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Description of the Rock City at Palo Pinto, Texas, With an Estimate on the Rate of Rock Creep*

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Approximately three miles west of Palo Pinto, Texas, on U. S. Highway 80, is a typical rock city known as Lovers' Retreat. The locality, one of several rock cities in Palo Pinto County, is roughly rectangular in shape and extends for a thousand feet or more along the north side of the highway (Fig. 1). Lovers' Retreat is well known in Texas and people come from all parts of the state to picnic in the groves along Eagle Creek and to explore the narrow passageways between the huge blocks of limestone on the north side of the stream.

Rock cities have been described by both Hall¹ and Lobeck,² and Sharpe³ included them in his classification of mass movements, but the authors were unable to find in the literature any attempt to measure the rate of creep of the blocks. The measurement of the rate of geological processes is a fundamental problem of the science; accordingly, this report contains, in addition to a description of the rock city at Palo Pinto, an account of a method for estimating the rate of creep of the joint blocks.

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¹Hall, James, "Geology of New York, Comprising the Survey of the Fourth Geological District," *Natural History of New York*, Part IV, 1843, pp. 284-307.

²Lobeck, A. C., "A Popular Guide to the Geology and Physiography of Allegany State Park," *New York State Museum*, 1927, pp. 78-79, 169-179.

³Sharpe, C. F. Stewart, *Landslides and Related Phenomena*, Columbia University Press, New York, 1938, pp. 21-48.

Geological Setting

The Palo Pinto region is a dissected plateau drained by the Brazos River and its tributaries. At Lovers' Retreat two formations of Middle Pennsylvanian age are exposed. The younger is the Palo Pinto limestone, basal unit of the Canyon Group. It is a hard, crystalline, thinly bedded, escarpment-forming limestone. The top of this formation has been removed by erosion at Lovers' Retreat, where the exposed thickness is about twenty feet. Conformably underlying the Palo Pinto formation is the Keechi Creek shale, a member of the Mineral Wells formation of the Strawn Group. This is a yellowish-gray shale reported by Plummer and Hornberger⁴ to be 60 feet thick. The base is not exposed at Lovers' Retreat.

These and the other Pennsylvanian beds in the region have a gentle regional dip to the northwest, upon which are superimposed minor flexures. The strata are broken along joints belonging to two systems trending at approximately right angles to each other (N. 27° E. and N. 70° W.). The joints are well-defined, straight, and spaced at regular intervals. They are perpendicular to the bedding and can be traced for many yards.

Origin and Description of Lovers' Retreat

At Lovers' Retreat, Eagle Creek, a tributary of the Brazos River, has cut down through the Palo Pinto limestone and the upper portion of the Keechi Creek shale. Here the stream makes a broad bend, convex toward the northwest, and has formed an undercut bank in the shale. Thus the limestone which caps the flat-topped hills to the north has been undermined, and large limestone joint blocks have crept over the underlying shale down the slope toward the creek at the bottom of the valley (Fig. 2). At one point a block has pulled away from a corner in the wall formed by the limestone outcrop, leaving the upper two or three beds in place, connected with the wall and forming a porch-like shelter (Fig. 3). In their progress toward the stream, the

⁴Plummer, F. B., and Hornberger, Joseph, Jr. "Geology of Palo Pinto County, Texas," *Univ. of Texas Bull.*, No. 3534, 1935, pp. 30-31, 44-45.

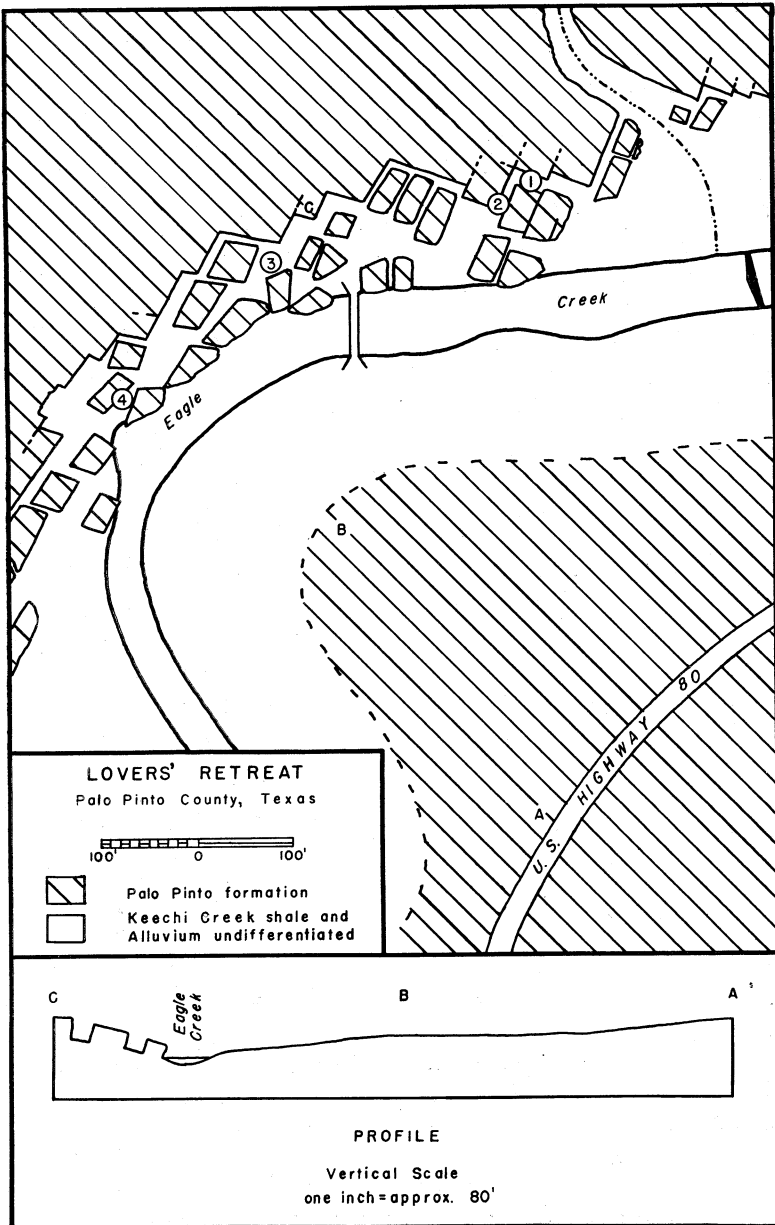


Fig. 1

blocks begin to tilt forward, or "nose over." In some cases the blocks tilt so far that the individual strata slide forward along the bedding planes as would playing cards from a deck (Fig. 4). The blocks end their journey in the stream bed where they are destroyed by erosion.

The blocks vary somewhat in size, but most of them are about 20 feet by 40 feet and all of them are about 20 feet high. As they break away from their original places in the limestone outcrop at the top of the hill and creep down the slope, they diverge so that what were originally narrow clefts between adjacent blocks grow to passageways that range from three or four feet to over fifty feet in width. As erosion proceeds, more limestone is undermined, more blocks are freed from the parent outcrop, and they begin the slow journey down to the stream. Accordingly there is more than one row of creeping blocks, rather a whole fleet of them creeping down the slope, and all of the valley side is studded with limestone blocks each about the size of a one-car garage. These rectangular blocks with their vertical sides separated by straight, comparatively narrow, intersecting passages produce an effect not unlike that of buildings and city streets so that it is easy to understand how the term rock city came to be applied to this sort of phenomenon.

Between the blocks in the "streets" of the city moderately large elm, hackberry, and oak trees are growing, while the tops of the blocks are covered with brush and scrubby cedar trees. The top surface of the blocks is often jaggedly irregular because of solution weathering, and *tinajitas*⁵ have been developed on the almost level surface of the limestone which caps the hill. Much of the drainage from the flat plateau is via the joints in the limestone. The joints discharge the water into the passages between the blocks, with the result that for several hours after a heavy rain, "streets" of the city are converted into canals.

Measuring the Rate of Rock Creep

As has been previously stated, there are several com-

⁵*Tinajita*, an etched pot hole.

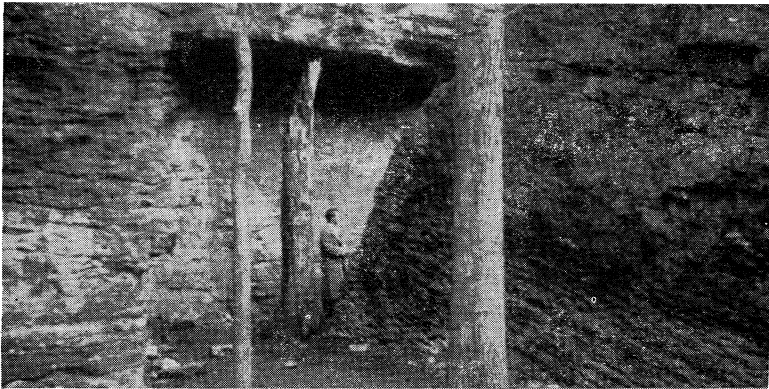


Fig. 2. Blocks of Palo Pinto limestone at bottom of slope in the bed of Eagle Creek.

Fig. 3. Street intersection in the rock city showing trees growing between blocks and a rock shelter.

Fig. 4 Imbrication of beds in a tipped over block.

paratively large trees growing in the passages between the blocks. That any tree could not take root until the block directly downslope from it had vacated the position occupied by its trunk, is obvious. If a tree took root immediately after its location was vacated by the block directly downslope from it, it is evident that the age of the tree would indicate the time required by the block to move from the location of the tree to its present site. Obviously it cannot be proved that any particular tree took root *immediately* after its *lebensraum*^{*} was bared by an adjacent downslope block, but by choosing from the available trees the ones which are the oldest and the nearest to their downslope blocks one can reduce the error to a minimum. It is clear that of two trees the same distance from a block, the older must have begun to grow sooner after the spot was vacated by the block than the younger. Similarly, of two trees of the same age but at different distances from the creeping block, the one nearer the block must have taken root sooner after its *lebensraum* was bared. Even so, the average rate of creep derived in this manner must be considered a maximum, since it is probable that even a carefully chosen tree did not take root in the same year that its location was vacated.

Four trees, all elms, were selected as the ones which would best eliminate error. These were cored with an increment borer, and their circumferences measured, as were the distances to the downslope blocks in the direction of motion. One of the trees was cored twice as a check. The radii of two of the trees were so great that their centers could not be reached by the increment borer. In the others, the core did not pass through the exact age center of the tree. The number of missing rings was estimated in two ways. The first was to reconstruct them on the bases of the curvature and distance between the rings shown. The second method was based upon the number of rings per inch as shown in the older end of the core; thus, if a core were seven inches long and had not reached the middle, and the radius was seven and a half inches, and there were

^{*}*Lebensraum*, space necessary for life.

ten lines per inch on the inner end of the core, one would add five rings. The two methods indicated results that were in fairly good agreement. Further, it was evident in every case that the core had not missed the age center very far, so the number of rings that had to be estimated in this manner was always comparatively small. Results are summarized in the following table.

	Core No. 1 ⁷ Tree 1	Core No. 2 Tree 2	Core No. 3 Tree 3	Core No. 4 Tree 3	Core No. 5 Tree 4
Total No. rings	102	72	102	107	53
Length of core (to center)	8.95 in.	5.70 in.	8.80 in.	7.90 in.	4.20 in.
No. rings per inch	11.2/in.	12.6/in.	11.65/in.	13.4/in.	13.0/in.
Circumference	54.5 in.	49.0 in.	67.0 in.	67.0 in.	39.0 in.
Radius	8.67 in.	7.93 in.	10.67 in.	10.67 in.	6.21 in.
No. rings to be added	indeterm.	1 or 2	4 or 6	6	4 or 6
Age of tree	102 + yrs.	73 yrs.	108 yrs.	113 yrs.	59 yrs.
Distance between tree and down- slope block in direction of movement	150 in.	172 in.	96 in.	96 in.	31 in.
Average rate of creep	1.53 in./yr.	2.35 in./yr.	.88 in./yr.	.85 in./yr.	.53 in./yr.

From the data and calculations presented in the table it can be seen that the average rate of creep varied from one half an inch to two and one half inches per year. The rate of creep of a block in this or any other rock city is dependent upon several variable factors, such as the size of the block, the mass of the block, the rainfall, the nature of the slippage surface and especially the inclination of the slope, which varied from 25° to 11° at Lovers' Retreat. It must be remembered that the rate of creep obtained is the maximum in every case and, although the rate may well have varied from place to place and from year to year, the lower figures are probably nearer the average.

⁷Locations shown on Figure 1.