Thermoluminescence as a Correlation Tool in the Austin Chalk in North Central Texas[1]

By JAMES E. BROOKS[2] and DAVID L. CLARK[3]

PURPOSE AND SCOPE

Methods for establishing precise correlations between isolated surface outcrops in flat-lying formations which are exposed poorly in areas of low relief are few in number if they exist at all. This point is well illustrated by the Upper Cretaceous Austin Chalk in north-central Texas. It is a relatively easy matter to correlate generally on the basis of lithology and stratigraphic or map position between the sparsely distributed outrcops and to recognize that one is within the lower, middle or upper Austin. However, acceptable correlations of a more specific nature (e.g., bed-for-bed or the exact relationships between two sequences which contain no apparent diagnostic criteria) have been difficult to achieve. Various techniques have been employed. C. I. Smith (1955) used a method whereby the vertical profile of a weathered outcrop was drawn to scale to show thickness of resistant and non-resistant beds and their resulting horizontal relief. Thus, by comparing and "fitting" the profiles of various outcrops, he believed that correlation could be achieved. The validity of Smith's method has never been conclusively evaluated. Some flaws are apparent, however. The degree of weathering of an outcrop is of paramount importance to his method. The present writers have observed the striking difference in horizontal profile that exists between deep road cuts in the Austin Chalk seen within about a year after they were made, as compared with stratigraphically and lithologically similar cuts which are five to ten years old. In addition to this principal factor of time, the rate of weathering is affected by such variables as orientation of exposure with respect to sunlight, drainage, degree of slope, and cover on adjacent areas. None of these is easily evaluated in terms of its effect on specific outcrops. Williams (1957a) employed a method in which the horizontal outcrop profile, the percent insoluble residue and the color

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[2] Department of Geology, Southern Methodist University.

[3] Department of Geology, Brigham Young University.

(using the National Research Council Standard Color Chart) were used as criteria for correlation. The added criteria of composition and color have added appreciably to the degree of validity of Smith's method. Williams was able to make detailed correlations with apparent success between outcrops separated by as much as three miles. Other geologists have employed fossils of very limited vertical range (e.g., *Parapuzosia*, Clark, 1960) as guides to the specific beds which contain them, assuming that over the short distances involved little disparity between time and lithologic surfaces would exist.

In view of the apparent success of correlations based on thermoluminescent glow-curves in other areas (Saunders, 1953, and Parks, 1953) we have applied this technique to selected outcrops of the Austin Chalk in Dallas County, Texas, with the hope that it might provide an additional tool with which to make detailed correlations in this formation and other similarly poorly-exposed, flatly-dipping rock sequences. With this in mind, representative samples were carefully selected from the collection made by Williams (*ibid.*) from the lower and middle Austin in southern and central Dallas County and were subjected to thermoluminescent ("glow-curve") studies. Samples were chosen from beds which Williams considered to be correlative at various stratigraphic horizons and over varying distances between outcrops. These samples also represented compositions ranging from about 88% carbonate and 12% insoluble (presumably terrigenous material) to 63% carbonate and 37% insoluble.

THEORY

Saunders (*ibid.*) and Handin *et al.* (1957) provide succinct summaries of the theory of thermoluminescence. These state, in effect, that thermoluminescence results from the light emitted when electrons trapped at metastable positions in the crystal are thermally agitated to the point where they can move out of the trap into a more stable position in the crystal lattice. In this process the electron gives up some of its excess energy, which is released in the form of light. When a natural crystal absorbs radiation in the form, for example, of gamma rays or X-rays, many energetic secondary electrons become excited and move to become trapped at imperfections in the crystal structure such as those resulting from impurities or missing ions. As the rock is heated at a constant rate and the trapped electrons become sufficiently active to move out of the traps into more stable positions within the crystals, light is emitted in a series of maxima (peaks on the glow-curve) which reflect the energy required to free electrons from each type of trap. Since at least some types of traps are related to the crystal structure of the minerals composing the rock, Handin *et al.* (*ibid.*, p. 1223-24) conclude in parts that

. . . appearance of new glow-curve peaks suggest the generation of vacancies (traps) by dislocations during deformation by translation gliding.

and that

The alteration of the shapes of thermoluminescence glow curves resulting from deformation may be preserved in naturally deformed rocks which have not been heated much above 200°C. If the natural thermoluminescence of the rock has been modified by folding or faulting, then caution must be observed in comparing glow curves for correlations or relative age determinations.

In addition it should be pointed out that glow-curves may likely be modified by processes of recrystallization other than those related to folding and faulting and that variation in the amount and type of impurity may also have a significant effect on glow-curve characteristics.

The application of "glow-curve" studies to stratigraphic problems of correlation has significance only if it is assumed that contemporaneous sediments contain similar traps. It is apparent that the probability of the lateral persistence of similar traps, even within contemporaneous sediments, diminishes with distance. Thus the use of glow-curves derived from widely spaced control points, between which considerable undetected tectonic or lithologic variation may exist, in our opinion does not constitute a valid single criterion on which to base correlation. In fact our present inability to evaluate all of the variables which affect thermoluminescence argues against the use of this tool as the *sole* basis of correlation under any circumstance. The present writers believe, however, that thermoluminescence when used in conjunction with other geological techniques, particularly when the work is restricted to a small area of uniform deformation, provides a satisfactory criterion for correlation. The study which is the subject of this report was made on rocks which were formed under these conditions.

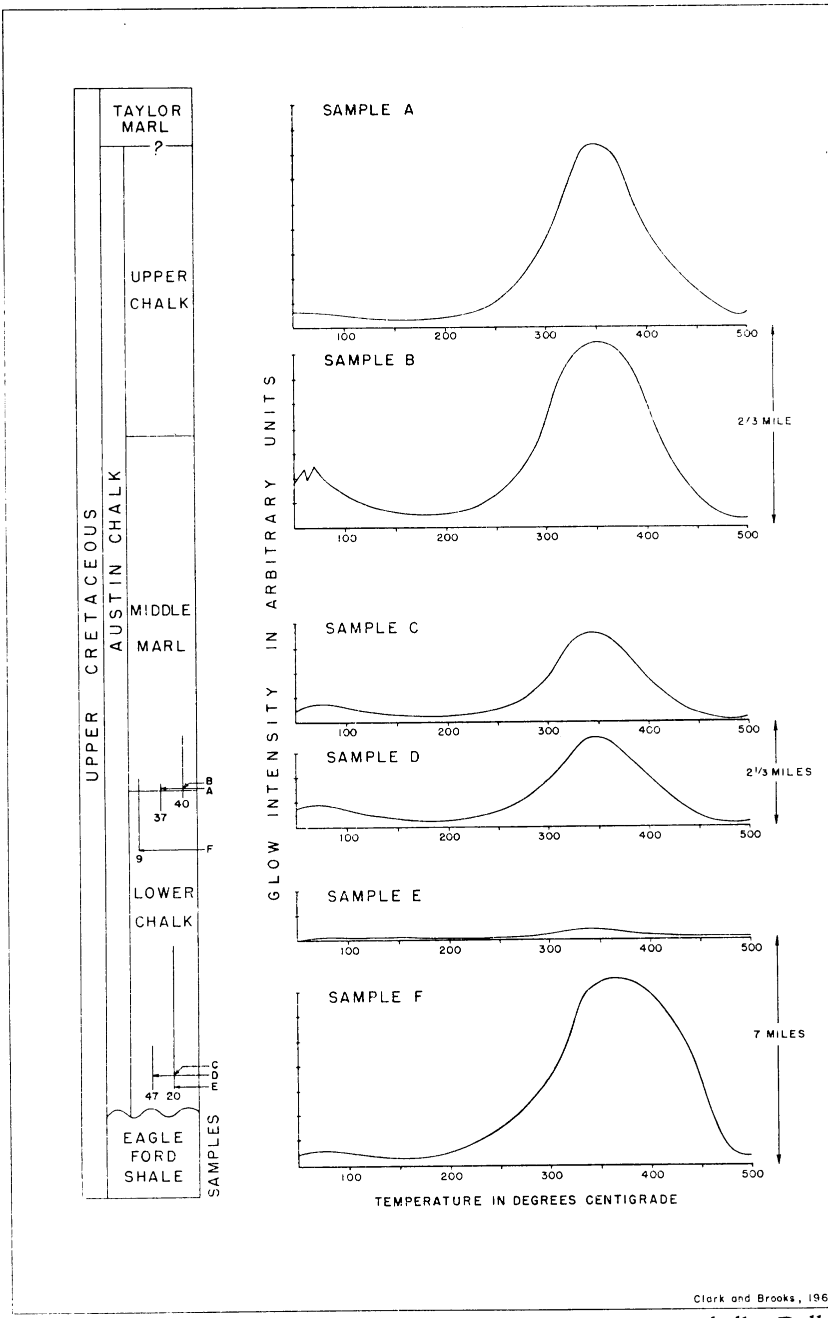

FIGURE 1. Representative Glow-curves from the Austin Chalk, Dallas County, Texas.

GLOW-CURVE VARIATIONS IN THE AUSTIN CHALK

Figure 1 illustrates typical variations in glow-curve shapes obtained from the Austin Chalk. While the six representative curves figured show a considerable variation in shape they possess characteristics in common, a tendency to have a low peak at 60° to 75°C. and to have a distinct peak (often very high) at the temperature range of 340° to 360°C. These two characteristics are discernible in the curves of all samples studied; and, since these are fairly well spaced throughout the lower and middle part of the formation and are from a variety of lithologies they may be taken as typical of the Austin Chalk as a whole.

TABLE 1. SAMPLE LOCATIONS.

All section numbers refer to Williams (1957b) Plate 1. Samples are numbered consecutively upward from the base of each section.

Sample	*Section - Sample*	*Section Location*
A	37 - 21	50 yards downstream from intersection of Ten Mile Creek and U.S. Highway 77.
B	40 - 5	Ten Mile Creek 0.8 airline miles below intersection of U.S. Highway 77 and Belt Line Road
C	20 - 14	Road cut 0.3 miles northwest of intersection of Farm Road 1382 and Strauss Road.
D	47 - 6	Road cut on Mansfield Road 0.8 miles west of intersection with Belt Line Road.
E	20 - 1	See "C" above.
F	9 - 2	1.2 airline miles north northeast of DeSoto at Ten Mile creek and Farm Road 1382.

TABLE 2. SAMPLE COLOR AND COMPOSITION

All data from Williams (1957b), Plate I.

Sample	*N.R.C. Color Code*	*Percent Insoluble*
A	N 8.5	12.0
B	N 8.5	11.5
C	N 8.5	12.5
D	10 YR 8/2	13.5
E	5 Y 8/1	30.0
F	N 6.5	29.5

Curves A and B are typical of the variations encountered in samples taken from the same horizons over short distances. These samples were collected from what Williams (*ibid.*) considers to be the same limestone bed at two localities about two-thirds of a mile apart (*refer* to Table 1). This stratum shows consistent composition, thickness and color between the points at which the two samples were collected. The similarity between curves A and B is apparent from Figure 1. It is clear in this case that, on the basis of criteria other than thermoluminescence, there is little question concerning the validity of correlation between the two sections. Therefore the close similarity of the glow-curves is taken as substantiating evidence of the applicability of this method as a tool of correlation and the near correspondence of curves A and B, and, in effect, serves as one check point on the thermoluminescent method. The variation to be noted between curves A-B and C, D, E and F lends further support to the suggestion that individual strata may be characterized by distinctive thermoluminescent patterns.

Samples C and D are from sections approximately 2⅓ miles apart (*refer* to Table 1). Similarity in stratigraphic position in sequence, lithology, and thickness of bed indicates that they are from the same bed. The similarity in glow-curves (Figure 1) supports this correlation. These curves, it should be noted, while similar to each other differ in gross shape and intensity from A, B, and F, taken from higher in the section and from E taken just slightly lower in the section than C and D. These curves, and others representative of this distance, suggest that over intermediate distances, also, thermoluminescence may provide one satisfactory criterion for correlation.

The limestone layer from which E was collected is demonstrably different than the one from which F was taken and neither of these coincides with the beds represented by A—B and C—D (Figure 1). The variation in glow-curve pattern and intensity is apparent from the comparison of the first two sets of curves and from the last two individual curves; and this may be taken as negative evidence to support the suggestion that certain strata may be recognized on the basis of their glow-curves. In the case of E and F the difference in curve-shape is unusually great, and these may be considered to represent approximately the limits of variation to be expected within the formation. More typical of the bed to bed variation is the comparison of either E or F with A—B or C—D or between A—B and C—D themselves.

It should be noted that, while all of the figured curves are from rocks relatively low in insoluble impurities (Table 2), the curves from samples running as high as 36% insoluble showed no significant variation in pattern or intensity of thermoluminescence.

SUMMARY

Insufficient samples have been examined to warrant more than tentative conclusions. Those samples run, however, are almost completely consistent in showing:

(a) The development of a very low peak at 60° to 75° C.; and a much more pronounced peak of varying width at 340° to 360° C.;

(b) A pronounced similarity of curves from the same bed over distances ranging from two-thirds to two and one-third miles; and,

(c) A variation in curve shape between demonstrably unrelated beds. On this basis it is suggested that thermoluminescence may provide a satisfactory correlation tool when used in situations similar to those in which the Austin Chalk occurs in north-central Texas.

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