EQUILIBRIUM VERSUS EVENTS IN BLIND VALLEY ENLARGEMENT

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ABSTRACT

Seventeen blind valleys of the Yarrangobilly karst are described with particular reference to shifting streamsink location and phases of downward incision. A series of measures based partly on ground traverses and partly on contoured maps is presented and discussed. Standard morphometry of the basins ending in the blind valleys is also presented. These truncated basins are shown to have normal morphometric relationships. Whether a stream sinks or not in the limestone appears generally to relate to the length of limestone to be crossed in relation to full stream or basin length, though basin relief ratio may intervene.

The hypothesis that there will be dynamic equilibrium between the dimensions of blind valleys and sinking stream catchments finds only limited support in the data. This is because underground stream capture represents an abnormal event in drainage basin development which is liable to upset equilibrium relationships and its timing may be adventitious in that development. With a larger population of blind valleys to be analysed, this factor of timing may become subordinate and a better predictive model of blind valley volume could be derived.

In recent decades, geometric relationships established between morphometric characteristics of river basins and between them and river behaviour have been interpreted as dynamic equilibria. The same theme has been carried into karst geomorphology, and the idea has developed that karst landforms evolve in a manner akin to the modelling of fluvial relief. Streamsinks and blind valleys have been investigated along these lines (Williams, 1966; White and White, 1979). Consistent with this work is the hypothesis that dynamic equilibrium will be achieved between the size of a blind valley and the energy of the sinking stream which has produced it. At Yarrangobilly Caves in New South Wales the incision which has taken place since certain streams went underground can be identified and this hypothesis can be tested here.

This karst is a meridional strike belt, about 9km by 1km, of Silurian limestone, chemically pure, mechanically strong and of low primary permeability, with a strong dip to the west. The limestone forms a strath terrace between a ridge of underlying volcanics to the east and one of overlying impermeable clastic sediments to the west (Figure 1). The Yarrangobilly River occupies a V-Valley or gorge, about 30m deep where it encounters the limestone and over 150m deep where it leaves it at the southern end. This lies

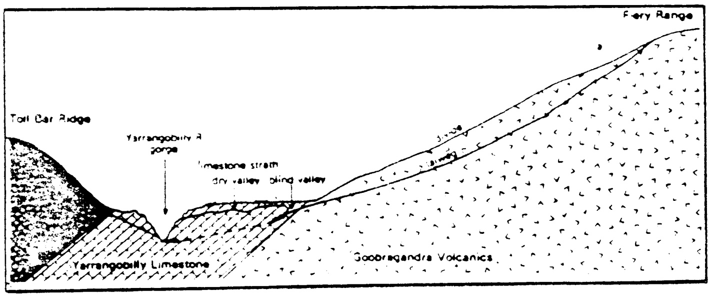

Figure 1: Schematic section showing the Yarrangobilly River valley, N.S.W. V.E. = 3X.

mainly along the western margin of the limestone with only a narrow strip of limestone on the west bank or none at all.

There are seventeen blind valleys in the sense that a perennial or intermittent stream channel ends against a threshold and goes underground. None is large but the range in size is considerably; some are simply dolines with a stream running into them. They are mainly found where streams run off the volcanics to the east onto the limestone strath. Only one is found to the west of the gorge where the limestone is narrow. The situation is more complex at the northern end of the strike belt where the Yarrangobilly River crosses the strike belt down dip and the outcrop is broken.

Estimates of the volumes of these blind valleys have been made from either contoured maps in a few larger cases or survey traverses and cross-sections for the majority. There may be errors as great as 20% in these estimates but a case has been made for regarding their use in the present context as valid (Jennings, Bao and Spate, 1980).

It is necessary to enquire whether the drainage basins truncated by underground capture have themselves maintained equilibria such as characterise normal fluvial systems. Long-term discharge data are not available so only morphometric relationships can be tested. Application of Strahler ordering gives the usual results from standard morphometry (Jennings, Bao and Spate, 1980). The regression of total stream lengths (L in km) against basin area (A in km^2) in these truncated catchments takes a form typical of normal systems.

$$L = 2.24\ A^{1.13} \qquad p = 0.001 \qquad r^2 = 0.95$$

The closed river basins from the Appalachians studied by White and White (1979) do not correspond completely in definition to the Yarrangobilly ones, some being composite in nature; nevertheless they yield a basically similar regression.

$$L = 2.29\ A^{0.85} \qquad r^2 = 0.88$$

Amongst other factors, stream erosion depends on discharge and velocity, long term measures of which are not available for the blind valley streams. Basin area has been selected as a surrogate for stream discharge; close relationships have been established elsewhere between that area on the one hand and mean annual flood and mean annual runoff on the other. Schumm's relief ratio is a convenient basis for comparison of gradients between catchments. Since withdrawal of material into caves at streamsinks will also affect blind valley size, underground hydraulic gradients were calculated on the basis of altitudes of the streamsinks and their connecting springs and the straightline distances between them.

Surveying of the blind valleys for this enquiry brought to the fore complexities, the existence of which was known but the significance not appreciated. One complexity is that the point of sinking has shifted in some cases and another is that terraces and breaks of slope reveal separate phases of incision which have succeeded one another in the formation of the blind valley. Figure 2 is a sketch map of a blind valley affected in both ways. Two blind valley volumes were calculated therefore:

1. present incision related to the present position of the streamsink and/or the last phase of incision;
2. total incision defined by the saddle beyond which there is an overall downward gradient in the abandoned dry valley continuing from the streamsink.

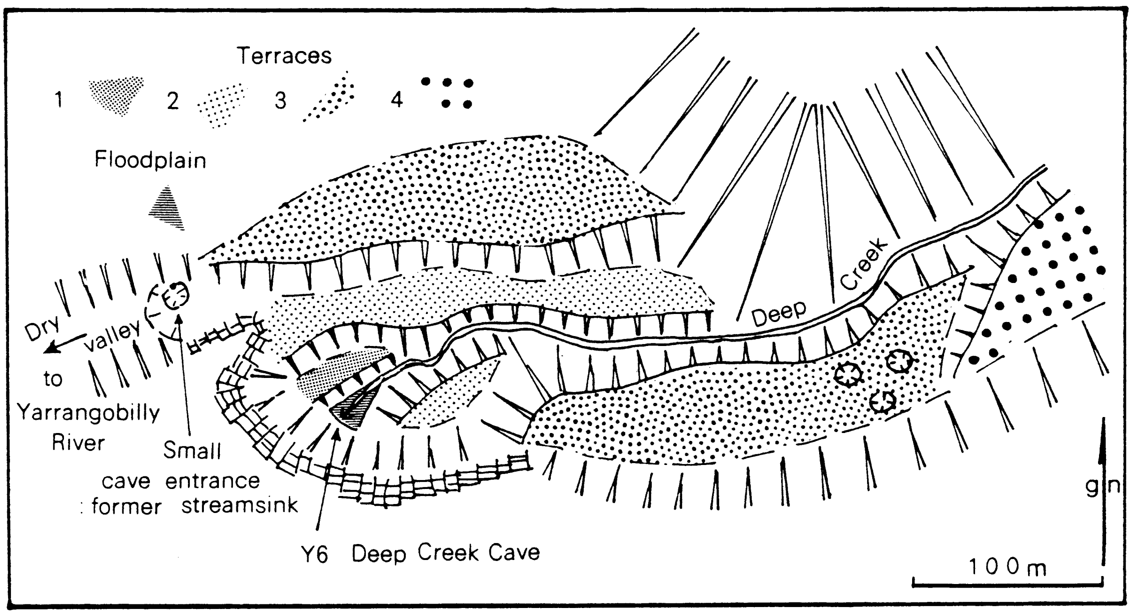

Figure 2: Shifting streamsink and phasing of incision, Deep Creek, Yarrangobilly.

Logarithmic plots of blind valley volumes for both present and total incision against both basin relief ratio and underground hydraulic gradient show a wide scatter in all cases with no prospect of significant regression. There is, however, no great range in these two gradients in this set of catchments and any effects they may have will be readily obscured by other factors.

There is a considerably greater range in basin area above streamsink. Even so when blind valley volume for present incision is plotted against it, again on a log–log basis (Figure 3a), the scatter remains as great and there is no significant relationship between the two.

The implication of these results is taken to be that the times when the different streams started to excavate these volumes of rock have varied so much as to prevent the dynamic factors controlling erosion from expressing themselves in the morphology in the manner hypothesised. Events have taken the upper hand and equilibrium not achieved.

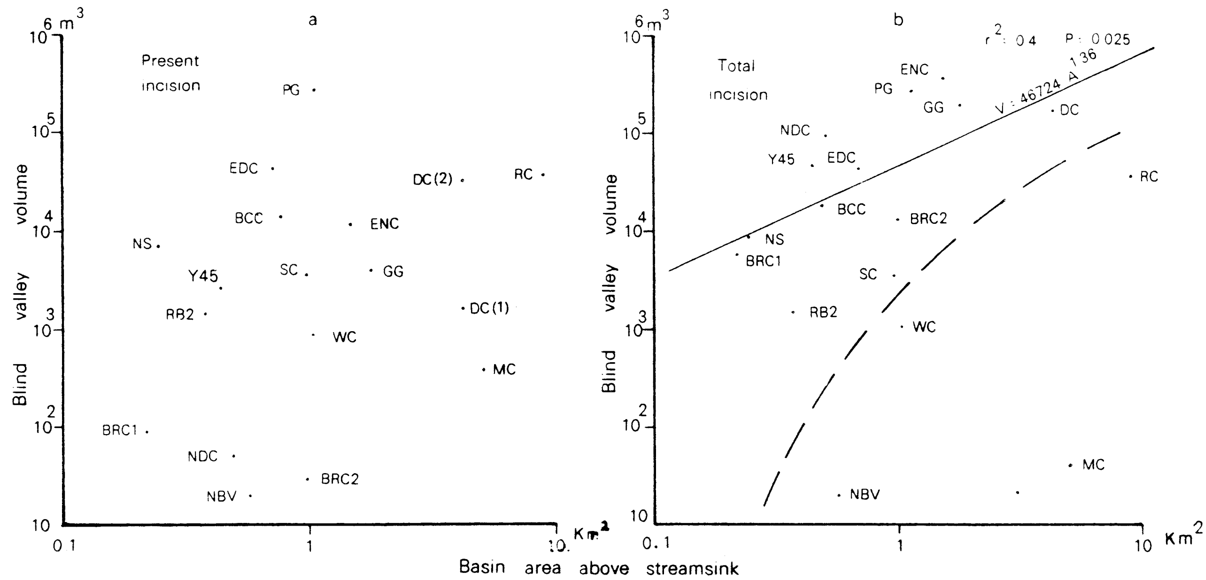

Figure 3: Scatter plots and regression of blind valley volume against basin area above streamsink, Deep Creek, Yarrangobilly.

However, the periods of time for the whole formation of the blind valleys may have varied less than the ages of the final events registered in the landforms. The more time there has been for the influence of the overall relief and geological structure to operate the more it could even out other effects. Figure 3b is a log-log plot of the total volume of the blind valleys against the stream basin area and it gives better indication of a linear relationship. Moreover, the four instances which depart most from this tendency are special cases which warrant exclusion from the set.

(a) Northernmost Blind Valley (NBV) is hardly more than tangential to the short northern boundary of the limestone, a disposition difference from that of the majority of the blind valleys. Moreover, there is a likelihood that this may be a semi-blind valley where surface flow follows round the margin of the limestone on occasion.

(b) Wombat Creek (WC) is also distinctively located structurally, with much of its headwater area being on limestone; its lower valley runs along the contact of the limestone with the overlying impervious clastics.

(c) Mill Creek (MC) has cut a gorge across the limestone and its streamsink close to the Yarrangobilly River has been triggered by a geologically recent rockfall, even though there is a little incision associated with its underground route through the bedrock.

(d) Rules Creek (RC) has also cut a gorge across the limestone. It has terrace remnants witnessing a longer, more complex history than Mill Creek's but its blind valley volume is small because of a recent cut through a former higher threshold.

If these four cases are excluded, the remaining set of 13 blind valleys have a common structural arrangement with non-karst rocks in the headwaters and limestone in the lower basin. For these a significant regression can be obtained

$$V = 46724\ A^{1.36} \qquad r^2 = 0.40 \qquad p = 0.025$$

where V = blind valley volume in m^3 and A = basin area above streamsink in km^2. Thus there is a tendency for a stream sinking underground here to produce a blind valley of a size matching its erosive power.

Nevertheless, this tendency is largely obscured by the variable timing of the underground captures. The streams have not had equal opportunities to achieve dynamic equilibrium since their drainage system was dislocated in this way. Details of geological structure are likely to have contributed to this but also the dynamic factors involved operate in contradictory fashion. Thus the bigger the stream is the more it will prevent or delay complete underground capture, although from the moment this happens the same factor will foster a larger blind valley. At Yarrangobilly this is evident when the stream is related to its opportunity for capture. Two ratios were calculated as measures of this for all streams which encounter the limestone:

$$(1) \qquad \frac{\text{length of present and/or former streamcourse over limestone}}{\text{whole length of streamcourse}}$$

$$(2) \qquad \frac{\text{straight line length across limestone}}{\text{basin length}}$$

The lower these ratios are the less the opportunity there is for a stream to form a blind valley.

The Yarrangobilly River itself, which crosses the limestone over three reaches, has low values; it only loses parts of its flow underground, most strikingly at the Natural Bridge, where however, high flows follow the meander bend bypassed by the baseflow.

Two tributaries with low ratios, Brownleys Back Creek and Traverse Creek, flow across their limestone reaches. The latter does so only in flood flow but it has not formed even a semi-blind valley. It was given its name by speleologists because it alone crosses the full width of the limestone strath on the surface.

Of the blind valleys, the lowest values are those of the Northernmost Blind Valley creek, Mill Creek and Rules Creek, thus helping to explain why these blind valleys are anomalous. The last two are the largest streams to have blind valleys and their size enabled them to evade underground capture till late and to cut gorges across the strath.

The factor of gradient, which failed to find expression in the analysis of the blind valley volumes, also operates contradictorily. Thus, although steep gradient is properly ex-

pected to enhance blind valley growth once capture occurs, it also promotes runoff and restrains engulfment of streams. Of six right bank tributaries in the Yarrangobilly gorge, only one has a blind valley. Of the other five, two have low limestone total course ratios which are unfavourable to engulfment. Of the other three which are not explicable on that count, two have high basin relief ratios, which explain their behaviour. At the other end of the scale, low gradients are also not conducive to underground capture and this factor contributes to the failure of the Yarrangobilly River to sink completely along its long course over the limestone; meander spur cutoffs offer the best opportunity here.
These several factors greatly vary the timing of captures so that only modest indications of dynamic equilibrium can be identified at Yarrangobilly. A capture represents an intervention in a fluvial system which is likely to derange morphometric relationships. Howard (1971) introduced capture simulation into computer modelling of surface river networks and improved morphometric prediction compared with the use of completely random walk models. Perhaps a larger population of blind valleys may provide a basis for more positive conclusions than Yarrangobilly does for the kind of study presented here.

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