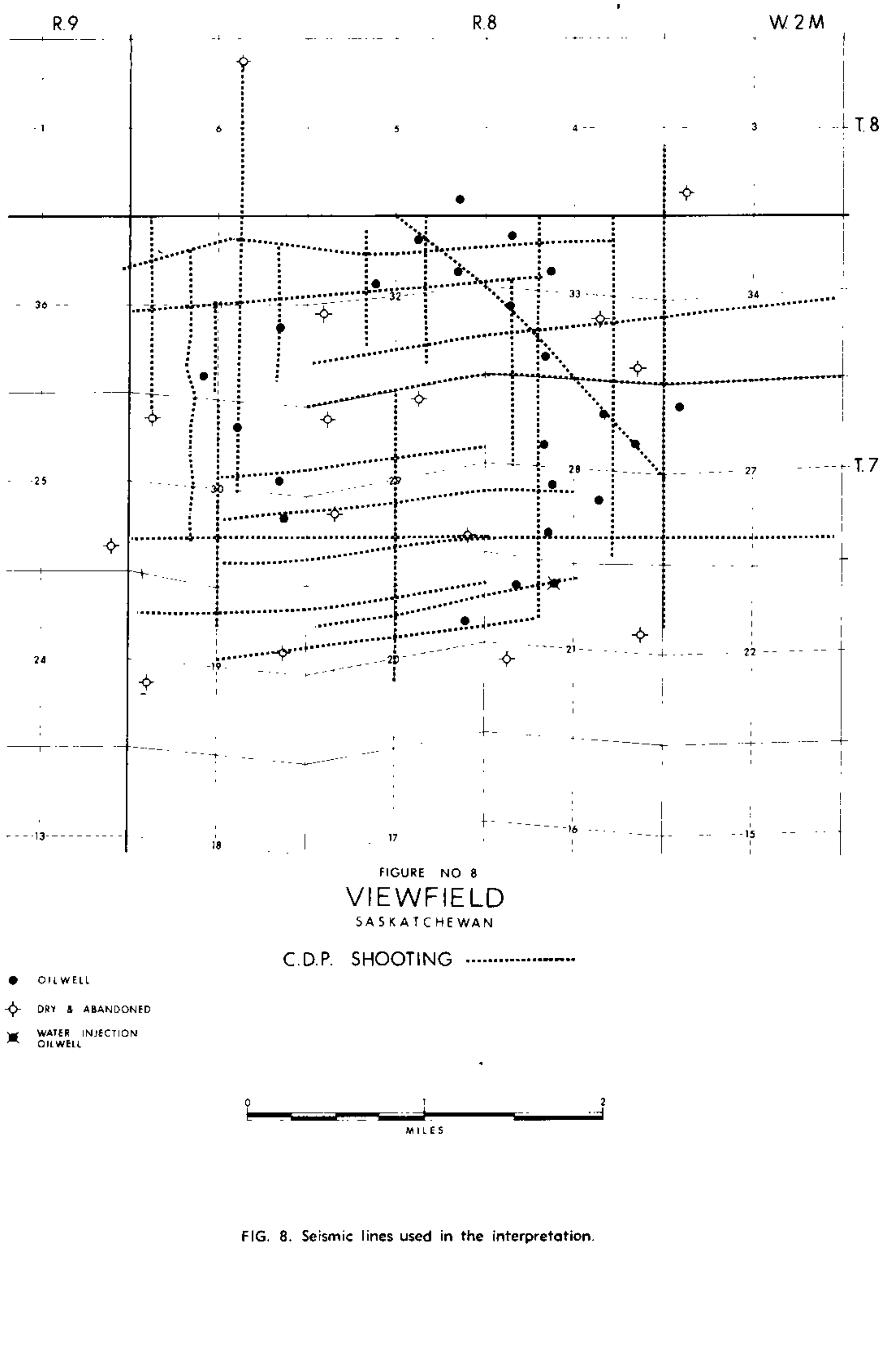

FIG. 8. Seismic lines used in the interpretation.

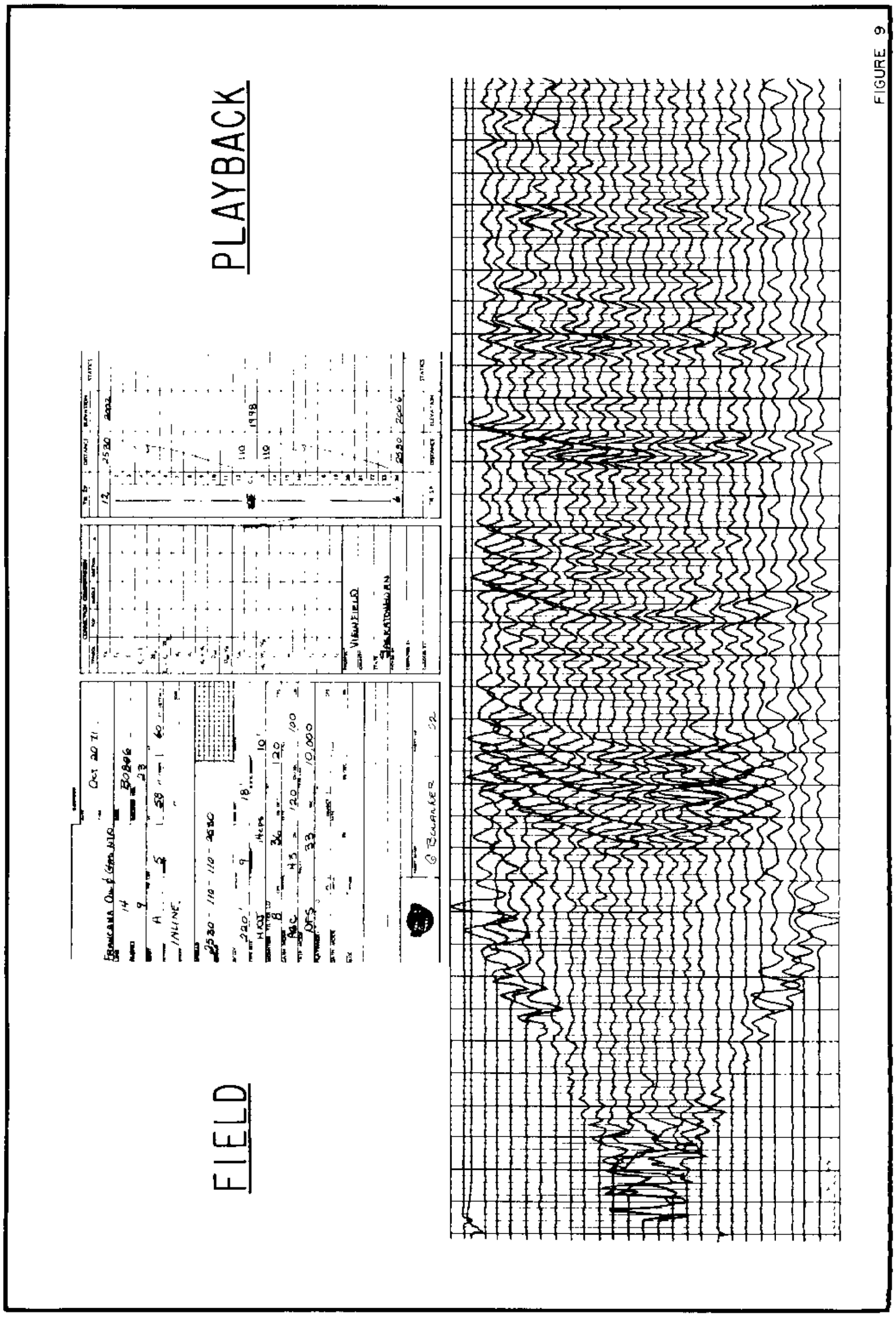

FIG 9. Unfiltered field playback record from Viewfield area.

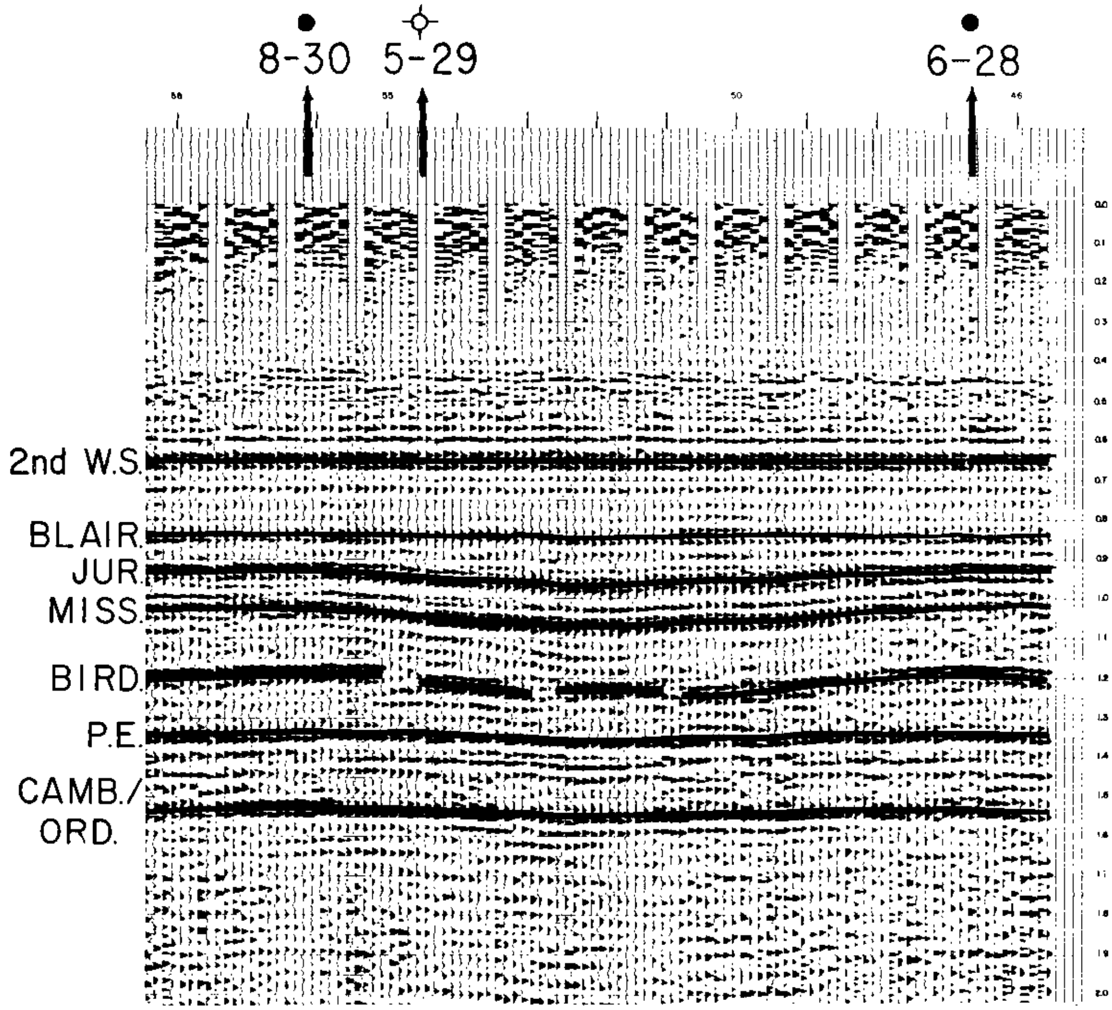

FIG 10. Seismic section flattened on 2nd White Specks

This will be demonstrated by later figures of several seismic record sections and a map on the Mississippian surface (including rim material) prepared from the well control.

Figure 5 shows the structural configuration at the Devonian (Birdbear) level. Again the Lower Colorado is used as a datum and the contour interval is 0.010 sec. which represents approximately 60 feet. However, we are no doubt getting some velocity "pull-up" effects under the rim and the reverse beneath the crater. Note that the size of the depression is somewhat reduced at this horizon.

Figure 6 illustrates seismic contours on the Prairie Evaporite with similar parameters to the two preceding figures. The crater, although still quite pronounced, is considerably reduced in both vertical and horizontal dimensions which is what one would expect. As mentioned earlier the depression at this level is believed due to a certain amount of plastic flow at the time of impact plus post-impact salt solution.

Although Figure 7 (Seismic contours on the Cambro-Ordovician horizon) displays a shallow depression in the vicinity of the crater, it is believed that this anomaly is due primarily to differential velocity effects mentioned earlier.

Figure 8 indicates the seismic lines used in the interpretations presented above. The line density is reminiscent of the Rainbow-Zama area of Northwest Alberta where this type of control is required to outline small pinnacle reefs. Adequate seismic control was really the key factor in resolving this problem as will be further demonstrated later.

The bulk of the data were gathered with TI 9000, 10,000, DFS III and S.I.E. PT700 instruments. 300% CDP coverage was obtained with a 2640 foot split spread configuration, nine geophones per trace and a 220 foot interval between stations. Hole depths were generally 60 feet and charge sizes varied between two and one-half and five pounds. Processing included a time variant filter and deconvolution operator. Structural sections, as well as sections flattened on the Second White Specks horizon, were prepared.

Contractors involved in the data acquisition were EXPLOR-ALTA and G.S.I., both DIGITECH and G.S.I. did the processing. The results were very satisfactory; however, lest the firms mentioned above burst with excess pride, it should be mentioned that shooting conditions in the Viewfield area are next to ideal and anyone not able to obtain good useable data shouldn't be in the business. This is illustrated by the unfiltered field playback in Figure 9 which is typical for the area.

Figure 10 is a seismic record section pertaining to an east-west line crossing the crater and passing by the wells indicated at the top of the figure. The section has been flattened on the Second White Specks at 0.650 sec. The top of the Blairmore horizon is essentially flat; however, the basal part of the Blairmore and Jurassic event show pronounced slumping into the crater. This is attributed to post-impact Middle Devonian salt solution and collapse as well as a certain amount of differential compaction of the clastic section over the crater. The event labelled "Mississippian" and mapped as such, appears to represent the same up to the rim position; however, as one proceeds across the crater it more accurately depicts the top of the Lower Watrous. The precise attitude of the Mississipian is difficult to follow through the crater but appears to be suggested by the strong dips indicated on the section between this horizon and the Birdbear event. In addition to showing the crater profile, the Birdbear displays several distinct dislocations. These are evident on a number of the lines associated with the impact area and the faults are no doubt instrumental in explaining some of the anomalous conditions encountered in the Mississippian to Birdbear interval as one proceeds from a rim position toward the center of the depression or in fact, from one flank position to another. (Figure 5 depicting contours on the Birdbear horizon does not show the dislocations). The Prairie Evaporite (salt) event can be carried continuously across the crater and as already explained, owes its configuration to a certain amount of plastic flow at the time of impact plus post-impact to Lower Blairmore solution. The Cambro Ordovician reflection can be correlated quite continuously and again as described earlier, is believed to display its regional character. Minor local wrinkles are attributed to differential velocity effects. Figure 11 is another east-west seismic section across the north end of the crater. It displays similar characteristics to those depicted in Figure 10.

Figure 12 is included to emphasize the need for adequate seismic control. These seismic contours on the Mississippian are based on 100% subsurface coverage obtained along lines indicated in the figure legend. This information, as well as similar information on several additional horizons has been available from the Saskatchewan Department of Mineral Resources since 1966 and although it reveals the strong depression centered in Section 29, it lacks the control points to properly map the surrounding rim. In the past, this type of shooting density has been frequently used to evaluate subsurface problems and guide the drill. However, when dealing with anomalies of the size and nature investigated here, it is considered grossly inadequate and should only be used as a guide to further shooting.

Who denies the fact that man's destiny is controlled by the stars? Note what happened to the original land survey in this area! In order to discount the possibility of conflicting compass bearings being at the

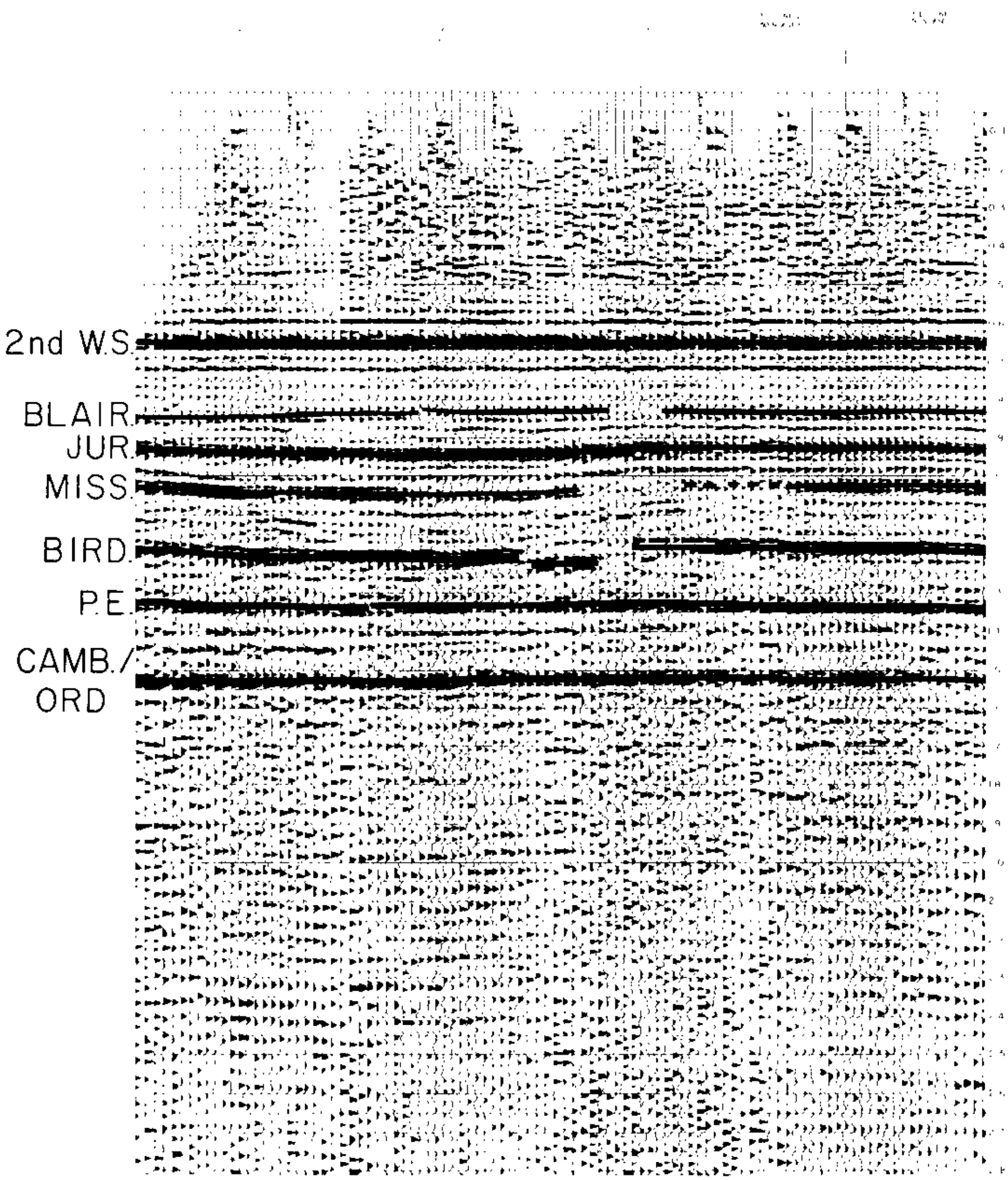

FIG. 11. Seismic section flattened at the 2nd White Specks

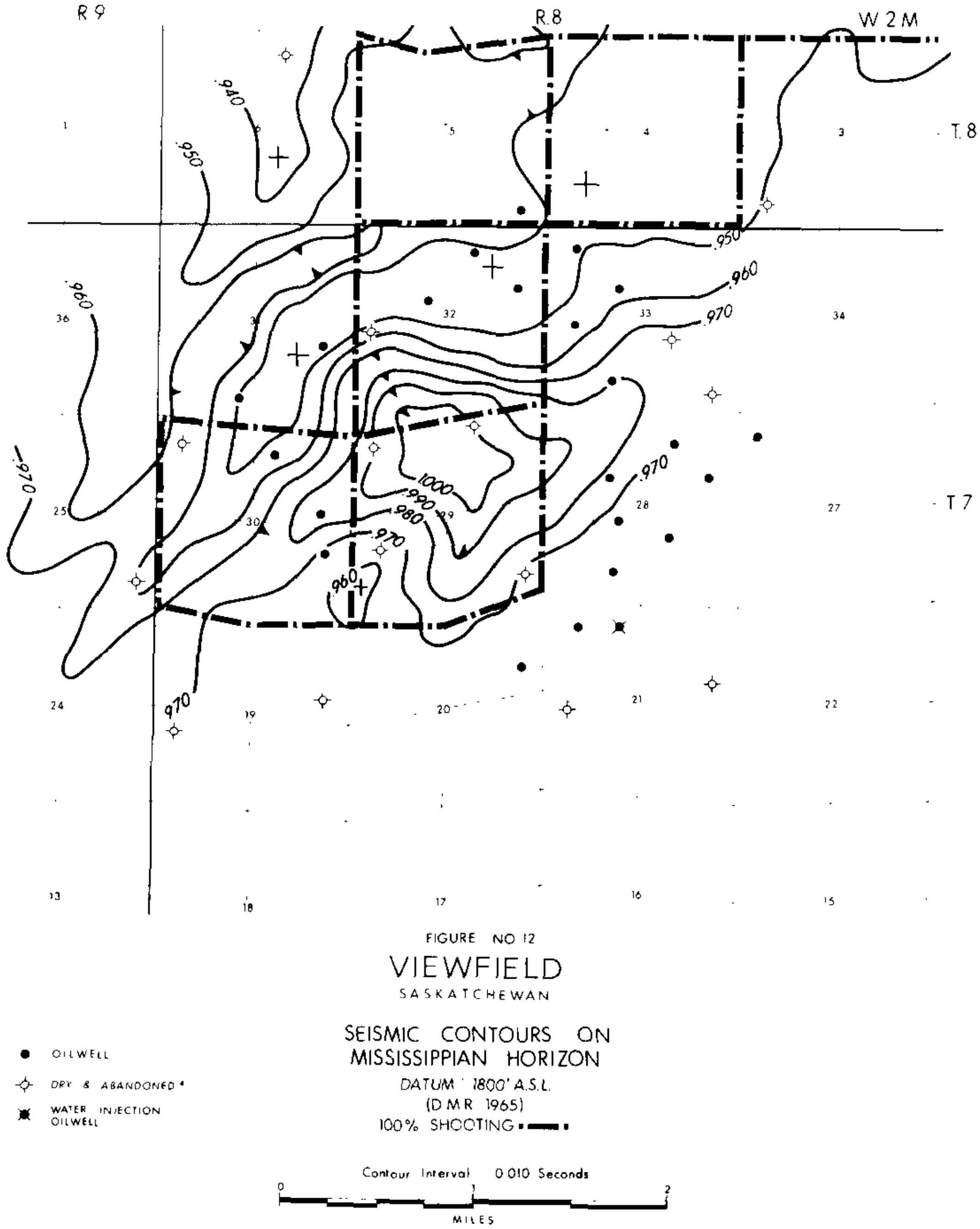

FIG. 12. Seismic contours on Mississippian horizon from the 100% shot lines indicated.

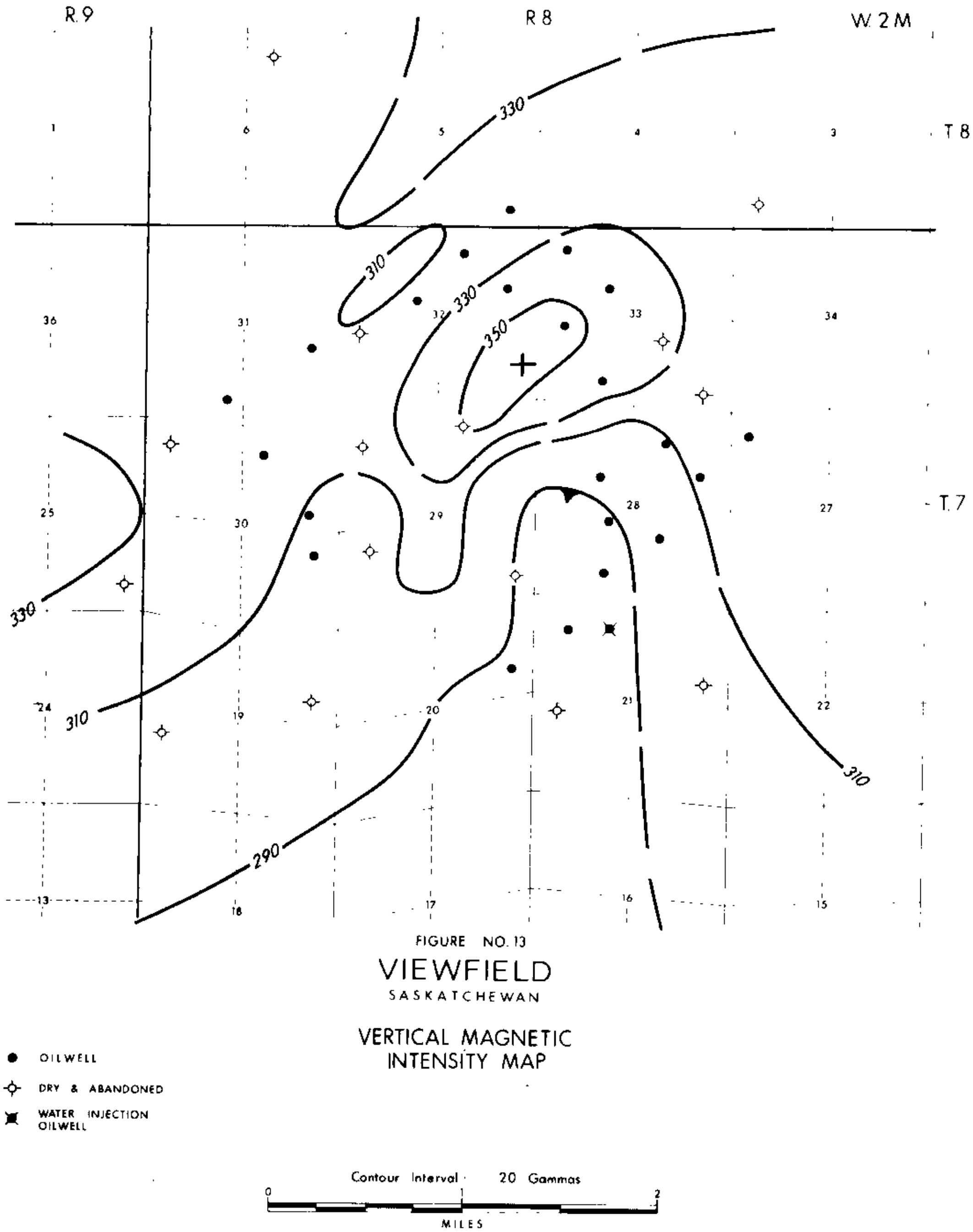

FIG. 13. Vertical magnetic intensity map.

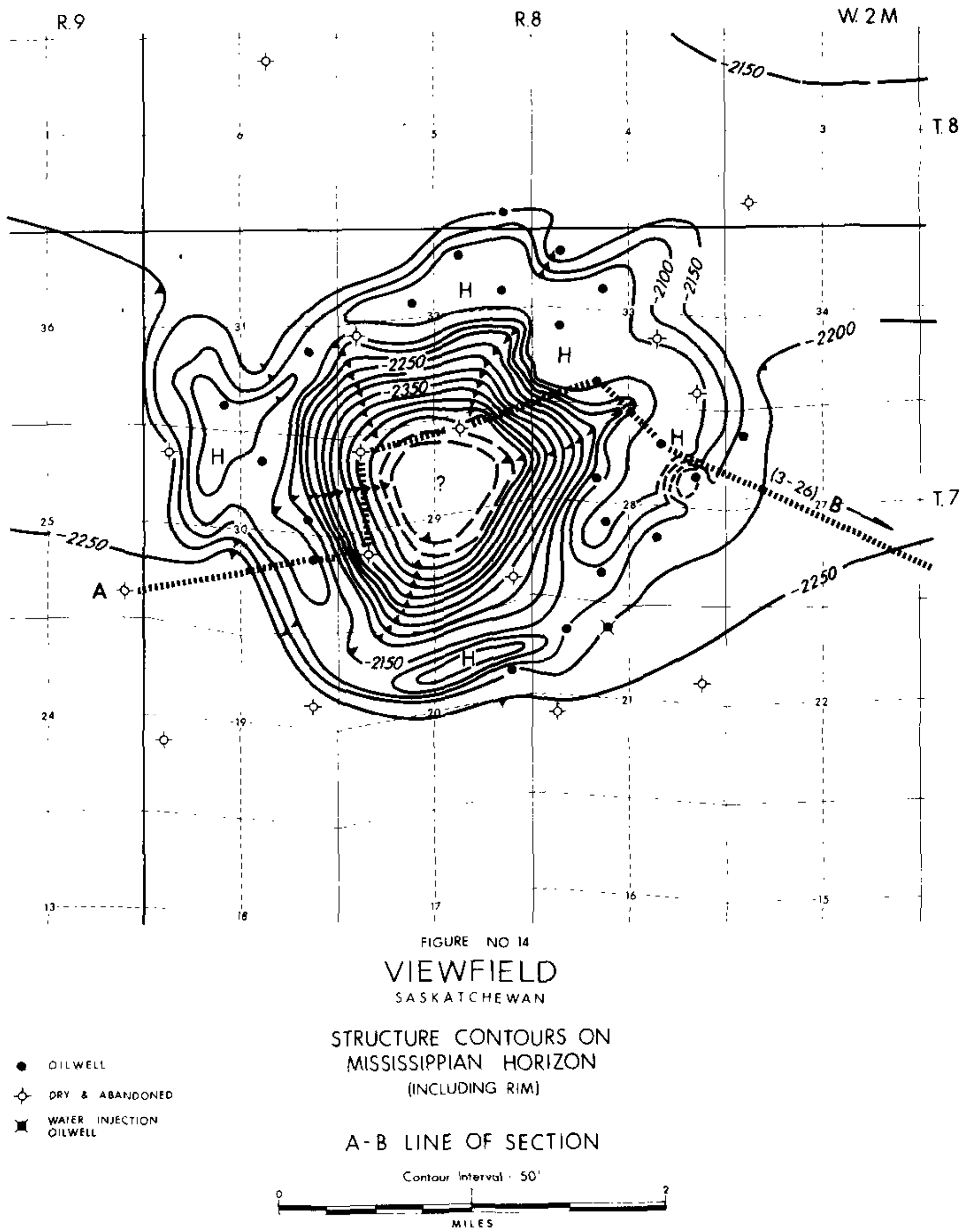

FIG. 14. Structure contours on Mississippian horizon.

root of this rather exceptional surveying anomaly, a check with the Saskatchewan Controller of Surveys indicated that originally concealed chaining errors were the cause.

A reconnaissance magnetic survey of the local area with a Sharpe Model MF-1 Fluxgate magnetometer resulted in the interpretation shown in Figure 13. Magnetic relief is very mild and appears to add very little diagnostic information to the interpretation of the crater. The 20 gamma closure in SE 32-7-8, W2 is not considered significant at this time.

Figure 14 shows the configuration of the anomaly on top of the Mississippian (including the rim) using well data. The contour interval is 50 feet. The correlation with the seismic control is good remembering that the crater slopes are depicted by steep dips on the record sections but that the top of the Lower Watrous was picked across the depression in the compilation of the seismic map on the Mississippian. Hence Figure 14 indicates considerably more relief with respect to the magnitude of the crater. The elevation difference between the top of the rim and the lowest well drilled in the depression is approximately 600 feet. However, note that neither 13-29 nor 15-29 reached the Mississippian top and it is conceivable that they may still be several hundred feet short of this target. If we employ Baldwin's (1949) empircally derived explosion crater equations:

(1) $D = 0.1083\, d^2 + 0.6917d + 0.75$
Where D is log rim diameter in feet and d is log depth in feet

(2) $E = -0.097D^2 + 1.542D - 1.841$
Where E is log rim height in feet

and consider an approximate crater diameter of one and one-half miles, a computed original rim height of approximately 495 feet and original crater depth of approximately 1200 feet is obtained. Since we now appear to have a residual rim elevation of approximately 200 feet, some 300 feet must have been lost due to erosion. Hence we can account for 900 feet of the original depth and as mentioned above, it would appear that the original crater floor may lie several hundred feet below the T.D. reached at the 13-29 location.

Francana Oil & Gas Ltd. was not involved in the wells drilled in 29-7-8, W2M. All of our locations were picked on the basis of detailed seismic control and to date, the results are 15 completions and 2 abandonments. The latter encountered rim material with no effective porosity.

Figure 15 illustrates a log section across the crater pertaining to the wells highlighted on the previous figure. The section is hung on the Lower Colorado and displays the following salient features:

1. The rim material sandwiched between Lower Watrous Red Beds.
2. The anomalous section between the top of the Mississippian and Birdbear as we proceed from a rim position (8-30) to one on the crater flank (5-29).
3. The 504 feet of Middle Devonian salt encountered in the 8-30 well. This, coupled with the fact that there is a minimum depression of at least 600 feet on the top of the Mississippian, precludes any possibility of explaining this entire anomaly by means of multistage solution and collapse phenomena, although post impact solution and collapse appears to have played a part in the present day configuration.

CONCLUSION

Much additional research work could be done on this feature with respect to the basic information gathered to date. Because of the nature of our endeavours, (exploration for petroleum) our primary interest in this anomaly has been one of economic return and therefore it does not warrant a great deal of additional work and study. However, from more of an academic point of view, at least one core hole located near the center of the crater should be drilled to the Precambrian and examined in detail.

The writer believes sufficient parameters have been presented in this paper to recognize the origin of this structure as being that of an impact crater. The basic outline is there. This situation could be likened to unfinished versus finished furniture. There is no difficulty in recognizing a chair, for example, regardless of which state it is in; however, considerable work and expense is involved in pursuing the final step.

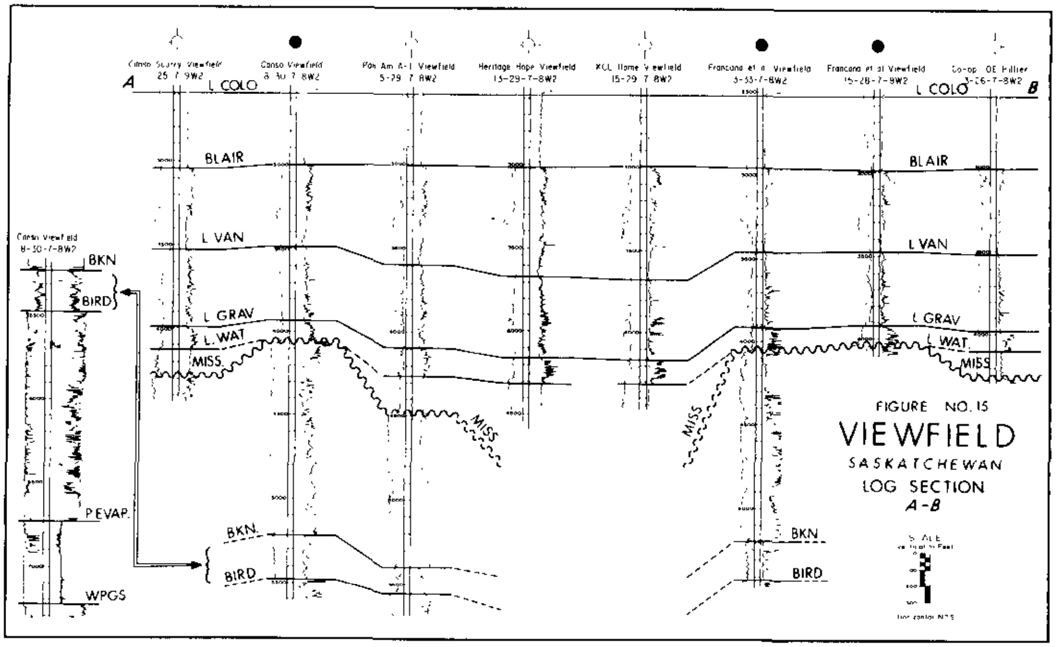

FIG. 15. Log section of wells referred to in previous figure.

If the above explanation is accepted, the reader is asked to consider the geometry of the structure that would evolve if all of the Prairie Evaporite (salt) were to be removed in this area with, of course, accompanying subsidence of the overlying section. The result would be the rather familiar sombrero feature, many of which have been mapped with the seismograph and/or drilled in widely scattered areas of the Williston Basin and attributed to two or more stages of salt solution and collapse. The typical sombrero is flat in pre-salt horizons and displays a central dome with encircling low on the post-salt horizon(s) involving the period up to the final stage of solution. The author subscribes to this generalized explanation. However, the cause for the initial removal of salt in these cases has always been a deep concern. If this subject is brought up at all, it is quickly cast off with vague expressions about deep-seated structures and/or faulting.

The striking characteristic about this type of anomaly is its radial nature. Why did the first stage of solution occur in this fashion? Surely, if faulting (in a conventional sense) was a root cause, then more of the features should have elongated configurations.

The reader is requested to consider the following thesis:

1. Post Paleozoic erosion will have erased most of the evidence of many of the actual craters that were formed; however, the scars of their much deeper radial fracture patterns will have been preserved in many instances and these acted as focal points for the commencement of local solution and collapse.

2. The initial stage of solution, with respect to the sombrero structure and the pronounced circular post-salt depression, was caused by a radial fracture pattern induced by impact. A number of these features can be located on the Composite Seismic Maps of Saskatchewan; some of which have been listed under Apendix.

3. If we consider the distribution of the features mentioned above with the known craters, we begin to get the type of pattern one would expect from having viewed conditions encountered on the Moon and Mars.

4. Many buried craters and crater scars still remain to be discovered. Some of the reasons for this are:

(a) We have failed to recognize the root cause for many of the subsurface anomalies that have been found.

(b) We lack sufficient subsurface control as indicated by the Viewfield example.

(c) Craters that occur in primarily clastic environments may be difficult to detect by geophysical means and furthermore would be less likely to cause secondary anomalies such as solution collapse structures because of a less effective fracture pattern.

5. The theory of continental drift (Plate Tectonics) has been with us for generations; however, it has only been widely accepted and applied in regional exploration problems during the past decade. It is time we caught up on our terrestrial impact history.

ACKNOWLEDGEMENTS

The author wishes to thank the Management of Francana Oil & Gas Ltd., for permission to publish this paper and would like to extend his appreciation, in particular, to Mr. W. E. Nicholson for drafting the illustrations.

APPENDIX

Sombrero features and a pronounced post-Middle Devonian radial depression that can be found on the composite seismic maps of Saskatchewan.

1. Birsay
   — Twp. 25, Rge. 8, W3M
2. Elbow
   — Twp. 23, Rge. 6, W3M
3. Teakle
   — Twp. 19, Rge. 9, W3M
4. Braddock
   — Twp. 14, Rge. 10 & 11, W3M
5. Vanguard
   — Twp. 12, Rge. 9 & 10, W3M
6. Johnstone Lake
   — Twp. 12, Rge. 2, W3M
7. Harptree
   — Twp. 4, Rge. 26, W2M
8. Avonlea
   · Twp. 12, Rge. 23, W2M
9. Dahinda
   — Twp. 9, Rge. 23, W M
10. Regina
   — Twp. 17 & 18, Rge. 19 & 20, W2M

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