Late Glacial and Holocene palaeoclimatology of the Drakensberg of the Eastern Cape, South Africa

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Abstract

Eight climatic events during the Holocene are evidenced in the East Cape Drakensberg by fluvial, archaeological and palynological deposits. Flood plain deposition under relatively moist conditions occurred in the Early Holocene, before ca. 7000 BP. Semi-arid conditions with limited fluvial activity dominated the Mid Holocene until ca. 3200 BP. Alternating flood plain erosion and deposition occurred in the Late Holocene. Four climatic events, for which there is palynological and limited archaeological evidence, have been identified in the Late Glacial.

1. Introduction

Unconsolidated sediments, deposited by fluvial and other processes, exist in valleys of rivers that drain northwards down the dip slope of the escarpment of the Drakensberg to enter the Kraai River in the vicinity of Barkly East, South Africa (Fig. 1). The unconsolidated sediments form flood plain, river terrace and other features on valley floors (Fig. 2 and Fig. 3). In rare cases they contain palaeosols that are suitable for numerical (radiocarbon) dating. Numerical dates have also been obtained in this and/or adjacent areas from archaeological investigations (Opperman (1987) and Opperman (1996); Opperman and Heydenrych, 1990; Tusenius, 1989); palynological studies (Coetzee,1967; Rosen et al.,1999); investigations of valley floor sediments that were interpreted as being of periglacial origin (Lewis and Dardis, 1985; Lewis and Hanvey (1991) and Lewis and Hanvey (1993)); and from examination of deposits in a presently active flood plain (Dollar, in preparation, vide Lewis, 2002).

The study focuses on second-, third- and fourth-order streams, which appear to have been sensitive to, and to reflect, environmental changes on both hill slopes and valley floors. Sediment production on hill slopes in the region during the Late Quaternary has been examined by Lewis and Dardis (1985), Hanvey et al., (1986), Hanvey and Lewis (1990) and Hanvey and Lewis (1991), Lewis and Hanvey (1988); Lewis and Hanvey (1991) and Lewis and Hanvey (1993), Dollar (1992), Lewis (1994a); Lewis (1994b) and Lewis (1999), Dollar and Rowntree (1995), Rowntree and Dollar (1996), Lewis and Illgner (2000) and Lewis and Illgner (2001), Kück and Lewis (2002) and this paper is a sequel to those studies. The information presented in this paper is critical for an understanding of Later Stone Age habitation and for environmental management in this sensitive climatic region.

The main objectives of this paper are to:

(i) describe the fluvial deposits,
(ii) establish the sequence of events that is recorded in the fluvial sedimentary and geomorphic archive,
(iii) use the fluvial evidence in conjunction with previously published archaeological and palynological data to indicate the palaeogeography (and especially the palaeoclimatology) of the Drakensberg of the Province of the Eastern Cape during the Late Glacial and Holocene.

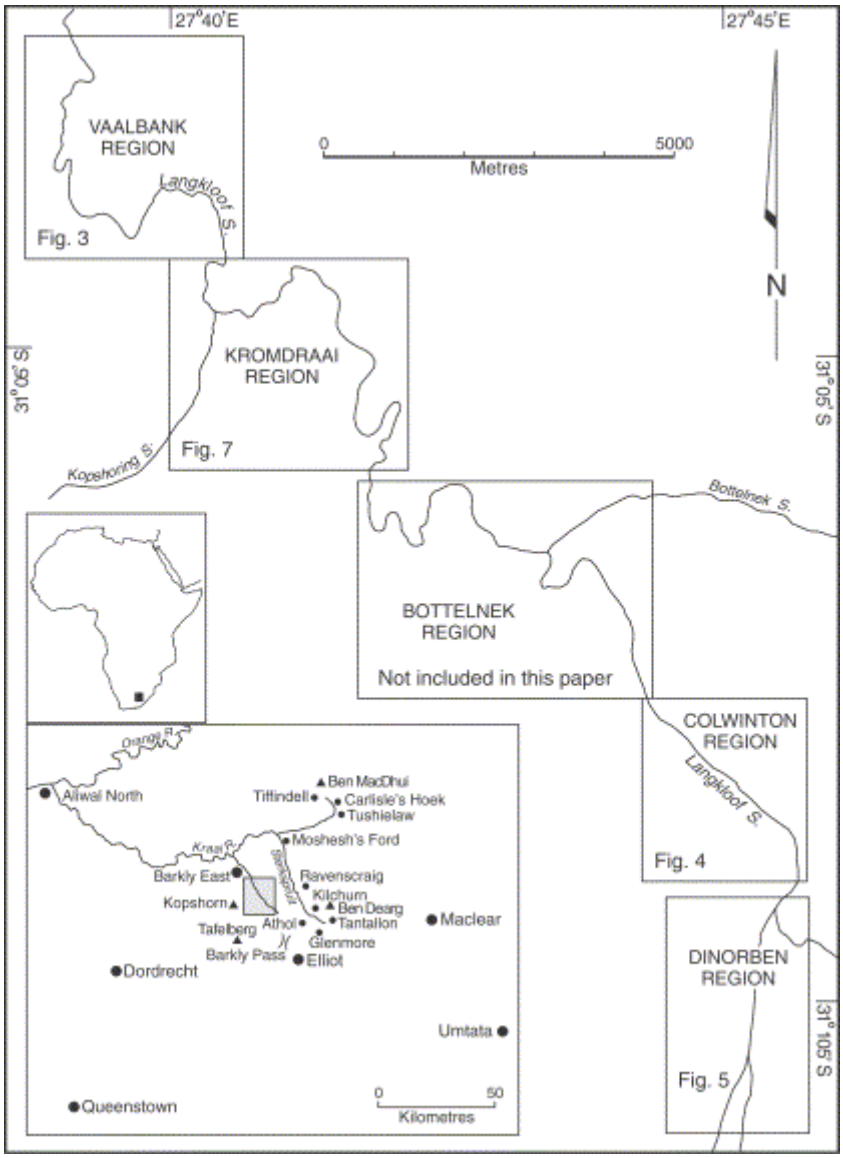

Fig. 1. The location of the main sites described and of the individual figures of fluvial landforms along the Langkloof and its Dinorben tributary.

2. Methodology

Field mapping of river terraces and other landforms in the Langkloof and its Dinorben headwaters at altitudes between 2675 and 1700 m was completed and sections in unconsolidated sediments were recorded. Less detailed geomorphic mapping, as well as the recording of sections, was undertaken in the valley of the Sterk Spruit and in some of its headwater valleys. Palaeosol and other samples were collected and submitted to the Quaternary Dating Research Unit (QUADRU) in Pretoria for analyses. The resultant radiocarbon dates were calibrated using the Pretoria Progamme (Talma and Vogel, 1993) as updated in 2000 (QUADRU, 2003) and the most probable calibrated dates are quoted. The $^{13}C/^{12}C$ isotope ratio was used to indicate former vegetation. Previously published archaeological and palynological data was tabulated and used to aid interpretation of palaeo-environmental conditions.

Fig. 2. The three-fold river terrace sequence is well displayed in the Langkloof, looking upstream towards Hendria (Fig. 3).

3. Drainage and valley floor deposits

The Barkly East area is drained westwards, to the Orange River, by the Kraai, which has its headwaters on the slopes of Ben Macdhui. The uplands south of the town are drained to the Kraai by the Langkloof Spruit ("Stream"), which has its origins in the Barkly Pass area and in the uplands west of that Pass. Parallel but to the east of the Langkloof ("Long valley") are the valleys of the Sterk Spruit ("Strong Stream") and its tributaries (Fig. 1). The rivers have dissected the summit plateau of the Drakensberg, which is formed mainly of Jurassic age basalt of the Drakensberg Formation (SACS, 1980), to expose the underlying sandstone of the Clarens Formation, of late Triassic/early Jurassic age (Schmitz and Rooyani, 1987).

Valley floor deposits containing palaeosols were identified in the Dinorben headwaters of the Langkloof and at a number of sites (Glenmore, Tantallon, Kilchurn in Glen Orchy, Athol) in the Sterk Spruit drainage system. No palaeosol or other material suitable for radiocarbon dating was discovered in the Langkloof when that valley was mapped in 2001–2003. Valley-side sections in the Langkloof and in its Kopshoring tributary provide information on slope processes. Apart from gravels exposed at Dynevor Park in the Langkloof (Fig. 4), that are overlain by what were interpreted as periglacial head deposits by Lewis and Dardis (1985), the valley side sediments appear to be slope deposits.

3.1. Dinorben

The Dinorben valley (Fig. 5) is floored with unconsolidated sediments. Section I, in a terrace (Fig. 6) on the right bank of the western headwater of the Dinorben Spruit, exposes about 5 m of deposits stacked in an ascending sequence of channels. There are gravels at the base of most channels, overlain by finer sediments. Bedrock is not exposed. The largest clasts (which do not exceed 4 cm in long axis length) occur in the lowest channel. The clasts are derived from the surrounding Clarens Formation and from the Drakensberg Formation which outcrops at the head of the valley and on the upper valley-side slopes. Some of the channels are offset from (i.e. not vertically in line with) lower channels. Fine charcoal fragments exist in the lowest and some of the other channels. Upper channels appear to have generally finer sediments than lower channels.

Palaeosols exist in the fine sediments of some channels. Samples for isotopic analyses were collected from the lowest and uppermost channels, some 4 m and 0.5 m below the modern surface of the terrace. The lower sample contained fine charcoal fragments while the upper sample contained what appeared to be reed fragments.

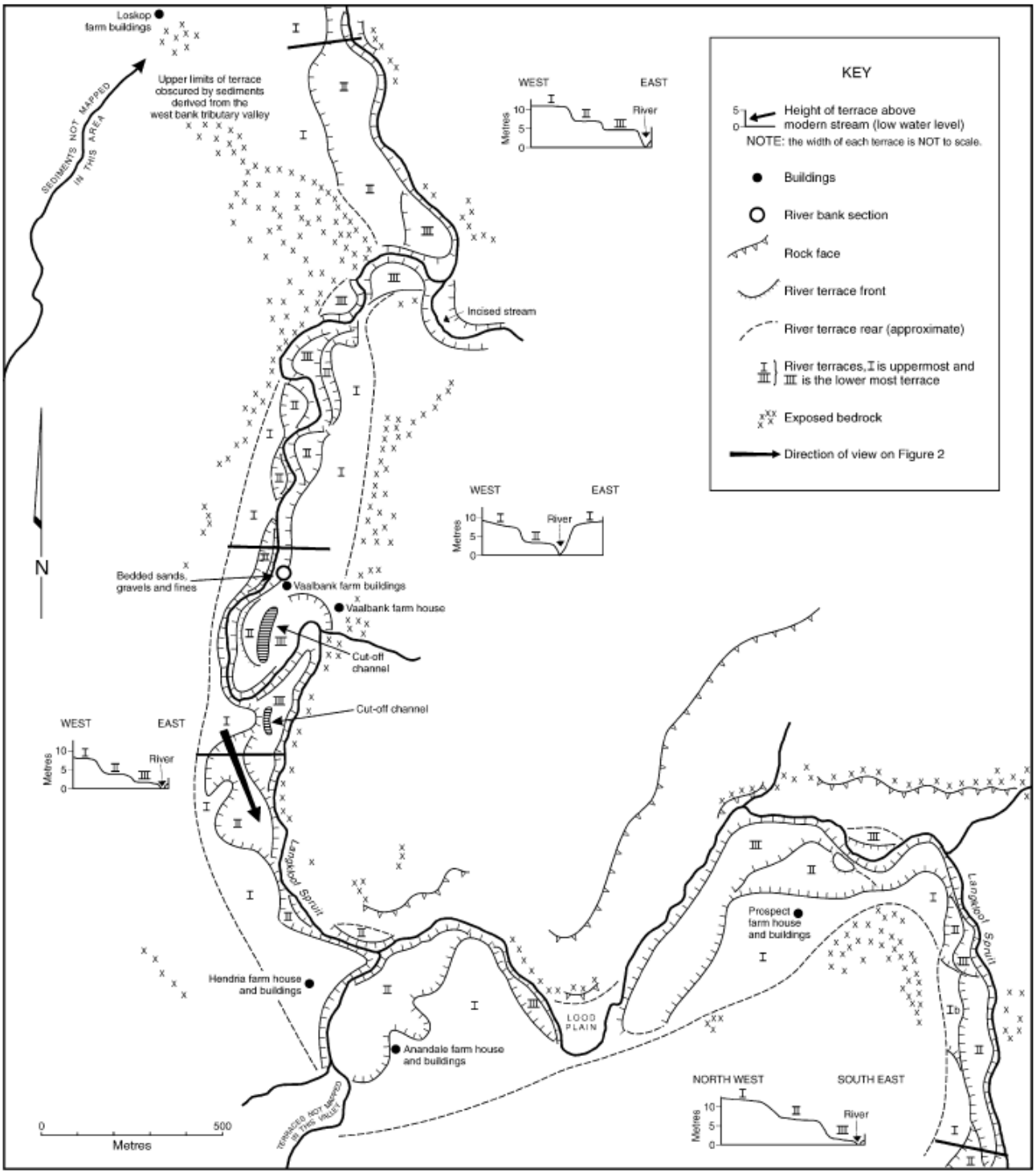

Fig. 3. River terraces, cut-off channels, flood plain and the location of stream side sections in the Vaalbank region of the Langkloof. The direction of the view on Fig. 2 is indicated.

At Section II, some 200 m further downstream and beside the main Dinorben Spruit (Fig. 5), about 6 m of unconsolidated sediment is exposed in a terrace on the eastern side of the valley. Bedrock is not exposed. The unconsolidated sediments are laid down in alternating layers of coarser and finer sediments, overlain by a similar sequence. Each coarser/finer layer forms an identifiable bed. Palaeosols exist in the finer sediments. A sample from the uppermost palaeosol, from approximately 1 m below the terrace surface, was collected for isotopic analyses. A lower terrace, with its surface less than 2 m above the modern stream, also exists in the Dinorben Valley, from which a sample was collected for analyses.

3.2. Tantallon

The Tantallon is a presently ephemeral right bank tributary of the Sterk Spruit (Fig. 1). Stream-side erosion downstream of a farm dam exposes some 5.5 m of alternating gravels (with clasts up to 4 cm in length) and silt and fine sand sediments, some of which exhibit laminae. All the clasts are derived from the Clarens Formation, into which the Tantallon valley is cut. Two palaeosols occur within the finer sediments. A sample from the lower palaeosol, at 3.9 m below the top of the stream bank, was collected for isotopic analyses.

A fan of 5.8 m of foreset gravels, overlain by alternating finer and coarser sediments that include imbricated gravels, debouches onto the floor of the main Sterk Spruit valley where it is joined by the Tantallon. There is lateral variation in the fan sediments, the base of which is not exposed. A palaeosol exists between 1.8 m and 3.2 m below the top of the fan, from which, at a depth of 2.6 m, a sample was collected for isotopic analyses.

3.3. Glenmore

Glenmore (Fig. 1) is a headwater of the Sterk Spruit system. The valley head is cut into Drakensberg Formation rocks. The Clarens Formation is exposed at lower altitudes. At the base of the steep (27°+) valley head slope, which rises to 2318 m, stream erosion has exposed a valley infill of 6.2 m of unconsolidated sediments at an altitude of about 2000 m. Bedrock, of basalt, underlies the unconsolidated sediments, the lowest 1.6 m of which consist of gravels up to 0.4 m long in a sand/silt matrix (Unit 1). The gravels are overlain by fines in which a faintly developed palaeosol exists (Unit 2). Eight more alternating fine gravel and palaeosol harbouring fine-sediment units succeed the lowest palaeosol (Units 3–10). The gravels exist in channel-like forms. Samples for isotopic analyses were taken from each palaeosol.

3.4. Kilchurn, in Glen Orchy

On the northern side of this east-west aligned Glen, on the farm of Kilchurn (Fig. 1), there is a 7 m high terrace (Lewis and Hanvey, 1991). The basal sediments of this terrace, 2 m thickness of which are exposed, are of rounded and sub-rounded gravel and boulders in a sandy matrix. The clasts are predominantly of basalt and are up to 1 m long. Bedrock is not exposed. The basal gravels are overlain by 1 m of fine sediments containing occasional rounded clasts up to 50 mm in length. Discontinuous lenses, not exceeding 5 m in length, of angular pebbles with a finer matrix, occur in this unit. The pebbles seldom exceed 50 mm in length. A third unit, of silt and fine sand displaying horizontal bedding, extends to the surface and is up to 4 m thick. Occasional inclusions of clast supported gravels, displaying both normal and inverse grading, occur in this unit. Some of the gravels are in channel form. Clasts do not exceed 30 mm in diameter. Two palaeosols exist in the silts and fine sands of this uppermost unit, from which, at depths of 1 and 2 m, samples were taken for isotopic analyses.

3.5. Athol

At Athol (Fig. 1), in a left bank tributary of the Sterk Spruit, a flood plain exists at altitudes between 1910 and 1920 m. According to local farmers the flood plain is inundated almost every year. An igneous dyke crosses and constricts the valley floor upstream of the flood plain while an outcrop of Clarens Formation sandstone restricts the downstream end of the flood plain. Linear scratches aligned parallel to the long axis of the adjacent Sterk Spruit valley, considered by local farmers to be plough marks, but resembling glacial striae, score the sandstone in fields south of Athol.

Stream bank erosion exposes basal gravels, some exhibiting foreset bedding, overlain by silt and fine sand sediments in which a palaeosol, 0.4 m thick, occurs. Up to 0.5 m of silt and fine sand overlies the palaeosol. Channels are cut into these and the lower fine sediments and the base of some channels is in contact with the basal gravels. Organic deposits exist in some channels and are covered by more recent silt and fine sand sediments. Samples for isotopic analyses were collected from the palaeosol 0.7 m below the surface, from a channel 2.7 m below the surface and from the modern soil 0.2 m below the surface of the river bank.

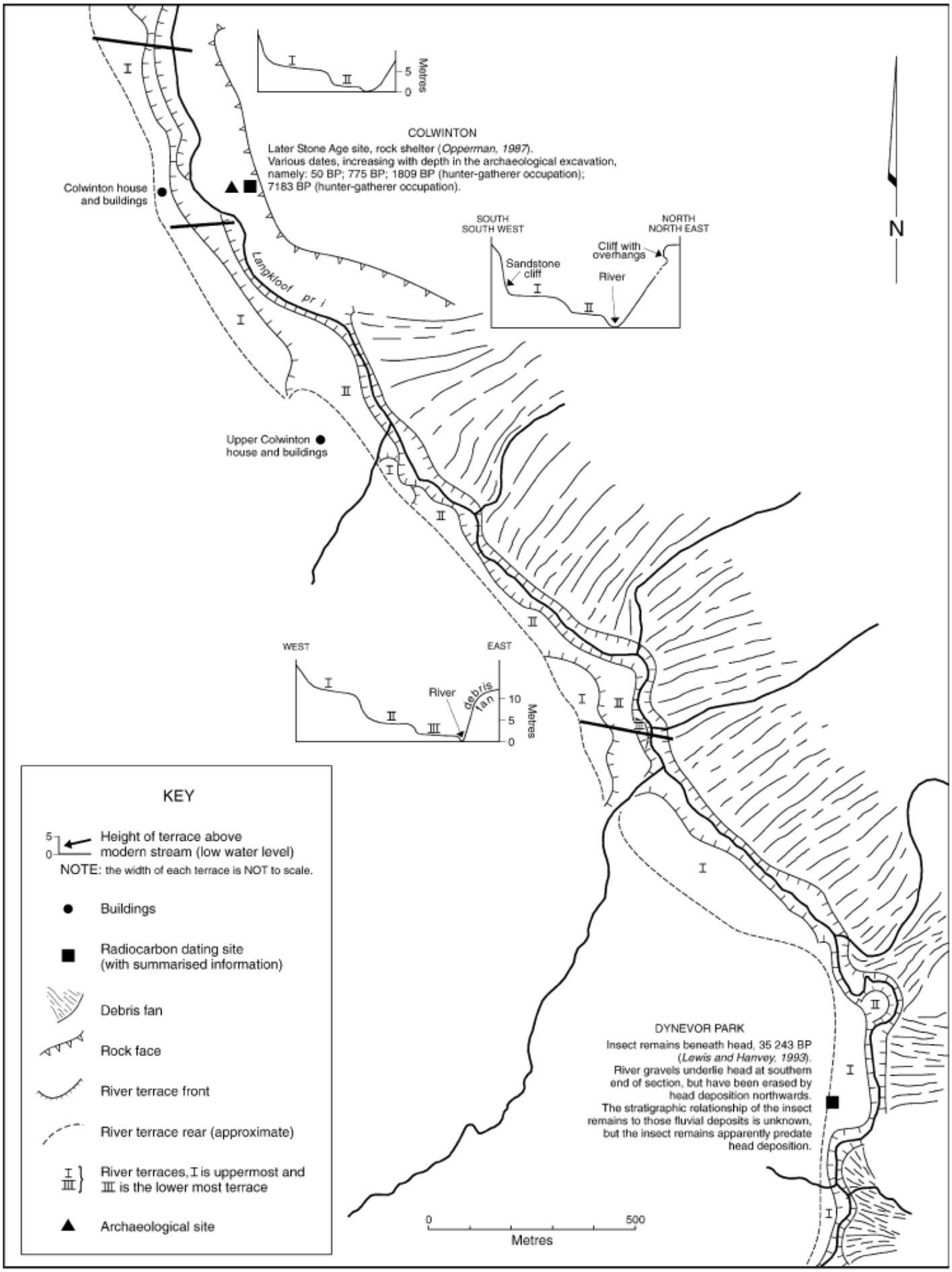

Fig. 4. The location of the Dynevor Park section and of the Colwinton rock shelter in the Langkloof.

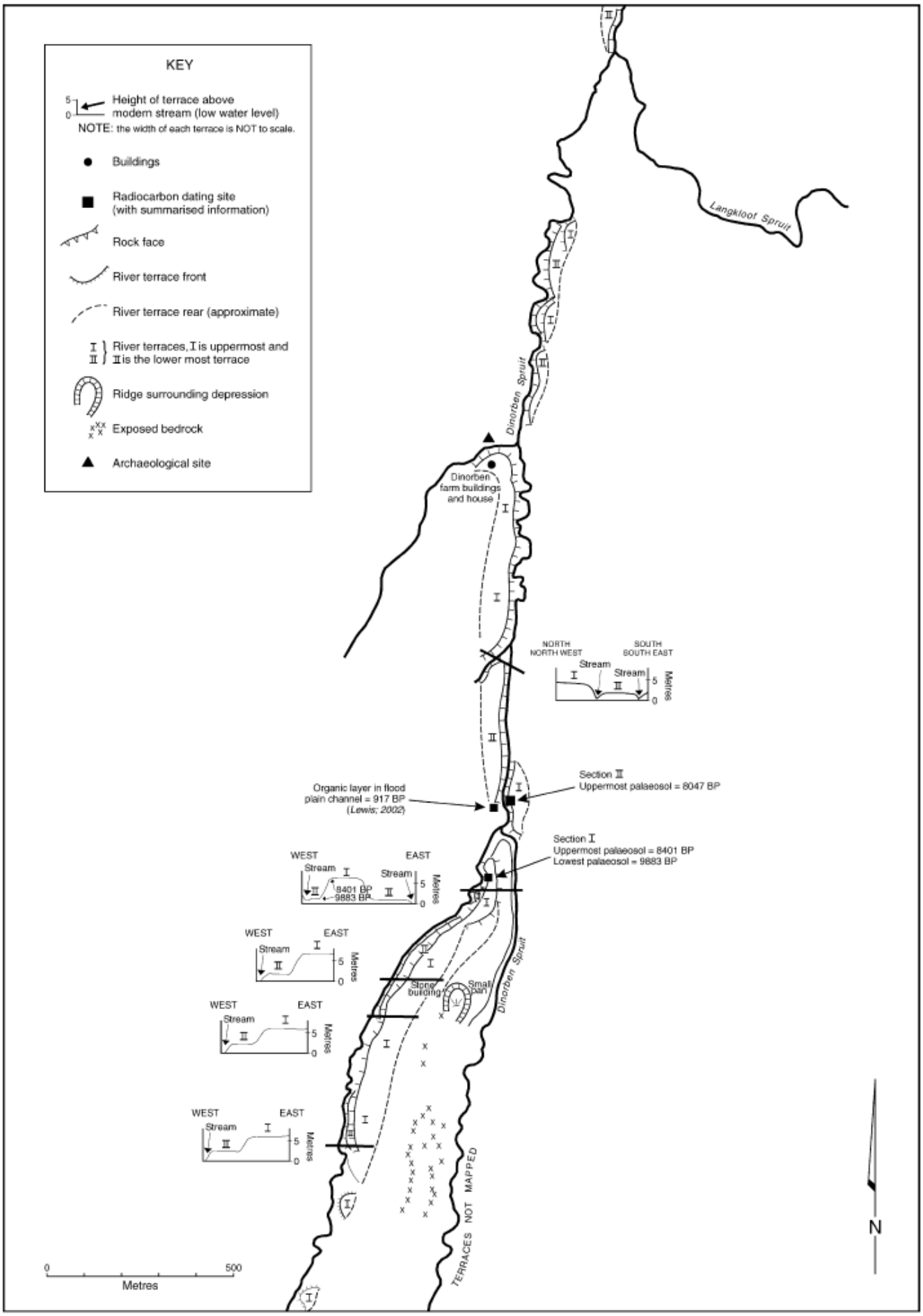

Fig. 5. River terraces and the location of Sections I and II in the Dinorben Spruit tributary valley of the Langkloof.

Fig. 6. The valley of the Dinorben Spruit. View downstream from the surface of Terrace I, with remnants of the same terrace seen on the opposite side of the valley and, on the same side of the valley, downstream towards the trees near Dinorben farm buildings. Terrace II is visible below the level of Terrace I. The upper part of Section I (Fig. 5) is seen in the left foreground. Section II is the exposure immediately left of centre of the figure, downstream and on the opposite side of the valley.

4. Interpretation of valley floor deposits

4.1. Dinorben

The channel form of the sediments at Section I indicates that they are of fluvial origin. The offset nature of some of the channels suggests that the stream that deposited them wandered over sediments that had already been laid down. The restricted size of the gravel clasts indicates that they were associated with relatively low stream energy. The general fining upwards nature of channel sediments suggests that stream energy tended to become less as time progressed. The fine charcoal fragments in some of the lower channels suggest that veld-fires periodically burnt the area. The multiple palaeosols indicate that phases of environmental stability long enough for soil formation occurred between at least some of the fluvial depositional events. These events may have been associated with floods that deposited relatively coarse material on top of the fines in which the palaeosols exist.

At Section II sediments are exposed in lateral view. The presence of partly rounded gravel and the fining upwards nature of the beds indicates that they are of fluvial origin. The coarser sediments probably relate to flood events and the finer sediments to the waning of those events as reduced stream flow and energy led to the deposition of progressively finer debris. The evidence at both Sections indicates that the sediments accumulated as a flood plain as individual flood events deposited debris on its surface. Subsequent erosion has transformed the flood plain into a river terrace.

4.2. Tantallon

The gravels and laminated fine sediments downstream of the farm dam are characteristic of fluvial sediments. The palaeosols indicate that soil formation occurred between sedimentary events. The sediments are interpreted as of

flood plain origin, possibly laid down under conditions of ephemeral stream flow, with sufficiently lengthy time periods between some flood events for soil development. Subsequent erosion has caused the stream to incise the flood plain. The basal sediments near the mouth of the Tantallon valley comprise foreset beds typical of an alluvial

fan. The channel deposits above the foreset beds are indicative of fluvial deposition. The imbricated gravels indicate deposition by a stream flowing down the Tantallon valley. The landform and the inorganic sediments within it is therefore interpreted as an alluvial fan deposited where stream flow was reduced as the steeply graded Tantallon valley opened into the less steeply graded Sterk Spruit valley. The palaeosol indicates that fan deposition was not continuous but was interrupted by a time long enough for soil formation. Erosion subsequent to the deposition of the fan has resulted in the Tantallon stream becoming incised below the surface of the landform.

4.3. Glenmore

The coarse gravels in a sand/silt matrix at the base of the section resemble and are interpreted as fluvial deposits. The channel-like forms containing finer gravels and located higher up the section indicate that the gravels were stream-deposited. The small size of the individual clasts indicates that deposition took place under low-energy conditions. The finer sediments above the gravel-filled channels may be of stream or of slope wash (colluvial) origin. The palaeosols indicate that deposition was not continuous. Erosion since deposition of the valley-fill has resulted in the modern stream becoming incised into the unconsolidated sediments.

4.4. Kilchurn in Glen Orchy

The rounded and sub-rounded clasts and the sandy matrix of the basal unit is characteristic of fluvial deposits. The size of clasts indicates deposition under relatively high-energy conditions. The channel-like features, occupied by finer-grade gravel and other sediments at higher levels in the section, resemble former stream channels. The horizontal bedding of the silts and fine sands in the uppermost unit is indicative of fluvial deposition. The two palaeosols within the uppermost unit indicate that deposition was not continuous. The sediments are therefore interpreted as being of fluvial origin, the lowest unit being deposited under conditions of higher energy than was responsible for the deposition of the upper units. Subsequent erosion has resulted in incision of the flood plain and the formation of a river terrace 7 m above the present stream level.

4.5. Athol

The foreset bedding of the basal gravels indicates water-related infilling of a valley-floor basin. The fine sediments that overlie the gravels are typical of a flood plain, as are the channels cut into those sediments. Organic deposition is typical of abandoned flood plain channels. The deposits at Athol are thus interpreted as of floodplain origin, and the flood plain is still active.

5. Age of fluvial deposits

Radiocarbon dating shows that the collected samples fall mainly into four age groups: Early Holocene, from 9883 BP to 6959 BP (Table 1); Mid Holocene, from 5735 BP to 4855 BP; third millennium BP; the last thirteen hundred years. Only two dates, (3219 BP from a bone beneath slope deposits at Kopshoring, and 3141 BP from the uppermost palaeosol at Glenmore), fall outside these groups.

Table 1. Radiocarbon dates from palaeosols in the Langkloof and Sterk Spruit basin valley floor infills and from a bone in slope sediments in Kopshoring

Site	General description	Depth below surface (m)	Radiocarbon Analyses			
			Analysis number	^{13}C ‰ PDB	^{14}C Age (Yrs BP)	Calibrated Age
Athol	Modern soil on flood plain	0.2	Pta—8419	−18.1	290 +/−50	298 BP
Dinorben	Organic deposit in sediments in the lowest river terrace in the Dinorben valley	0.7	Pta—5483	−21.3	1000 +/−50	917 BP
Athol	Channel in flood plain deposits	2.7	Pta—8396	−18	1180 +/−50	1055 BP
Athol	Palaeosol in flood plain deposits	0.7	Pta—8425	−18.6	2400 +/−90	2351 BP
Kilchurn Upper palaeosol	Palaeosol in river terrace	1.0	Pta—5211	−16.1	2440 +/−60	2362 BP
Kilchurn Lower palaeosol	Palaeosol in river terrace	2.0	Pta—5089	−15.4	2470 +/−45	2412 BP
Glenmore Unit 10	Palaeosol in fines	0.5	Pta—8508	−20.4	3000 +/−60	3141 BP
Kopshoring	Bone in slope sediments	3.1	Pta—8988	−18.0	3050 +/−70	3219 BP
Glenmore Unit 8	Palaeosol in fines	1.0	Pta—8501	−21.3	4350 +/−70	4855 BP
Glenmore Unit 6	Palaeosol in fines	1.5	Pta—8386	−19.7	4590 +/−70	5298 BP
Glenmore Unit 4	Palaeosol in fines	2.3	Pta—8385	−21.1	5050 +/−60	5735 BP
Glenmore Unit 2	Palaeosol in fines	4.2	Pta—8383	−19.9	6140+/−80	6959 BP
Tantallon II	Palaeosol in an alluvial fan	2.0	Pta—8407	−15.7	6690 +/−60	7559 BP
Tantallon I	Palaeosol within overbank sediments	3.9	Pta—8402	−18.4	7240 +/−70	7989 BP
Dinorben upper terrace	Uppermost palaeosol in former flood plain, now a river terrace	1.0	Pta—8859	−20.4	7320 +/−70	8047 BP
Dinorben II	Uppermost channel, containing organic deposits, within stacked fluvial sediments	0.5	Pta—8712	−21.9	7660 +/−210	8401 BP
Dinorben I	Channel, containing fine charcoal fragments, at base of stacked fluvial deposits. Bedrock not exposed	4.0	Pta—8708	−20.8	8840 +/−130	9883 BP

5.1. Early Holocene

The dates from Dinorben I, II and the upper terrace indicate that deposition of flood plain sediments began before 9883 BP and terminated more recently than 8047 BP. Subsequently the stream incised the flood plain, which was transformed into a river terrace. At Tantallon flood plain sediments accumulated prior to 7989 BP while the bulk of the alluvial fan at the mouth of the valley was deposited prior to 7559 BP. A thickness of at least 3 m of flood plain sediments was deposited more recently than 7989 BP before fluvial erosion transformed the flood plain into an incised valley-floor infill. At Glenmore relatively coarse gravels were deposited on the valley floor prior to 6959 BP, but only much finer debris, indicative of lesser stream energy and of colluviation, was deposited after that date.

5.2. Mid-Holocene

Mid Holocene events are evidenced from Glenmore. Approximately 1224 years elapsed between covering of the lowest soil by 0.55 m of fluvial gravels and fines at around 6959 BP, converting it into a palaeosol, and formation of the next palaeosol in the stratigraphic sequence. Subsequent intervals of about 437, 443 and 1714 years then occurred between depositionary events sufficiently pronounced to bury soils. Less than 0.6 m of sediment was deposited in each interval. Depositionary rates were therefore low and little geomorphic activity took place at the site between approximately 6959 BP and 3141 BP.

5.3. Third Millennium BP

At Kilchurn, coarse torrent gravel, indicative of considerable stream energy, was laid down prior to 2412 BP, while foreset bedded gravels (also indicative of considerable stream energy) were deposited prior to 2351 BP at Athol. Fine overbank deposition took place on top of the coarse gravels at Kilchurn from an unknown time prior to 2412 BP with flood plain deposition burying soil at about that date. There was then sufficient time for further soil formation before another depositionary event occurred at about 2362 BP in which fine (presumably overbank) sediments buried that soil, causing it to become a palaeosol. Over 3 m of fine slope sediments, that contain three palaeosols, overlay an antelope bone that was collected from the left side of the Kopshoring valley some 1.1 km above the confluence of that valley with the Langkloof and near a rock shelter containing archaeological material (Fig. 7). The bone dates to 3219 BP. There has thus been appreciable slope erosion and deposition on the Kopshoring valley side and this may have begun at the same time as erosion and deposition at Kilchurn.

5.4. The last thirteen hundred years

At Athol a river channel cut into fine flood plain deposits contains organic-rich sediments that date to 1055 BP. They evidence fluvial downcutting into already existing flood plain sediments at or somewhat before that date, presumably due to increased river energy. Comparable sediments in the lowest river terrace at Dinorben (917 BP) also witnessed fluvial erosion and incision at about that date, in which a low-level flood plain was transformed into a river terrace. Finally, the modern soil on the flood plain at Athol dates to 298 BP, suggesting that soil formation within the last three hundred years has not been terminated by any sedimentary event appreciable enough to bury flood plain (and hence soil influencing) vegetation and transform surficial soil into palaeosol.

6. Isotopes and vegetation

Vogel et al. (1978) showed that the $^{13}C/^{12}C$ isotope ratio (δ) indicates whether C_3 or C_4 grasses grew in an area. C_3 grasses presently occupy regions where mean daily maxima are below 25°C during their growth (rainy) period. C_4 grasses presently occupy the eastern areas of southern Africa, where summer daily maximum temperatures are above 25°C. C_3 grasses are most common in the Western Cape, and at high altitudes in the Drakensberg where the effects of altitude moderate temperature. Although there are problems in relating the isotopic evidence to vegetation (since, for example, where C_3 plants are indicated they could have been derived from aquatics, semi-aquatics, karoo bushes, shrubs or other herbs and not necessarily from C_3 grasses), the isotopic evidence remains valuable. ^{13}C-enriched samples indicate summer rain, although not how much of it. The $\delta\ ^{13}C$ values of the samples analysed from the Dinorben-Sterk Spruit area are shown on Table 1.

The $\delta\ ^{13}C$ values at Dinorben I, II, upper terrace and lowest river terrace, suggest that C_3 plants existed in the area between at least 9883 BP and 8047 BP and around 917 BP. At Tantallon, the $\delta\ ^{13}C$ values show that C_4 plants were important in that area immediately prior to 7559 BP, suggesting that the area experienced summer rainfall at that time.

At Glenmore, C_3 plants apparently dominated the vicinity of the sample sites between at least 6959-3141 BP. At Kilchurn, C_4 plants were probably dominant in the vicinity of the sample sites at around 2400 BP. The three samples analysed from Athol suggest that a mixture of C_3 and C_4 plants has existed in this area since at least 2351 BP.

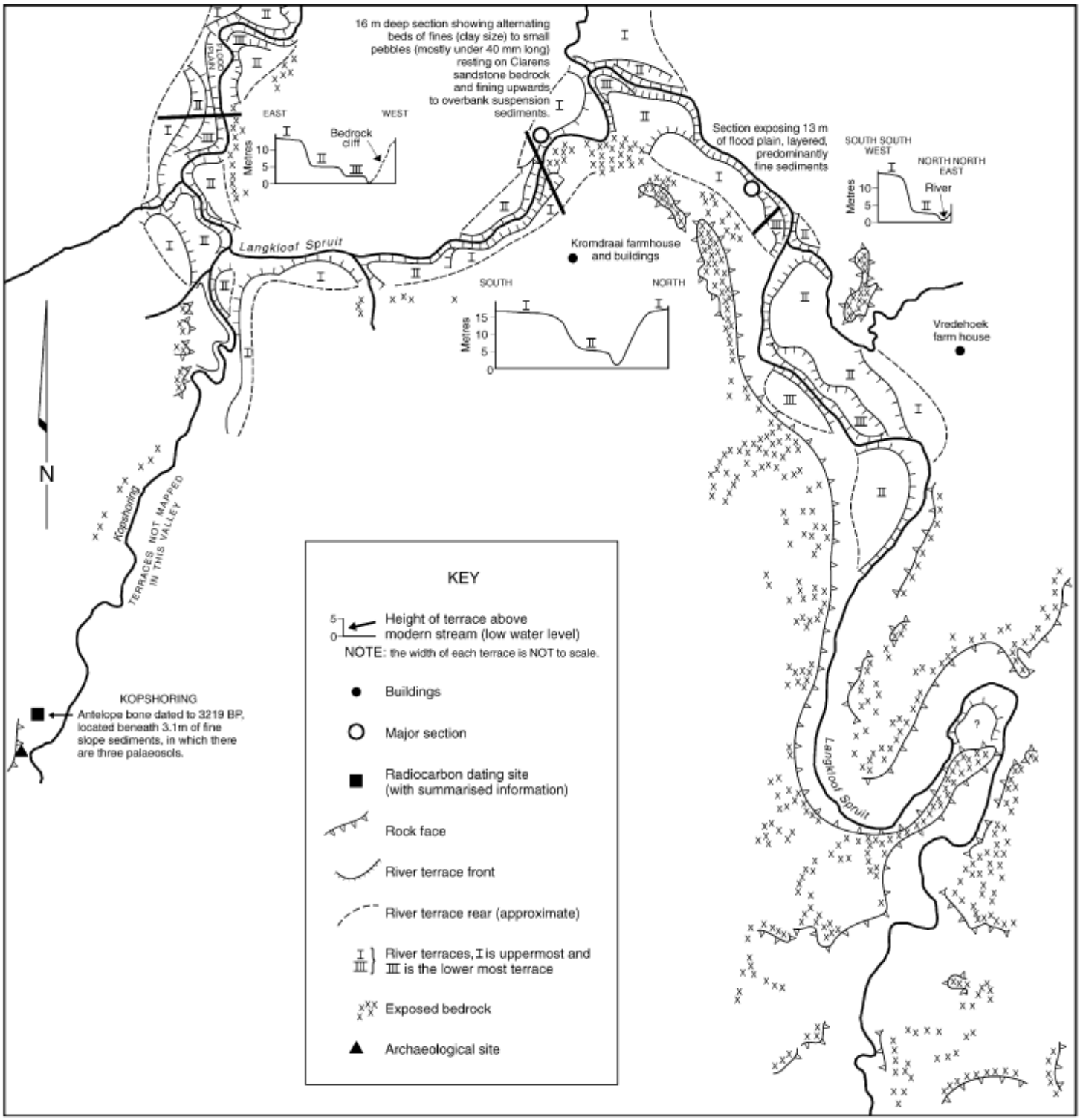

Fig. 7. The location of the Kopshoring slope sediment site in relation to the Kromdraai region of the Langkloof.

7. Archaeological evidence

Opperman (1987) and Tusenius (1989) have published work based on excavations of rock shelters at Ravenscraig in the Sterk Spruit valley and at Colwinton in the Langkloof, which is summarised on Table 2 and Table 3. Opperman and Heydenrych (1990) and Opperman (1996) have also dated Middle Stone Age occupation of an adjacent area in

the Drakensberg, showing that a site at Strathalan, near Maclear (Fig. 1), was occupied by Middle Stone Age hunter–gatherers at 25,031 BP but abandoned before 23,908 BP. Lewis and Illgner (2001) have shown that at least small glaciers existed in the region in the Late Quaternary, while Lewis and Hanvey (1993) have shown that rock glaciers were active at or soon after 24,000 BP in at least one tributary valley of the Langkloof. Hunter–gatherers may have abandoned the Drakensberg after about 25,000 BP due to adverse environmental conditions caused by intensely cold climatic conditions.

Table 2
Archaeological and environmental evidence of Holocene age from the Ravenscraig rock shelter, Sterkspruit valley (based on Opperman, 1987; Tusenius,1989

Stratigraphic layer	Human event	Radiocarbon Analyses					
		Analysis number	^{14}C Age (yrs BP)	Calibrated Age	Vegetation (based on charcoal analyses)	Fauna (only most common shown)	Inferred climate (Tusenius, 1989)
1	Occupation by people using pottery	Pta—3192	460 +/−45 (dates bottom part of layer)	499 BP	*Leucosidea*	Eland[a]	Relatively moist
2	Occupation, possibly more frequently than before	Pta—3450 (from upper part of layer)	3040 +/−50	3210 BP	*Euryops*	Grey rhebuck[b] Klipspringer[c]	Dry and warm
3	Occupation				*Euryops*	Wildebeest[d]/ Hartebeest[e]	Dry and warm
4	Occupation, but "Much less cultural material is present than in [layer 1]) (Opperman, 1987, p.137)	Pta—3194	10,000 +/−80	11,295 BP	*Euryops*	Klipspringer[c]	Dry and warm
5	Occupation	Pta—3451	10,200 +/−100	11,853 BP	*Euryops* *Leucosidea*	Wildebeest[d]/ Hartebeest[e] *Equus* sp.	Relatively moist

[a] Taurotragus oryx.
[b] Pelea capreolus.
[c] Oreotragus oreotragus.
[d] Connochaetes.
[e] Alcelaphus.

Human occupation of the Langkloof–Sterk Spruit region by Later Stone Age hunter–gatherers is first evidenced by artifacts, and by charcoal remains from fires that date to 11,853 BP, at Ravenscraig (Table 2). Charcoal includes remains of *Leucosidea,* which suggests relatively moist conditions, as well as *Euryops.* By 11,295 BP 'Much less cultural material is present' [at Ravenscraig] than in the earlier occupation level (Opperman, 1987, p.137), suggesting a reduction in human occupancy while the predominance of *Euryops* (a Karoo plant) in the charcoal (Tusenius,1989) suggests increasingly dry conditions.

The earliest occupancy by Later Stone Age people of the Colwinton rock shelter, in the Langkloof (Fig. 4), has not been dated. The shelter was, however, used before 7183 BP (Table 3). Subsequently the shelter was 'intensively visited by people who differed culturally from the previous occupants' (Opperman, 1987, p. 44).The date of this reutilisation is uncertain, but there may have been a considerable Mid Holocene time gap in occupation. The Karoo plant, *Euryops*, was important in the charcoal remains of the fire places of the new occupants, suggesting rather dry conditions. Subsequently, but before 1809 BP, it was replaced by *Cliffortia* as the dominant contributor to charcoal, while Grey rhebuck replaced Hartebeest and/or Wildebeest as important contributors to the diet of the hunter–gatherers. The charcoal and faunal changes at Colwinton and, by 3210 BP at Ravenscraig (Table 2) suggest the

presence of ‘more shrubs than [in] the early Holocene grassland’ (Tusenius, 1989, p. 80) and increasingly moist climatic conditions. The earliest date for the use of pottery at Colwinton was 775 BP (Table 3).

8. Palynological evidence

Two important sites have been studied in the general vicinity of the Langkloof-Sterk Spruit region: at Aliwal North, some 90 km north–northwest of Barkly East (Fig. 1; Coetzee,1967), and at Tiffindell, about 45 km northeast of Barkly East (Fig. 1; Rosen et al.,1999). Coetzee (1967) dated the start of organic sedimentation at Aliwal North to 15,007 BP (Table 4), when pollens indicated that the climate was warming but dry. By 14,481 BP grasslands apparently occupied the Aliwal North region and conditions were relatively moist. Coetzee (1967) considered that Karoo-type vegetation existed by 13,757 BP, indicative of drier conditions than immediately previously. By 11,855 BP grasslands were apparently re-established in the Aliwal North region, indicating a moister climate. By 10,927 BP drier conditions prevailed, with Karoid vegetation dominant at Aliwal North.

Rosen et al. (1999) date the onset of organic accumulation at Tiffindell (a site at an altitude of 2780 m) to ca. 5385 BP (Pta—7041, the date quoted in the present paper has been calibrated). This suggests that relatively moist conditions existed at that time. Rosen et al. (1999) also considered that there was a marked increase in precipitation, which caused some gully erosion, at ca. 2800 BP.

Table 3
Archaeological and environmental evidence of Holocene age from the Colwinton rock shelter in the Langkloof (based on Opperman, 1987; Tusenius, 1989

Stratigraphic layer	Human event	Radiocarbon Analyses					
		Analysis number	^{14}C Age (Yrs BP)	Calibrated age	Vegetation (based on charcoal analyses)	Fauna (only most common shown)	Inferred Climate
1	Occupation, but less frequently than previously	Pta—2547	70 +/−40BP	50 BP	*Cliffortia*	Rock hyrax[a]	Relatively moist
2	Occupation, earliest pottery at site	Pta—2608	920 +/−50BP	775 BP	*Cliffortia*	Rock hyrax[a] Grey rhebuck[b]	Relatively moist
		Pta—2549	1890 +/−45BP	1809 BP			
3	Occupation				*Cliffortia*	Rock hyrax[a] Grey rhebuck[b]	Relatively moist
4	Occupation “…the shelter was intensively visited by people who differed culturally.from the previous occupants” (Opperman, 1987, p. 44)				*Euryops*	Rock hyrax[a] Hartebeest[c]/ Wildebeest[d]	More arid than 1–3
		Pta—2550	6270 +/−40BP	7183 BP			
5	Occupation, but contains less cultural material than any other occupation layer (Opperman 1987, p. 44)				*No information*	Hartebeest[c]/ Wildebeest[d]	More arid than 1–3
6	“Earliest occupation of the rock shelter” (Opperman, 1987, p. 44)					Hartebeest[c]/ Wildebeestd[d]	More arid than 1–3
Sterile sand	No evidence of human occupation						No information

Note: The terms ‘relatively moist’ and ‘more arid’ have not been quantified but suggest that conditions around 7000 BP were semi-arid, possibly resembling the modern Karoo, while conditions after and somewhat before 1800 BP were relatively moister (Tusenius, 1989, p. 80).

[a] Procavia capensis.
[b] Pelea capreolus.
[c] Alcelaphus.
[d] Connochaetes.

9. Discussion

9.1. Late Glacial

Palynological evidence from Aliwal North (Coetzee, 1967) suggests that four different climatic phases existed in the region during the Late Glacial (Table 4). The earliest phase (Table 4, Event A) is evidenced by the onset of organic accumulation at ca. 15,007 BP, when Coetzee (1967) believed that climate was warming. Rock glaciers, that were in their early stages of development by 23,982 BP (Pta—5654; Lewis and Hanvey, 1993), and possibly snow beds, small cirque and valley-side glaciers (Lewis, 1994a; Lewis and Illgner (2000) and Lewis and Illgner (2001)), existed in the region during the Bottelnek Stadial (Lewis (1994b) and Lewis (1996)). The onset of organic accumulation probably documents the change from those Stadial conditions to the less harsh conditions of the Late Glacial.

Table 4
Climatic events in the Drakensberg of the Province of the Eastern Cape as evidenced by fluvial, archaeological and palynological data

Event	Character	Typesite/s	Radiocarbon age (yrs BP)	Calibrated age (yrs BP)	Inferred climatic conditions	Approximate dates (calibrated BP)
Holocene						
8	Gully erosion on valley sides, flood plain deposition on valley floors	Athol Tushielaw	290 +/−50 990 +/−50	298 BP 913 BP	Relatively moist	900–Present
7	Incision into flood plains	Dinorben Athol Colwinton	1000 +/−50 1180 +/−50 1890 +/−45	917 BP 1055 BP 1890 BP	Relatively wet	2000–900
6	Flood plain deposition	Athol Kilchurn	2400 +/−90 2440 +/−60	2351 BP 2412 BP	Relatively moist	2500–2000
5	Erosion of fans (Glen Orchy) and valley sides	Tiffindell Kopshoring	2730 +/−45 3050 +/−70	2776 BP 3219 BP	Relatively wet	3200–2500
4	Limited valley floor infilling adjacent to valleyhead	Glenmore Glenmore	3000 +/−60 6140 +/−80	3141 BP 6959 BP	Semi-arid and cool	7000–3200
3	Alluvial fan deposition terminates	Colwinton Tantallon II	6270 +/−40 6690 +/−60	7183 BP 7559 BP	Increasingly dry	7500–7000
2	Flood plain and alluvial fan deposition	Tantallon I Dinorben I	7240 +/−70 8840 +/−130	7989 BP 9883 BP	Relatively moist and cool	10,000–7500
	No evidence of fluvial events has been identified and dated from this time period					
1	Decline in human occupation of the area and existence of Karroid vegetation	Aliwal North Ravenscraig	9650 +/−150 10,000 +/−80	10,927 BP 11,295 BP	Dry and warm	11,500–10,000
Late Glacial						
No evidence of fluvial events in the region during the Late Glacial has, as yet, been identified. The events listed below are based on palynological and archaeological evidence. Considerable information exists for earlier times in the Late Quaternary, as has been summarized by Lewis (2002)						
D	Grassveld (grasslands) with some bushy areas, initial occupation of the area by Later Stone Age hunter–gatherers	Ravenscraig Aliwal North	10,200 +/−100 10,200 +/−180	11,853 BP 11,855 BP	Relatively moist	12,000–11,500
C	Karoo-type vegetation	Aliwal North	11,650 +/−170	13,757 BP	Relatively dry	14,000–12,000
B	Grassveld (grasslands)	Aliwal North	12,200 +/−180	14,481 BP	Relatively moist and cool	15,000–14,000
A	Start of organic sedimentation at Aliwal North (Coetzee, 1967) and at other sites in the Eastern Cape and Lesotho (Meadows, 1988)	Aliwal North	12,600 +/−110	15,007 BP	Warming	?–15,000

By 14,481 BP grasslands apparently existed in the Aliwal North area. Coetzee (1967) inferred that conditions then were relatively moist and cool. This phase (Table 4, Event B) evidenced an appreciable amelioration of climate. By 13,757 BP (Table 4, Event C) Karoo-type vegetation had invaded the Aliwal North area, indicating that conditions were relatively dry. Climatic improvement, with an increase in moisture, had taken place by 11,855 BP (Table 4, Event D) when Coetzee (1967) identified evidence of grasslands replacing the Karoo vegetation of the previous phase. The earliest occupation of the Ravenscraig rock shelter has been dated to 11,853 BP, at which time the

charcoal and faunal records indicate that conditions there were relatively moist (Opperman, 1987), thus supporting Coetzee's palynological findings. No fluvial sediments or landforms dating to the Late Glacial have, as yet, been identified in the Langkloof-Sterk Spruit region.

9.2. Holocene

By 11,295 BP human occupation of the Sterk Spruit rock shelter appears to have been in decline and *Euryops*, a Karoo plant, had replaced the more moist-loving *Leucosidea* as the main firewood, as judged by charcoal remains (Table 2). At Aliwal North, by 10,927 BP, Coetzee (1967) considered that Karoid vegetation with 'dry grasslands' existed. These facts suggest that the climate had become dry and possibly warm. The ice-core record from Greenland indicates that, ca 11,500 years ago, there were rapid temperature increases as transition took place from the Late Glacial to the Holocene (Vandenberghe et al., 2001). The climatic changes indicated for the Barkly East region at that time therefore appear to have been in step with events elsewhere in the world. No fluvial sediments or landforms dating to this time have been identified in the Langkloof-Sterk Spruit region.

Deposition of flood plain sediments took place in the Langkloof drainage system, at Dinorben, between before 9883 BP and some time after 8047 BP. Similar deposition took place in the Sterk Spruit system, at Tantallon, from before 7989 BP until some time after 7559 BP. Deposition appears to have been associated with ephemeral and rather low energy stream flow, which suggests that the climate was "moist" rather than "wet". C_3 plants were apparently common in the catchments except towards the end of the dated period. They may indicate that summer was not the wet and growing season. This suggests that temperatures may have been relatively cool. The presence of charcoal in the Dinorben deposits evidences veld fires, suggestive of dry conditions. Flood plain and alluvial fan deposition therefore took place between before 9883 BP and some time after 7559 BP, apparently under relatively moist and relatively cool conditions in which, occasionally, the landscape was dry enough for veld fires. The region may have been utilised by Later Stone Age people during this time, although there is less cultural material in what may be the equivalent stratigraphic layer at Colwinton than in any other occupation layer (Table 3; Opperman, 1987, p. 44) which suggests that the area was thinly populated. The Ravenscraig rock shelter was also apparently utilised, but probably not as frequently as subsequently (Table 2; Opperman, 1987).

The termination of alluvial fan deposition at Tantallon somewhat after 7559 BP was probably due to a decline in run off as climatic conditions became drier. Charcoal remains at Colwinton (Table 3) dated to 7183 BP indicate that Karoo-type vegetation, which is indicative of relatively dry conditions, existed at that date. Climatic conditions were therefore apparently increasingly dry after ca. 7559 BP.

The infilling of the valley floor adjacent to the valley head at Glenmore took place from before 6959 BP until somewhat after 3141 BP. This was a time of limited geomorphic activity when identifiable depositionary events, due to fluvial and/or slope wash processes, occurred at greater than 400 year intervals. This suggests that semi-arid conditions, with occasional heavy rainfall or snow-melt (which moved sediments down the valley head and into the valley floor deposits), occurred in this time period. These conditions were probably an intensification of the increasingly dry conditions already inferred as existing after ca. 7559 BP.

At Kilchurn there is a fan with a surface 12 m above the modern stream (Lewis and Hanvey, 1991) as well as the already described 7 m river terrace. There are further fans, many of which contain coarse basalt gravels and boulders, further up the Glen. The toes of some fans terminate in stream-cut bluffs. The 12 m fan at Kilchurn also ends in a steep slope that resembles a stream-cut bluff, but that rises above the 7 m terrace. The basalt gravels and boulders that form unit one at the base of the 7 m terrace at Kilchurn may have been derived from fluvial erosion of fans further upstream, and subsequent transportation and deposition of sediment derived from them.

Rosen et al. (1999) have shown that, at Tiffindell, there is evidence of gully erosion ca 2800-2700 BP, which may have been associated with a marked increase in precipitation and runoff. Van Geel et al. (1996) state that 'A sudden

and sharp rise in the ^{14}C content of the atmosphere...ca. 2750 BP–2450 BP on the radiocarbon time-scale...was contemporaneous with an abrupt climate change' in which there was a marked increase in precipitation in non-equatorial and non-tropical parts of the world. Such an increase, if it occurred in the Drakensberg, would account for stream erosion of the toes of fans with associated sediment transportation and deposition. There may therefore have been a marked phase of increased precipitation and runoff subsequent to 3210 BP (when archaeological evidence from Ravenscraig indicates that the Karoo plant *Euryops* was the dominant contributor to firewood, as judged by charcoal remains; Table 2) and prior to the deposition of fine overbank sediments in a flood plain on top of the coarse torrent gravels. The flood plain was subsequently incised to form the 7 m terrace at Kilchurn. Since the lowest palaeosol in the 7 m terrace dates to 2412 BP the presumed wet period was short-lived and existed after ca. 3210 BP and before 2412 BP.

The overbank deposits and palaeosols at Kilchurn indicate flood plain accumulation from before 2412 BP to after 2362 BP at that site. They also evidence a reduction in stream power and runoff compared with the torrent gravels and boulders of the basal unit. The fine-gravel filled channels within fine overbank sediments above the basal unit were deposited in stream channels cut into the surface of the accumulating flood plain. They are less common in the upper units, suggesting that stream flow was decreasingly powerful and indicating progression to climatically drier conditions. The isotopic evidence (Table 1) suggests that C_4 plants were common ca. 2412 BP. This may mean that the area lay in a summer rainfall region at that time. Flood plain deposition at Athol continued until at least 2351 BP.

Subsequent to the formation of the upper palaeosol at Kilchurn, ca. 2362 BP, flood plain incision took place. The archaeological evidence at Colwinton (Table 3) indicates that *Cliffortia*, a more moist-loving plant than *Euryops*, replaced the latter plant as the most common element in fireplace charcoal. Additionally there was an increased incidence of browsers in the diet of the hunter–gatherers who used the shelter, which indicates an increase in shrubs consequent upon moister conditions than previously. The archaeological findings thus support the geomorphic evidence and jointly indicate increased precipitation and runoff as compared with the previous climatic phase.

By 1055 BP channels were being incised into flood plain deposits at Athol (Table 1). Incision is also evidenced at 953 BP in Carlisle's Hoek (Fig. 1; Lewis, 2002) and at 917 BP in Dinorben, where erosion into valley floor sediments resulted in the formation of the lowest river terraces in both valleys. Considerable runoff must have been necessary for incision to take place, indicating that the climate was relatively wet.

By 913 BP flood plain deposition was taking place at Tushielaw (Fig. 1, Table 4; Dollar, vide Lewis, 2002), indicating that stream flow was sufficiently powerful for transportation and deposition but not for incision into valley floor sediments. Gully erosion, which presently occurs on valley sides, post dates 3.1 m of slope wash accumulation on top of a bone dating to 3219 BP at Kopshoring, but the date of initiation of this erosion is unknown. Gully erosion may have been influenced by a reduction in vegetation cover on valley slopes due to changes in land use, thereby reducing the capability of slope sediments to withstand erosion when rain or snow melt caused valley side runoff.

By 775 BP pottery had been introduced at Colwinton (Table 3). Although Opperman (1987) surmised that it was used by hunter–gatherers, the pottery may have been associated with pastoralists and the introduction of domestic grazing animals to the area. Gully and other forms of valley side erosion, that presently supplies sediments for redistribution on valley floors (Dollar and Rowntree, 1995; Rowntree and Dollar, 1996), may have been exacerbated, or even initiated, by the grazing of these animals.

Flood plain deposition still continues, as at Athol. Commercial farming since the late nineteenth century, and the consequent heavy grazing and increased erosion of hillsides and increased sediment supply to streams, also appears to have caused accelerated channel instability in the upper reaches of the Kraai River (Rowntree and Dollar, 1996), and possibly elsewhere in the region.

The modern climate is that of a summer rainfall region with relatively cool summers and with winters in which frost is a regular occurrence. The landscape is dominated by grasslands, into which man has intruded patches of cultivated land. Additionally, along the sides of some of the major streams, as in reaches of the Langkloof Spruit and, to a lesser extent, the Sterk Spruit, people have introduced exotic trees, such as *Salix caprea* (Rowntree and Dollar, 1996).

10. Conclusions

Four climatic phases are evidenced in the region during the Late Glacial (Table 4), during which there were appreciable fluctuations of climate (Coetzee, 1967). These have been identified from palynological and, to a lesser extent, archaeological studies. They have not been recognised in the fluvial record. Eight climatic phases have been identified during the Holocene (Table 4), all but the first of which is apparent in the fluvial record. The earliest phase, of relatively dry conditions, is apparent in the palynological record (Coetzee, 1967) and is hinted at in the archaeological record (Opperman, 1987).

The fluvial record is dominated by deposition and the development of flood plains in the Early Holocene. There was a prolonged semi-arid phase in the Mid Holocene in which there is little evidence of aggradation or erosion, except near valley heads where aggradation occurred. The Later Holocene was marked by alternating flood plain erosion and deposition, especially since ca. 3200 BP. This pattern of flood plain accumulation in the Early Holocene and repeated incision and aggradation in the Later Holocene has already been identified elsewhere in the Eastern Cape, as at Howison's Poort near Grahamstown (Lewis and Illgner, 1998).

Prolonged Mid Holocene semi-arid conditions have been reported from various sites in the Karoo (Partridge et al., 1990), although they may have lasted longer in the Barkly East region of the Drakensberg than in other areas already examined. Pronounced increases in wetness have also been reported from the Karoo since about 5000 BP (Partridge et al.,1990) although the onset of Holocene wetness took place progressively later at higher latitudes and was delayed until 3500 BP (uncalibrated date) at Cango (33°S) in the Western Cape (Scott, 1993). The Barkly East area is at 31°S. A marked increase in wetness after about 2000 years ago has been reported from the Karoo and the eastern (summer rainfall) palaeoclimatic regions of southern Africa, with a lesser increase in the Southern and Western Cape regions (Partridge et al., 1990). This is reflected by the most recent phase of major incision into flood plains in the Barkly East region.

The Drakensberg of the Province of the Eastern Cape during the Holocene appear to have had characteristics of both the Karoo and the Eastern (summer rainfall) regions and to have fluctuated climatically between both regions. These fluctuations may have been due to ‘anomolous meridional circulations over southern Africa.’ (Partridge, 1997), which Tyson (1986) and Tyson and Lindesay (1992) ascribe to forcing by the tropical easterlies (causing extended wet spells) and expansion of the circumpolar vortex (causing decreases in annual rainfall).

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