CHAPTER 9

LANDSCAPE EVOLUTION IN THE ARMIDALE-URALLA REGION

9.1 BEGINNINGS

The landscape evolution of the Armidale-Uralla region began in the mid-Permian when rocks of the Sandon Association (Korsch, 1977) were deformed and welded onto the Australian craton (Korsch and Harrington, 1981). From this point continental landforms evolved. The early drainage that developed on the continental parts of New England resulted in deposition of erosion products in sedimentary basins such as the Clarence-Moreton Basin. At the end of the Permian period, while deposition in sedimentary basins was still taking place to the northeast of the Armidale-Uralla region, the granitic rocks of the New England Batholith were intruded. Parts of the New England Batholith such as Mount Duval, were probably diapirically emplaced close to the surface (Korsch, 1977, 1982a, 1982b). The localised doming of the land surface resulting from these diapiric intrusions in such areas as Mount Duval (Korsch, 1977, 1982a, 1982b), would have had the immediate effect of increasing erosion rates around the diapir. The deposition of the Dummy Creek Conglomerate in the rim synclines that formed as the Mount Duval diapir rose to near the surface, was a direct result of this increased capacity for erosion.

Sea floor spreading in the Tasman Sea, and the associated formation of a new east Australian continental margin 80-60 my ago, probably had little immediate effect on the landform evolution of the Armidale-Uralla region. However the accelerated erosion on the new continental margin has moved progressively further inland, as the gorges that developed at the new continental edge eroded their heads to the west. In New England the gorges are now located just east of the Armidale-Uralla region.

9.2 FORMATION OF THE EAST AUSTRALIAN HIGHLANDS

There is no generally accepted explanation for the development of the east Australian highlands of which the Armidale-Uralla region is a part, though there have been numerous attempts at explanation. I will critically review several recent attempts, with the aim of extracting information that will help explain the geomorphic history of the Armidale-Uralla region.

Wellman (1979a) plotted the relative amounts of river downcutting in the southeast Australian highlands against the time of downcutting, and concluded first, that the rate of downcutting has been constant for the last 45 my, and secondly, that assuming uplift was at a constant rate, it started 90 ± 30 my ago. These conclusions were based on five main assumptions.

1. That 'most major rivers can easily erode or alluviate their beds, so that these river beds quickly reach an equilibrium with the base level outside the highlands'.
2. That interfluves are little affected by these rapid adjustments to changing base level.
3. That as interfluves are little affected by changes in base level, river beds 'provide better estimates of highland relief than the erosion surfaces between the rivers'.
4. That 'the rate of river downcutting gives the rate of highland uplift, and the total amount of downcutting gives the total amount of uplift'.
5. 'That the uplift history is reasonably uniform throughout the highland'.

There are several problems with these assumptions. The assumption that most major rivers adjust quickly to changes in base level is dubious. The presence of gorges along the eastern scarp from Victoria to north Queensland indicates that most major coastal rivers are still adjusting to the changes in base level associated with the formation of the eastern highlands, and possibly even the much older change in base level that may have resulted from the opening of the Tasman Sea 80-60 my ago. Response to changes in base level does not take place simultaneously along the length of a river. The response is in the form of one or more knickpoints that are eroded progressively upstream (Leopold et al., 1964; Morisawa, 1968)

The assumption that interfluves are little affected during the adjustment of rivers to changes in base level, would be tenable if these adjustments were rapid. But adjustments can take a very long time to move upstream. As a result interfluves downstream can be almost completely removed by erosion while the landscape upstream of the knickpoint is still unaffected by the change in base level. The Macleay River below the eastern scarp, and its tributaries on the New England plateau (Figure 4) illustrate this, with gentle gradients on the plateau and steep gradients east of the scarp, decreasing towards the coast. As there can be substantial erosion of interfluves while rivers are adjusting to changes in base level, it is unlikely that river beds really do 'provide better estimates of highland relief than the erosion surfaces between the rivers' (Wellman, 1979a).

The assumption that the rate of downcutting is equal to the rate of uplift has little relevance in real landscapes where downcutting in response to a lowering of base level does not take place simultaneously along the length of the river. For example a diachronous landscape has developed in eastern Australia as the major coastal rivers have adjusted to changes in base level. The relative relief on the coastal plain, and the gradient of the coastal rivers, increases to the west. Once the scarp is neared, the amount of stream incision decreases until at the tops of the gorges stream incision is negligible. As a result, attempts to equate total river downcutting with total uplift are futile, as downcutting is variable along the length of rivers.

The conclusions of Wellman (1979a) have been criticised by Crohn (1979), who argued that in the southeast Australian highlands Cainozoic block faulting was an important contributor to the total amount of uplift. The existence of block faults in the southeast highlands had been postulated by Crohn (1949) and Browne _et al._ (1944), on the physiographic evidence of straight-line river segments, concordant summits, and inferred examples of river capture. While there may have been faulting in the southeast highlands, it cannot be confirmed on physiographic evidence alone. Even if there was faulting, Wellman (1979b), claimed that 'there is no clear evidence to restrict the faulting to the late Cainozoic', in which case faulting could therefore belong to a quite different tectonic phase than the Cainozoic uplift suggested by Wellman (1979a).

Bishop and Young (1980) have also criticised the conclusions of Wellman (1979a). Bishop and Young (1980) argued that the rate of highland uplift is not given by the rate of river downcutting. They presented data for the Lachlan River indicating that while the gradient of the modern Lachlan River in the Gunning and Crookwell region is 0.001 measured along the channel, the gradient of the basalt-filled palaeochannel in the same area is 0.003. The calculated difference in gradient is substantiated by the much coarser bedload in the palaeochannel (Bishop and Young, 1980). The problems discussed above suggest that Wellman's (1979a) conclusions should be viewed with caution.

Another recent explanation of the formation of the Main Divide, considered the eastern highlands formed as a result of updoming associated with the separation of the Lord Howe Rise from continental Australia (Herbert, 1980). Following continental breakup 'thermal contraction would have caused progressive subsidence of the continental margin involving block faulting' (Herbert, 1980). Throughout the Tertiary and probably to the present, 'a dividing range has been pushed gradually and spasmodically westwards by progressive collapse of more easterly blocks' (Herbert, 1980). Herbert claimed that this migration of the Main Divide to the west has resulted in 'complex, largescale stream capture'. Field evidence in the Armidale-Uralla region does not substantiate these claims, and in fact suggests a close relationship between pre-basalt and modern streams, and between the pre-basalt and modern Main Divide. This field evidence and its significance in interpreting landscape history is considered in this chapter.

The Main Divide and eastern scarp are shown diagrammatically by Herbert (1980) as being identical, and as having formed by block faulting. The present eastern coastline is also shown as the steep edge of a fault block. None of these interpretations are correct for New England. In reality the eastern scarp is up to 80 km east of the Main Divide. Further, in New England the modern eastern scarp is an erosional feature, not a result of faulting. There is no evidence of significant faulting along the scarp, and the convoluted nature of the scarp is visibly related to drainage development and the progressive backwearing of gorges. Finally, the present coastline does not follow any known fault (1:250,000 Dorrigo-Coffs Harbour Geological Sheet). Its embayments and headlands are probably valleys and interfluves that were inundated by Recent marine transgressions (Bird, 1968).

In contrast to Herbert (1980), Bishop (1982) has argued on the basis of existing geological evidence, that the drainage in eastern New South Wales has been stable for at least the last 30 my, with the Tertiary basalt extrusions following generally the same direction as present streams. As Bishop (1982) pointed out, many of the river features in New South Wales that supposedly result from river capture and drainage diversion (such as boathook bends and 'crossed fork' tributaries), have been interpreted without regard for the geology and structure of the site.

Similarly, Young and McDougall (1982) have suggested that the eastern highlands had been uplifted to their present height by at least the early Tertiary. This conclusion was based on the occurrence of mid-Oligocene basalts on the coastal lowlands of southern New South Wales. In places these basalts are interbedded with fluvial sediments,indicating that the lowlands landscape had a well developed drainage system at the time of the basalt extrusions. As there is no evidence of significant faulting or warping between the highlands and lowlands, Young and McDougall (1982) argued that the difference in elevation between the two (approximately 350 m), due to erosion rather than tectonism.

M.C. Brown (1983) has claimed Young and McDougall (1982) were not justified in ruling out the possibility of tilting and warping before and after the basalt extrusions. He quoted Herbert's (1980) hypothesis (discussed above) is support of this claim. In reply, Young and McDougall (1983) noted that the low relief of the sub-basalt surface makes the possibility of post-basaltic warping unlikely. They also argued that the pre-basalt warping in the area is ancient, and is thought to have been contemporaneous with sedimentation in the southern parts of the Sydney Basin.

The suggestion by M.C. Brown (1983) that the present landscape in the southern highlands and lowlands of New South Wales can be explained by repeated tilting and warping, is very complicated. Young and McDougall's (1982, 1983) explanation, leading to the conclusion that the highlands were uplifted by at least the early Tertiary, is much simpler, and on the present evidence is preferable for this reason, and for its consistency with the basalt field relationships in the coastal lowlands.

Grimes (1980) postulated three tectonic phases of uplift and erosion for Queensland during the Cainozoic. He suggested these tectonic episodes took place during the late Cretaceous or Paleocene to Oligicene; the Oligocene to late Miocene; and the Pliocene to Quaternary. Grimes (1980) thought that each phase upwarped regions to become areas of erosion, and downwarped neighbouring areas which then became regions of deposition. Jones and Veevers (1982) have suggested a complicated tectonic origin for the present east Australian highlands and Main Divide, a view that has some similarity to that of Grimes (1980). Jones and Veevers (1982) have argued that there were three or more 'major episodes of uplift followed by settling, with concurrent...volcanism', in the southeast highlands of Australia, based on evidence that periods of volcanism coincided with periods of deposition in basins flanking the highlands. From this Jones and Veevers (1982) drew the conclusion that 'periods of more intense volcanism correspond with uplift of the highlands and concomitant subsidence of the flanking basins', and that during periods of less intense volcanism, the highlands settled and the flanking basins rose.

This theory has the eastern highlands and adjacent basins operating like giant out-of-phase pistons, one rising while the other subsides, then falling while the other rises. However the close relationships between pre-basalt and modern streams, and between the pre-basalt and modern Main Divide in the Armidale-Uralla region do not support Jones and Veevers' (1982) theory. Nor do the consistently low rates of erosion in the Armidale-Uralla region that are suggested in this thesis (Section 9.7). Repeated phases of uplift and subsidence during and since the Tertiary basalt extrusions could be expected to have caused major drainage modification, with greatly accelerated rates of erosion during phases of uplift.

Jones and Veevers' (1982) theory of alternating periods of uplift and subsidence in the eastern highlands and flanking basins was an attempt to explain what they called the 'sedimentation signature' of the Murray Basin, that is, the depositional history of the region. More recently it has been argued (C.M. Brown, 1983) that the stratigraphic relationships of sedimentation in the Murray Basin can be explained equally well and perhaps better by the eustatic sea-level model. The stratigraphic relationships in the Murray Basin have been reinterpreted by Brown, who argued that changes in sediment deposition and preservation, and periods of little or no deposition correlate well with changes in base level due to eustatic variations. This explanation is simpler than Jones and Veevers' (1982) theory of regions alternately rising and subsiding. Brown's (1983) explanation has the further advantage that it is relatable to known global processes, rather than being a special theory to explain landform evolution in just one region, as is the case with Jones and Veevers' theory.

In reply to C.M. Brown (1983), Jones and Veevers (1983b) claimed his view was an 'unjustifiable oversimplification' of the sedimentary history of the Murray Basin, and of the relationship of this history to basaltic volcanism in the highlands. A full evaluation of Jones and Veevers' (1983b) hypothesis, as outlined above, must probably await more detailed information about the sediment record on the continental shelf offshore from the mouth of the Murray River. The stratigraphy of these sediments could then be compared with the volcanic record, and with the sediment record within the basin itself, to assess the viability of Jones and Veevers' (1983b) hypothesis.

Recent studies in the northern Monaro region of the southern highlands of New South Wales (Taylor, 1983; Taylor _et al._, 1983) have supplied more information about the uplift history of the southeast Australian highlands. The land uplifted to form the present highlands was a gently undulating paleoplain that was in existence by the late Cretaceous to Palaeocene (the Monaro Surface). This means the uplift of the modern highlands cannot have started before about the Palaeocene. Taylor (1983) suggested uplift started about 59 my ago. Deep valleys cut in the developing highlands were filled with basalt, and modern valleys in the Monaro region closely parallel this pre-basalt drainage, indicating a continuity in drainage direction at least back to pre-basalt times prior to the Eocene (Taylor _et al._, 1983). These modern valleys have cut through the basalt to the same level as the pre-basalt valleys, and Taylor (1983) thought this indicated that there has been no uplift since the cessation of basaltic volcanism in the early Oligocene. The validity of this claim cannot be assessed. The modern streams may be at the same level as the pre-basalt streams because they are stranded on resistant rocks, not because thay have attained the same base level as the pre-basalt streams. It is also possible that the modern streams are still downcutting, and their present position near the level of the pre-basalt streams is fortuitous.

9.3 EOCENE DEPOSITION

The landscape of the Armidale-Uralla region is predominantly erosional, but two exceptions to this are landforms on the Armidale Beds and on the Oligocene-Miocene basalt flows. Several exposures of the Eocene fluvial sediments of the Armidale Beds, such as in the road cutting in Madgwick Drive at Armidale GR 705256 (Plate 53), exhibit cross-bedding. This indicates deposition in a variable stream environment, probably with braids and cutoffs.

Slade (1966) studied the variety and structure of the Eocene sediments and associated fossil flora throughout New England, and concluded that the Eocene was 'a period of deposition of sediment by streams of changing activity in braids, cutoffs or lakes'. The rounding of the pebbles in the conglomerates of the Armidale Formation indicates that the pebbles were transported either long distances, or in a high-energy fluvial environment, before being deposited. Their deposition took place in areas of lower fluvial energy in the absence of downcutting. This was followed by a period of downcutting, possibly at a low rate, that has left the Eocene gravels stranded.

The gravel lithofaces containing sand and silt, and the cross-bedding and gravel imbrication exhibited in the Madgwick Drive cutting, indicate the presence of longitudal or transverse bars and channel lag deposits (Miall, 1977). In general, stream braiding such as that shown by the sediments in the Madgwick Drive cutting, is the result of sediment sorting as a stream drops the load it is incompetent to carry. This dropped load initiates the development of mid-channel bars (Miall, 1977). Unfortunately the probability that one or more Eocene streams in the Armidale-Uralla region were braided, does not enable conclusions to be drawn about the environment at the time the streams were active. Miall (1977) reviewed many studies of braided streams and found these streams were not characterised by any specific climate or tectonic setting.

9.4 TERTIARY BASALT EXTRUSIONS

I have already concluded that there is an absence of volcanic vents in the Armidale-Uralla region, and the Tertiary basalts in this region have possibly come from vents in the Glen Innes area. If these conclusions are correct, the flows in the Armidale-Uralla region belong to regional rather than localised volcanic phases. Although the Tertiary lava flows may have travelled as far as 60-100 km from the Glen Innes area, by the time they reached the Armidale-Uralla region they were mostly well contained in existing valleys and did not completely inundate the landscape. This can be seen from the present relationship between basalt remnants and the fluvial sands and gravels they consistently overlie (Section 6.3.3). Saumarez and Dumaresq Creeks formed as lateral streams following the basalt extrusions (Section 9.5), and are therefore closely related to the the pre-basalt drainage system. If the basalt flows had inundated the landscape a completely new post-basalt drainage system would have developed showing no relationship to pre-basalt drainage lines

9.5 POST-BASALT LANDFORM EVOLUTION

The evolution of the Armidale-Uralla landscape since the first extrusions of Tertiary basalt can be explained in at least two different ways. The explanations are related, but differ in their interpretation of the origin of the silcrete and other cemented and uncemented sediments now prominent in the Armidale-Uralla region. Common to both explanations is the assumption that prior to the dated basalt extrusions in the Armidale-Uralla region, basalts from an earlier extrusive phase, here called the Saumarez-Arding basalts, filled a north-trending river valley that ran through the Armidale-Uralla region, taking in what is now the Saumarez-Arding area (Figures 19, 20). The evidence for these older basalts is that well-weathered basalt underlying ferricrete in the Saumarez-Arding area is flanked to the east and west by fluvial sediments that in places lie on the ferricrete. These sediments are in turn overlain by higher-level, relief-inverted basalts, such as the dated Armidale Airport basalts. The trend of the valley filled by the old Saumarez-Arding basalts is unclear, and its stream is therefore shown flowing north (Figure 20), in the same direction as the lateral streams that succeeded it.

The ages of dated basalts (57.5, 48.2, 45.1 my) in the Walcha area 50-80 km south of the Armidale-Uralla region, are consistent with them having been a source for the Saumarez-Arding basalts, but this suggestion is unproven. These early basalt flows filled the existing valley and diverted the stream to form lateral streams flowing in a northerly direction. Remnants of basalt on modern interfluves between Uralla and Mount Duval mark the dendritic drainage pattern of these lateral streams (Map 1; Figure 18), which were later themselves filled with basalt. The rise in the sub-basalt topography to the north of the Armidale-Uralla region (Figure 17), discussed in detail in Chapter 5, suggests that these lateral streams flowed out of the region somewhere north of the Saumarez-Arding area.

In this first explanation, the lateral streams incised and formed minor floodplains either side of the Saumarez-Arding basalt, and may have in places meandered onto the weathering flow, depositing alluvial sediments (Figure 21). There are remnants of these sediments at Armidale GR 593202, 569188, 566172. During this time ferricrete profiles started forming in the soils that were developing on the weathering basalt in the Saumarez-Arding area (Map 1; Figure 2). After these lateral streams had cut valleys, a series of lava flows between 33 and 22 my filled the lateral valleys and in places spilled onto the older Saumarez-Arding basalt. Some of the fluvial sediments and ferricrete on the basalt margins were covered by these later flows (Figure 22). The younger, dated lava flows diverted the existing drainage to form the present Dumaresq and Saumarez Creeks. Continuing erosion has resulted in another phase of relief inversion, and the lateral streams that once flanked the Saumarez-Arding basalt are now partly preserved under basalt remnants that

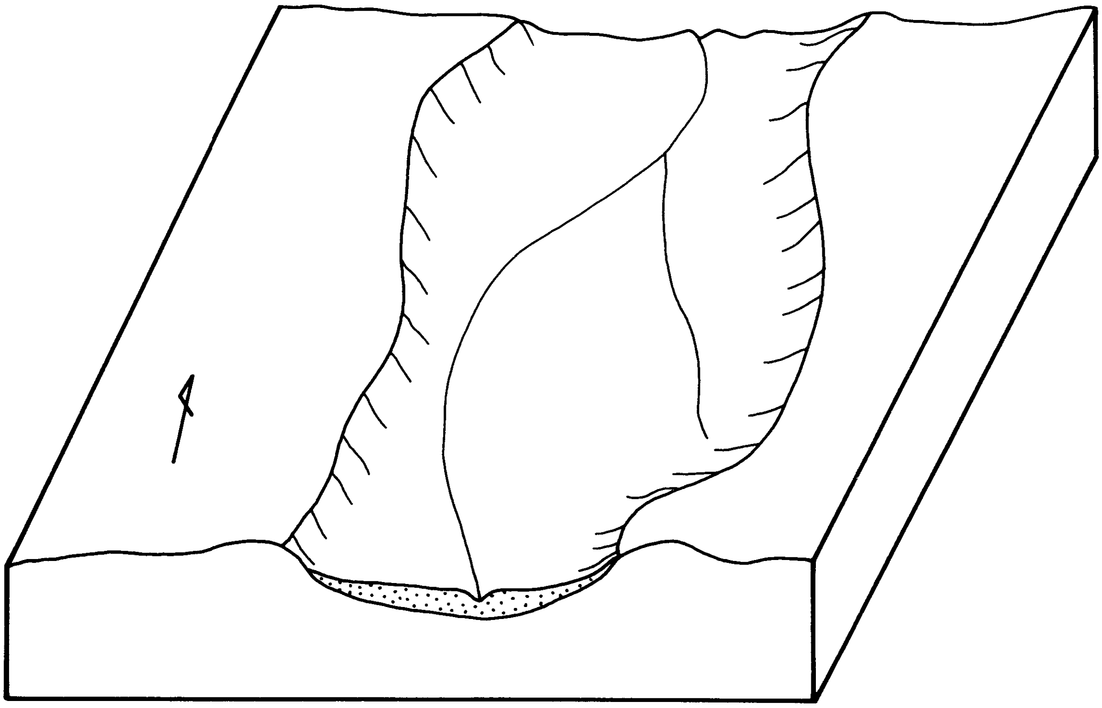

Figure 19. The central part of the Armidale-Uralla region as it may have looked before the extrusion of the Saumarez-Arding basalt. In the absence of further evidence the pre-basalt stream is shown flowing in the same direction as the lateral streams that succeeded it. The valley profile is schematic.

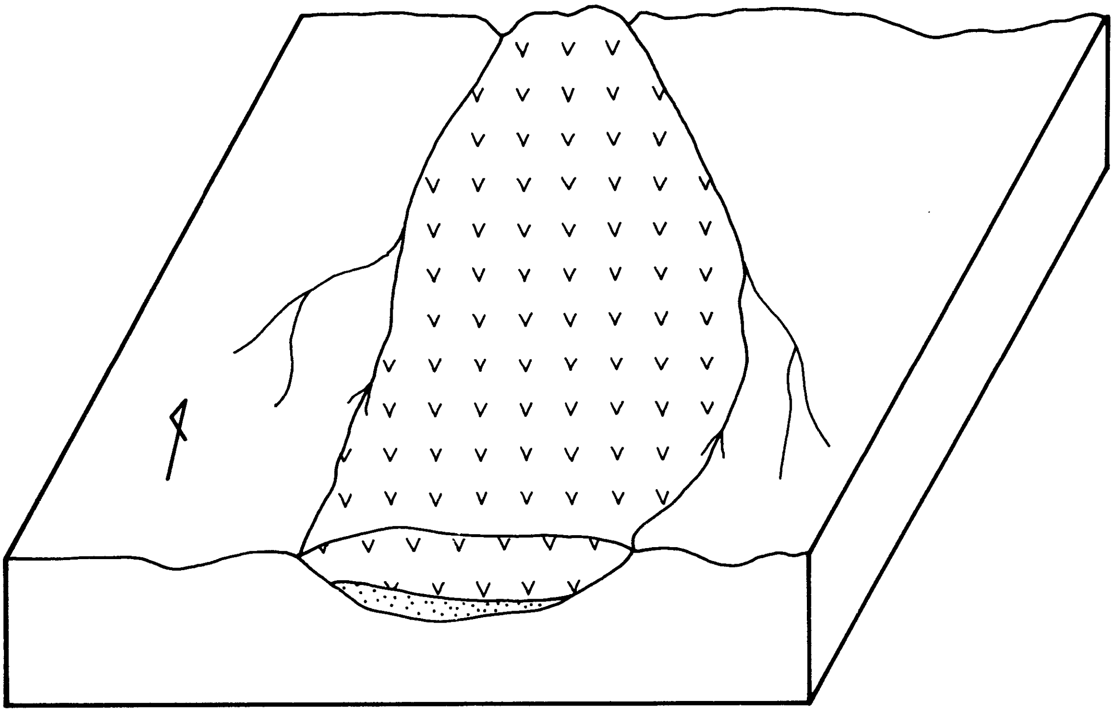

Figure 20. The valley is filled by a lava flow that may have come from the Walcha area 60-80 km south of Armidale, and north-flowing lateral streams develop. This lava flow may have preceded the dated flows in the Armidale-Uralla region.

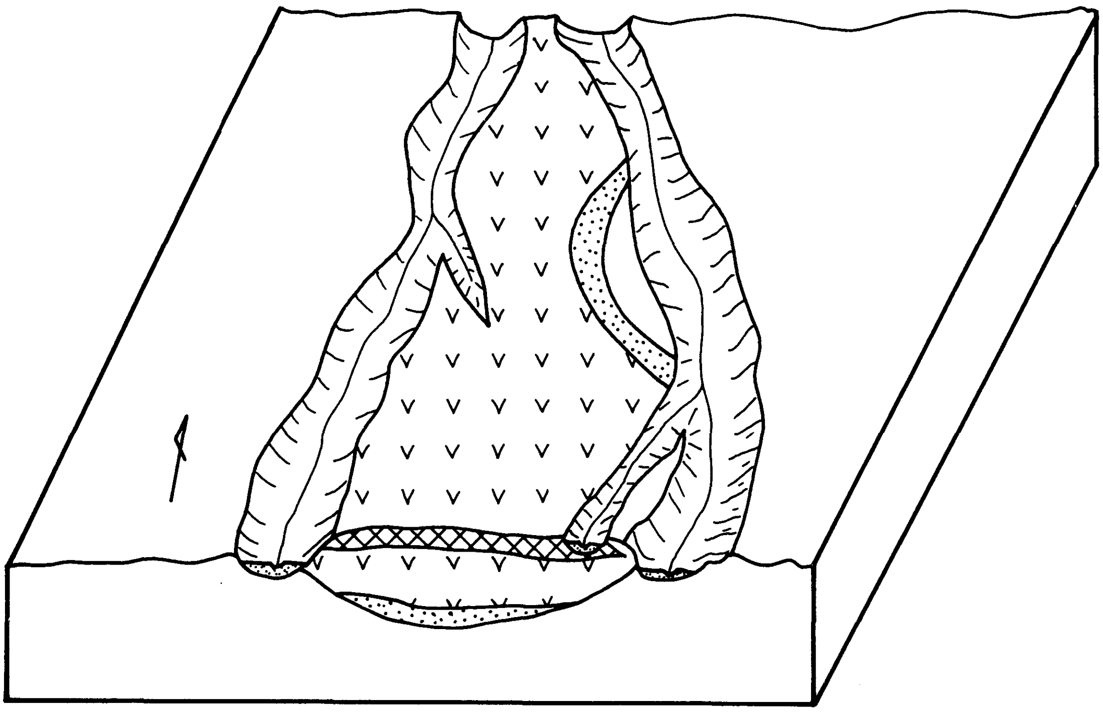

Figure 21. *The lateral streams incise valleys, and meander curves on the basalt leave deposits of fluvial sediments. Ferricrete begins forming on the basaltic soil profile that developed in the Saumarez-Arding area.*

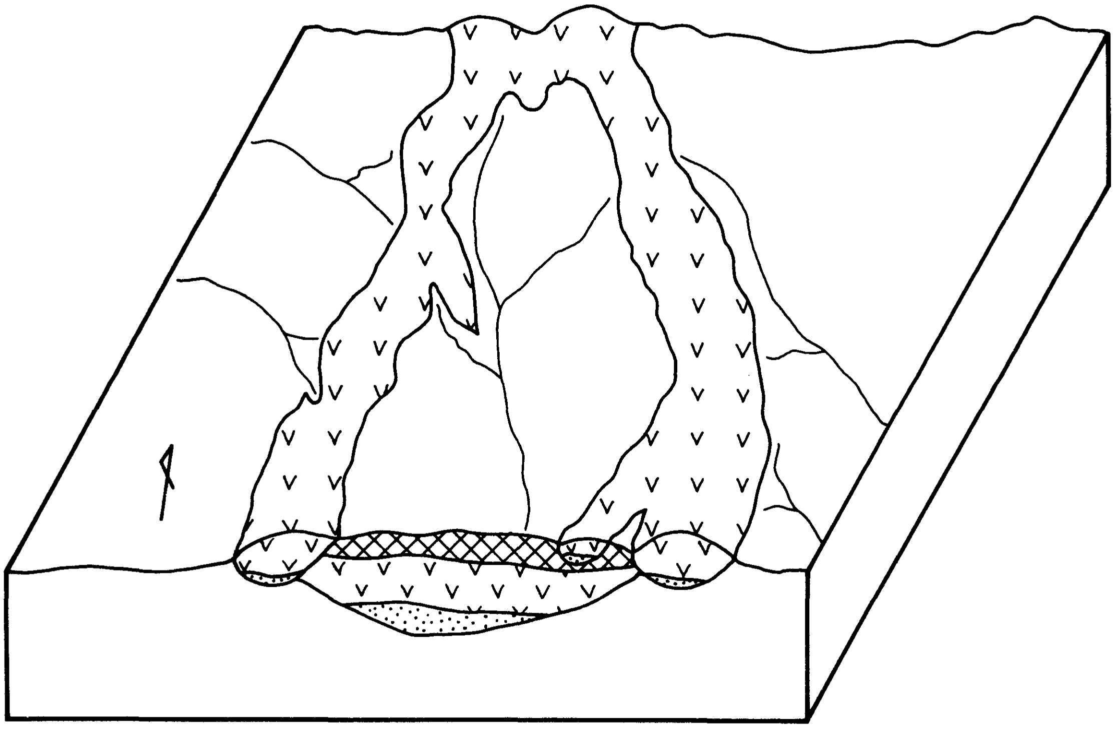

Figure 22. *The lateral valleys are flooded by lava flows that possibly emanated from the Glen Innes region 80-100 km north of Armidale. These flows, extruded between at least 33 and 22 my, may have been thicker in the north of the Armidale-Uralla region, and thinner further south where they backed up into the low-gradient valleys. They may have caused drainage reversal in this area*

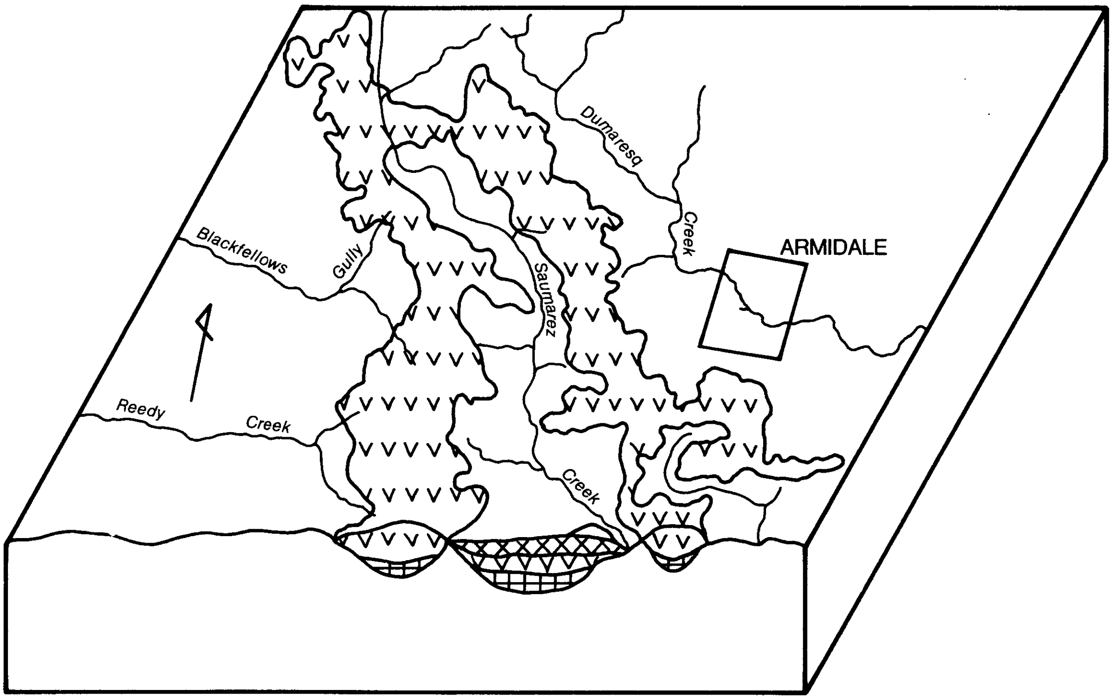

Figure 23. *The present landscape in the Armidale-Uralla region, with deep leads underlying basalts that may have been extruded during two distinct periods of extrusion. The younger, dated basalts in the west of the Armidale-Uralla region form the modern Main Divide. In the east of the region the younger basalts form the drainage divide between Saumarez and Dumaresq Creeks. The older Saumarez-Arding basalts underlie the ferricrete in the Saumarez-Arding ferricrete area.*

form the higher parts of the present Armidale landscape (Figure 23).

In this sequence of events the silcrete now present in the Saumarez-Arding area was formed by silicification of sediments derived from the north- and west-trending lateral streams that developed to the east and west of the Saumarez-Arding basalt. The difficulty with this explanation of Tertiary landscape evolution in the Armidale-Uralla region is that there are deposits of silica-cemented sediments up to 30 m above the present level of Saumarez Creek and its tributaries in the Saumarez-Arding area, at Armidale sheet GR 602182 and 625148. These deposits are up to 5 m thick, and are unlikely to have been derived from a thin floodplain veneer of sediments deposited by a lateral stream.Field inspection of deposits from holes bored for power poles revealed that silcrete in this area overlies the ferricrete veneered Saumarez-Arding basalt, and in the south, Sandon Beds exposed by Lambing Gully. They are themselves partly overlain by basalt, which is in places (such as at Armidale sheet GR 613189) contiguous with the dated basalts at Armidale Airport.

A sequence of events by which these sediments could come to be silicified and perched above the surrounding drainage is suggested below. This second explanation of the Tertiary landscape evolution of the Armidale-Uralla region begins like the first, with basalts older than those so far dated, filling a north trending valley in the Armidale-Uralla region. This caused diversion of the pre-basalt river to form lateral streams flowing in a northerly then westerly direction. At this point the explanations diverge.

In this second possible sequence of events, an old north trending valley running through the centre of the Armidale-Uralla region, was flanked by terraces of sand and gravel. These terraces were covered by the lava flows that filled the original Saumarez-Arding valley (Figure 24). The drainage of the original valley was diverted to form lateral streams flowing north then west, and as the lateral streams incised, the Saumarez-Arding basalt became relief-inverted. During this time the sub-basalt river terrace sediments were silicified, and ferricrete development may have begun on the soils of the basalt flow (Figure 25).

In the next phase of landscape development a series of lava flows between 33 and 22 my filled the lateral stream valleys and diverted both streams east from the lateral valleys to form what is now Saumarez Creek (Figure 26). The basalt in the western lateral valley became the Main Divide in the Armidale-Uralla region. The modern low relative relief of the eastern side of the Main Divide has resulted from the lack of stream erosion in that area, the incipient lateral stream having moved to the eastern side of the Saumarez-Arding basalt. The lateral stream on the eastern side of the more recent flow has incised to form the modern Martins Gully (Figure 27), a tributary of Dumaresq Creek. This eastern valley-fill basalt has been relief-inverted and now forms the drainage divide between Saumarez and Dumaresq Creeks (Figures 27, 28).

This second explanation is more satisfactory than the first, as it enables adequate explanation of the substantial deposits of silcrete present today on mid-slopes and upper slopes in the Armidale-Uralla region. Despite this it is quite probable that some of the thinner floodplain sequences of both unconsolidated and silicified fluvial sediments may have been deposited and preserved by the sequence of events suggested in the first explanation, as the two explanation are partly compatible. The preceding explanations and accompanying Figures show the close field relationship between basalt residuals, silicified and unsilicified sediments, pre-basalt drainage lines and present streams.

There are two problems in reconciling this second explanation with the reconstructed sub-basalt landscape (Figure 17), and with the suggested positions of pre-basalt streams and drainage divides (Figure 18). First, it is necessary to try to explain why the basalts didn't flow to the west, right out of the Armidale-Uralla region, through the broad east-west trending valley shown in Figure 17. Secondly, I have argued that the basalts were mainly valley-fills; yet their present occurrence on the Main Divide is very close to

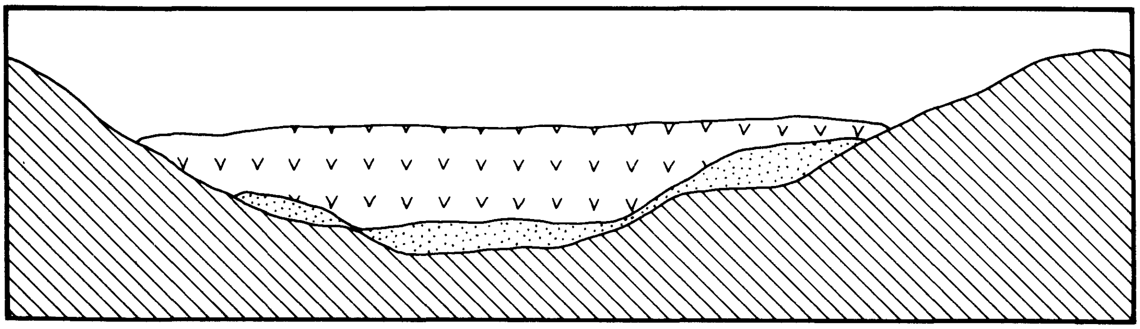

Figure 24. *Basalt fills an old north-trending valley and its terraces in the central area of the Armidale-Uralla region, to form the Saumarez-Arding basalt. These flows may have come from the Walcha area 60-80 km south of Armidale. Silicification of the fluvial sediments begins.*

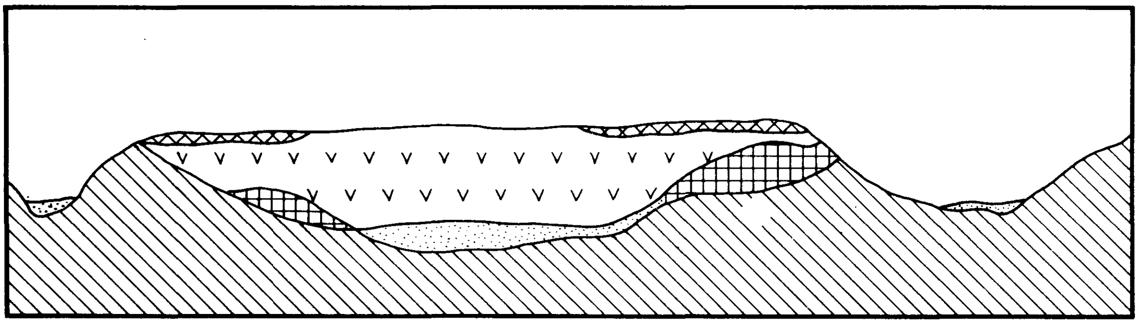

Figure 25. *Twin lateral streams develop, the Saumarez-Arding basalt becomes relief inverted, and the river terrace sediments beneath the basalts continue to silicify. Ferricrete forms on the soil profile that developed on the Saumarez-Arding basalt.*

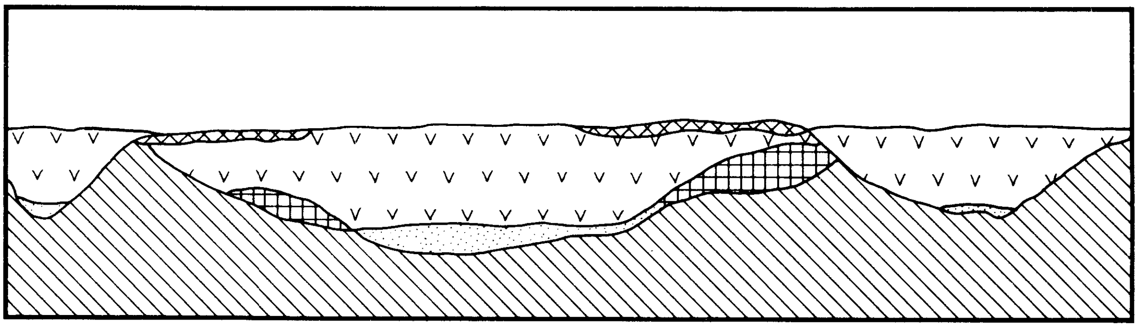

Figure 26. Basalt flows between at least 33 and 22 my fill the lateral stream valleys east and west of the Saumarez-Arding basalt, covering the fluvial sediments in these valleys. In places these younger flows lapped onto the Saumarez-Arding basalt.

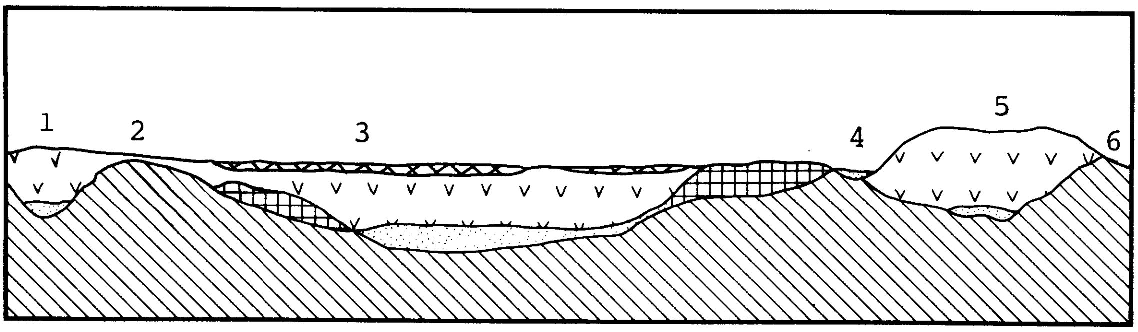

Figure 27. The lateral streams east and west of the Saumarez-Arding basalt are diverted to the east by the younger basalt extrusions, to form what is now Saumarez Creek. These dated valley fill basalts were relief inverted to form the modern Main Divide in the west, and the drainage divide between Saumarez and Dumaresq Creeks in the east. Continuing erosion in the Armidale-Uralla region has re-exposed some of the now-silicified original valley terrace sediments that were buried by the Saumarez-Arding basalt. The contacts shown between younger and older basalts are approximate. Numbered locations in Figure are: 1-Main Divide; 2-pre-basalt divide; 3-Saumarez-Arding area; 4-Saumarez Creek; 5-Armidale Airport; 6-Martins Gully.

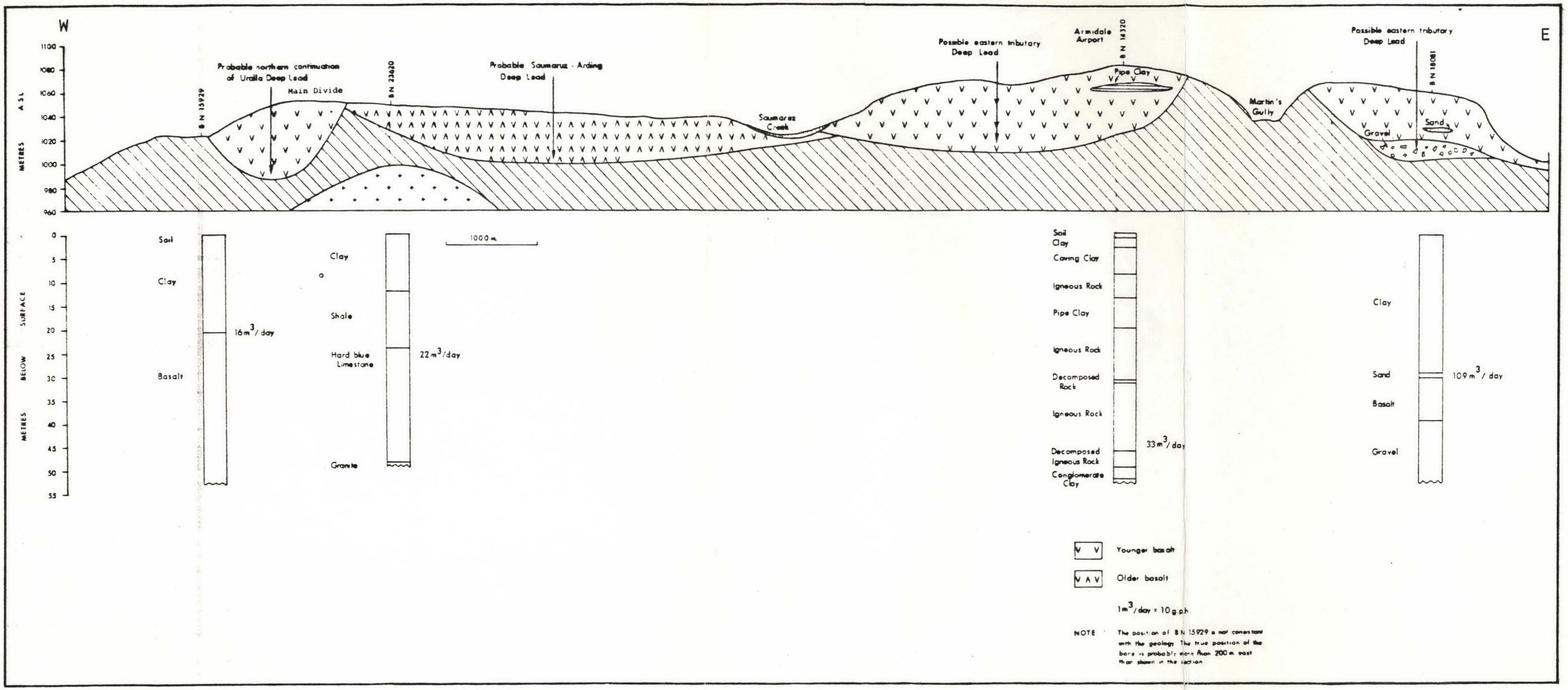

Figure 28. *Cross-section 1. The location is shown in Map 1. The Saumarez-Arding ferricrete area and the Saumarez-Arding basalt are shown between the Main Divide and Saumarez Creek. The sub-basalt gravels at the eastern end of the cross-section are probably river terrace sediments. No limestone has been reliably recorded in the Armidale-Uralla region, and the 'hard blue limestone' recorded in bore no. 23620 has been interpreted as belonging to the Sandon Beds. The presence of younger and older basalts shown in this Figure and in Figures 29-31 is inferred from the drainage and landscape reconstruction postulated in Figures 24-27.*

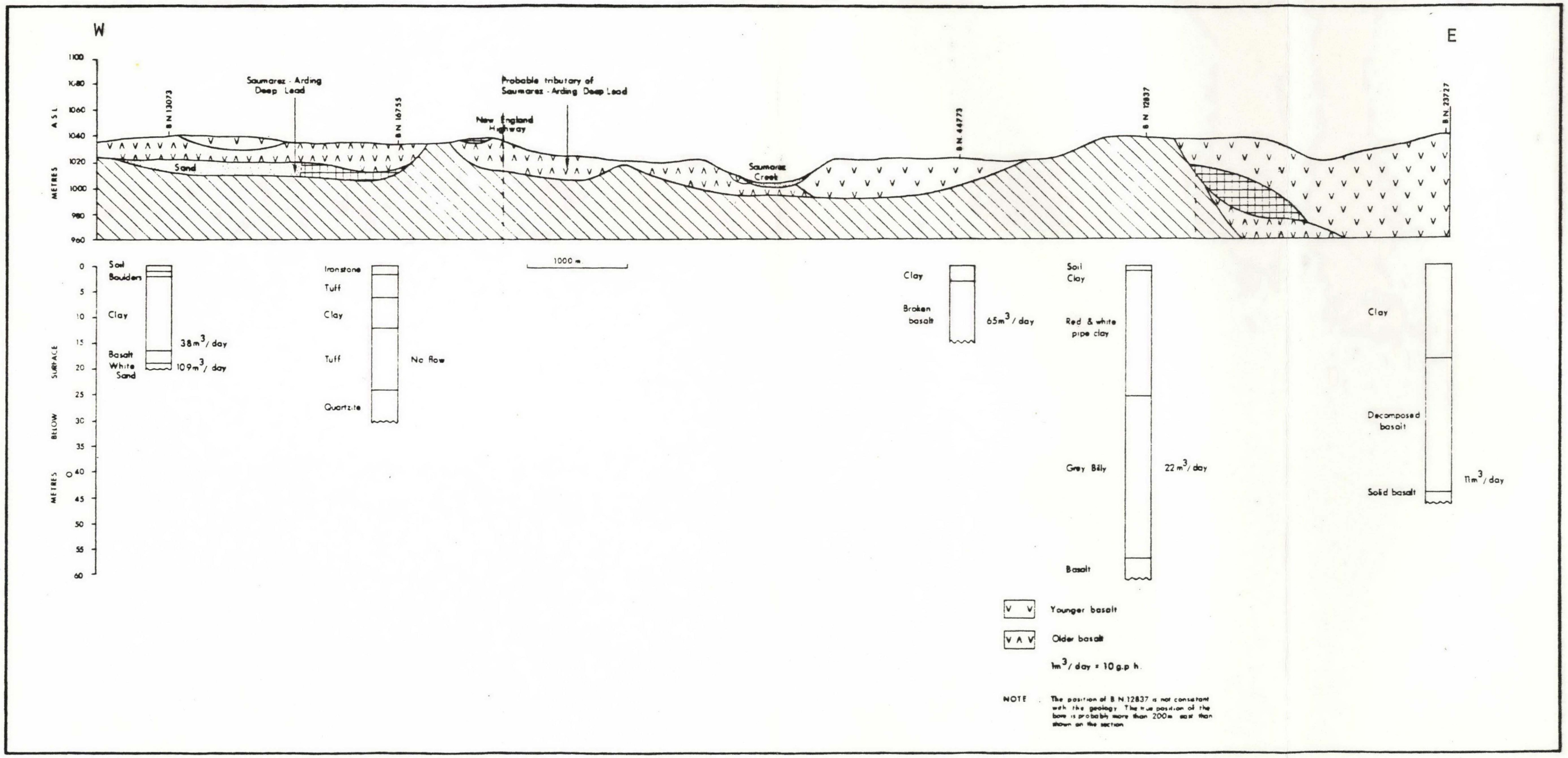

Figure 29. *Cross-section 2. The location is shown in Map 1. This cross-section verifies the existence of the Saumarez-Arding deep lead, and shows the variable silicification that is common in deep lead sediments in the Armidale-Uralla region. The contacts shown between younger and older basalts are approximate.*