Drainage Evolution in the Lake Disappointment Catchment, Western Australia – a discussion

J S Beard

6 Fraser Road, Applecross, Western Australia

Manuscript received May 2004; accepted May 2005

Abstract

Lake Disappointment, one of the largest playa lakes in Western Australia, lies in an interior basin at the lowest point of a catchment 600 km E-W by 500 km N-S. A major tributary in the NW, Savory Creek, is still intermittently active but most other drainage channels are dry. Except for occasional rocky ranges the country is dominated by linear sand ridges which are vegetated with spiny grasses inedible to stock, and make access difficult. The country is therefore unoccupied. The sand ridges are thought to date from the last glacial maximum when climate was windy and dry. Drainage channels were formed much earlier under wetter conditions and have often been obscured by sand so that mapping must depend on contours, on valley-bottom calcrete deposits, salt lakes and pans. The catchment features a major palaeochannel, the Disappointment Palaeoriver, extending due south from the lake and receiving tributaries from both east and west. It is situated along the geological boundary between Proterozoic rocks of the Western Shield and Phanerozoic sedimentary rocks to the east. Lake Disappointment has no outlet nor any obvious sign of one. It must originally have reached the Percival Palaeoriver to the north and previous authors have favoured an outlet running north-east from the Lake and then north to Lake Winifred. It is suggested here that the Disappointment Palaeoriver continued to the NW to join Savory Creek, then passing north to join the Rudall River which would have been the lower course of a major river draining the whole Disappointment catchment. Disruption of drainage was presumably caused by tectonic movement, either slight uplift of the ridges to the north, sinking of a basin at the lake site, or both. A date of Miocene for this event is suggested.

Keywords: drainage evolution, Lake Disappointment, palaeoriver, playa,

Introduction

This paper continues a series on drainage evolution on the Western Shield (Beard 1998, 1999, 2000, 2002, 2003), and in particular continues to the north the study in Beard (2002) which the area adjoins. The work involves an analysis of the geological, topographical and biological features of the catchment and from historical records working out the course taken by waterways in the past and how these have changed to the present day. Lake Disappointment lies at approximately 23° 30'S, 122º 45'E and is one of the largest playa lakes in Western Australia measuring 45 km north to south and averaging about 25 km east to west, thus covering more than 1000 km². It is situated in a basin at the lowest point of an extensive catchment 600 km east to west and 500 km north to south, of which the southern section was partly dealt with in Beard (2002). At the present time most drainage channels in the catchment are dry or flow briefly after rain, having been formed in more pluvial periods in the past. The lake lies in the phytogeographic region known as the Little Sandy Desert (Beard 1969), bounded by the Great Sandy Desert on the north, the Gibson Desert on the east and the Pilbara region on the west. The catchment itself falls partly in the Little Sandy Desert region and partly in the Gibson Desert. Figures 1 and 2 show it in its phytogeographic and geological settings. Owing to the remoteness of the area the lake was not found and named until 1897. Ernest Giles on his west to east desert crossing of 1878 passed to the south on lat. 24° and did not sight it, while the Calvert Exploring Expedition of 1896 travelled from south to north on the west side of the lake, without sighting it. The lake is not mentioned in either account of this expedition (Hill 1905, Steele 1978). It was left to Frank Hann in the course of an exploring/prospecting expedition travelling east from Nullagine to sight and name the lake on 20 April 1897. Hann had travelled from Nullagine across the Davis River to the Coolbro Creek, then to the southeast following and naming the Broadhurst Range, crossing the upper Rudall River and the Cotton Creek as far as the Harbutt Range where he turned south to the Mckay Range. Here to the southward he sighted a large lake ten miles distant, and they made their way to it next day, but "found it was all white salt….it is the largest thing in lakes I ever saw… I shall call the lake Lake Disappointment as I was disappointed in not finding water in it" (from Frank Hann's diary quoted by Donaldson & Elliott, 1998).

The country surrounding the lake is uninhabited and very remote, largely because it is covered for the most part by linear sand ridges through which occasional rocky ranges protrude. The Canning Stock Route, used at one time for driving stock south from the Kimberley and today by venturesome tourists in 4-wheel drive vehicles, passes from the Durba Hills round the west and north of the Lake, and a similar east-west driveable track, the Talawana track, passes on the north of the Lake, joining tracks in the Gibson Desert to the outside world at Talawana Station. The Aboriginal population reported by the 19th century explorers later gradually withdrew to settlements on the fringes of the desert, mainly to the

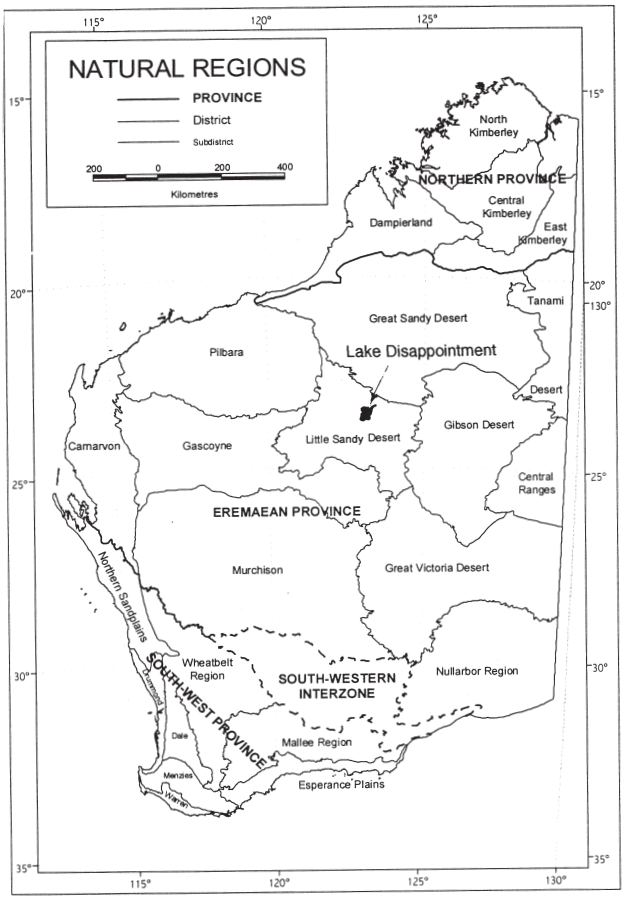

Figure 1. Lake Disappointment in its phytogeographical setting. Natural Regions after Beard & Sprenger (1964).

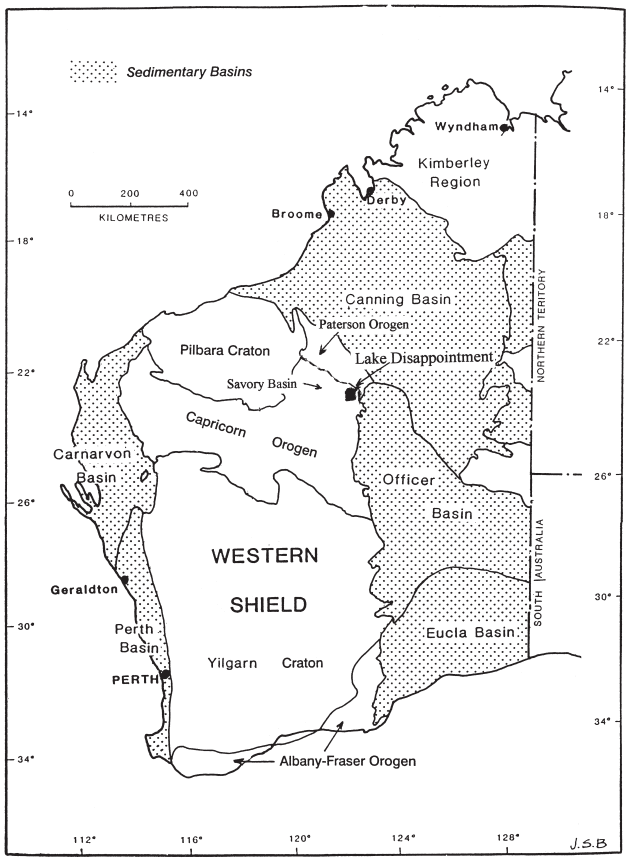

Figure 2. Lake Disappointment in its geological setting. From figure in Beard (1998) based on Figures. 3.1 and 4.1 of Anon (1990).

Jigalong community (see map, on Robertson sheet).The country has not been subsequently developed for pastoral use largely because it is covered by "hard spinifex", spiny species of *Triodia* which are inedible by stock. The general cover of sand ridges, also, makes access difficult.

It is difficult to map precisely the boundaries of the catchment because much of the topography is so obscured by sand ridges that drainage lines and watersheds are hard to trace. The catchment features a main north-south axis, formed by the Disappointment Palaeoriver, extending south from the lake for 300 km, which receives palaeotributaries from both east and west (Fig. 3). The principal of these are the Keene Palaeoriver on the east and the Ilgarari Palaeoriver (Williams 1995) on the west, both over 300 km long. In the northern part of the region and flowing directly into the lake from the north-west, there is a well-marked intermittent stream, Savory Creek. The lake itself has no present outlet nor any readily discernible former outlet, so that it seems likely that it has been formed as a result of some tectonic movement, either sinking of the lake basin or uplift of ridges to the north, or both of these.

Methods

The southern and eastern parts of the catchment had been mapped and studied as part of a similar paper on drainage evolution in the Gibson and Great Victoria Deserts (Beard 2002), and this paper extends the study to the north and west. The latest series of 1:250,000 topographic maps was examined, drainage lines and watersheds were marked and transferred to compilation sheets at 1:1,000,000. Since in sandhill country it is often difficult to distinguish such features accurately, reference was also made to the 1:250,000 Geological Survey reports which normally include a "physiographic diagram". These are not standard but in various ways indicate physical features and drainage lines. Where no actual creeks are shown, drainage lines can be inferred from valley-bottom calcrete deposits. The map in Figure 3 is the result of this compilation. In addition, a request was addressed to the Water and Rivers Commission for any available borehole data from within 100 km radius of Lake Disappointment, and figures were supplied from 28 bores and/or wells within this area, all on the west and north sides of the lake. Unfortunately, the remoteness of this area and the lack of mineral prospects meant that all had been sunk to relatively shallow depths in the quest for water alone, and in particular there were no bores in the bed of the lake. Of the 28 bores/wells, four had no depths recorded, and 11 were pre-existing wells of the Canning Stock Route between bore/well numbers 15 and 26. Some of these had perhaps been deepened, and reached depths of 16 m. Of the rest, only five went to depths of more than 30 m, with a maximum of 65m. Average depth of all bores/wells was 19.20 m. Drilling was through surface sand into sandstone or calcrete. A

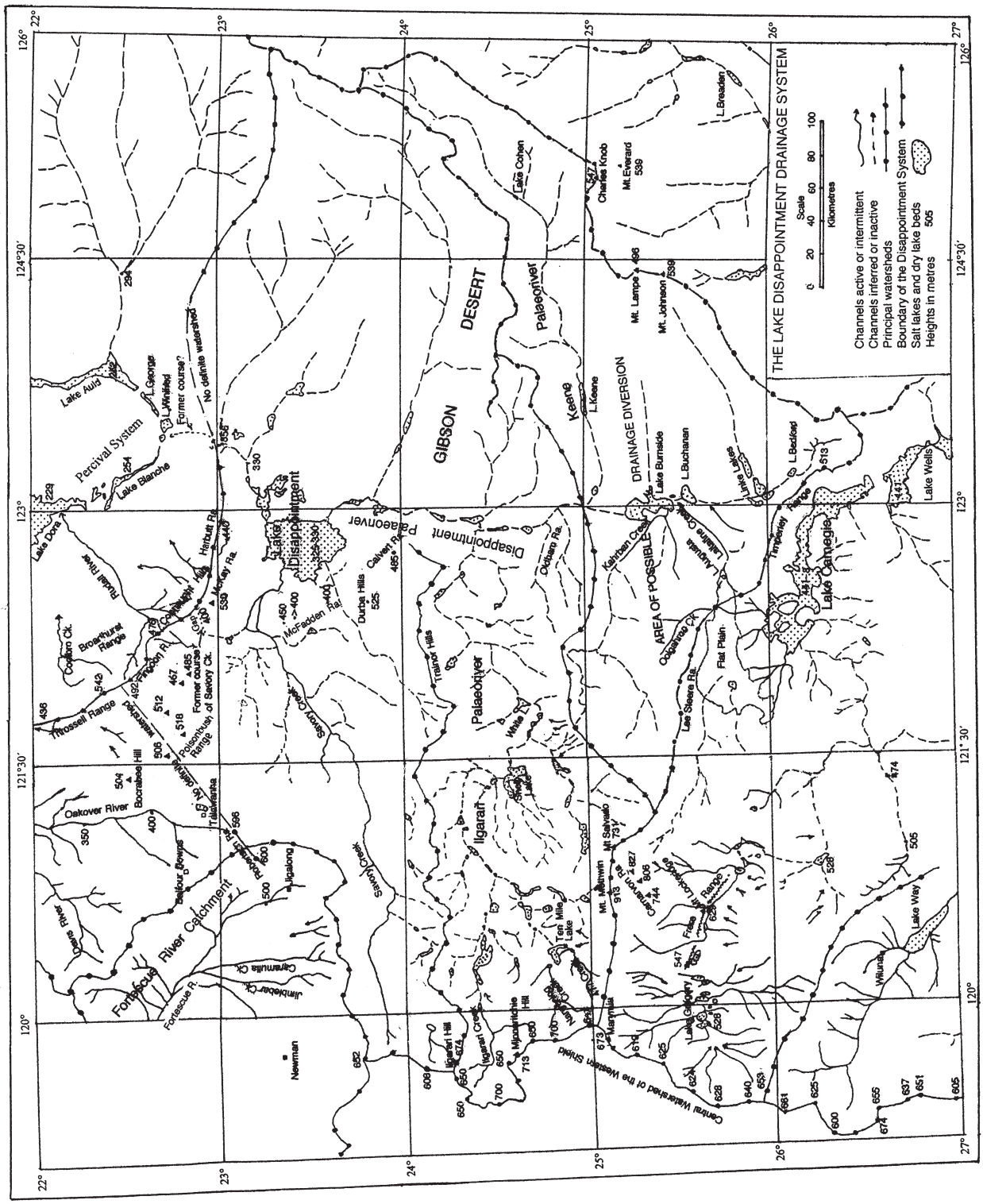

Figure 3. The Lake Disappointment Drainage System with the entire catchment outlined in blue.

complete study of Lake Disappointment and the history of its formation would require a drilling programme in the lake bed to determine the depth, age and nature of buried sediments, and this is not at present available.

Features of the Area

The name Little Sandy Desert was proposed by Beard (1969) for "a sector of the desert which appears to have been nameless hitherto and is chosen to reflect the fact that its character is much the same as that of the Great Sandy Desert from which it is partly isolated by a chain of hills and ranges". Both of these Deserts were described as "an impenetrable waste of sandhills"(ibid.), but the Little Sandy differs in being underlain by Proterozoic rocks instead of Tertiary sediments. This basement forms rounded hills and mountains emerging from a sea of parallel sandhills each of which may be as much as 160 km long and spaced at six to the kilometre. The bed of Lake Disappointment is at 325–330 m above sea level and the catchment slopes down towards it from all sides from a maximum height at Mt. Methwin of 913m.

Climate

This is a desert area, in which high day-time summer temperatures of 45°or more can be experienced as well as night-time winter temperatures below freezing. Rainfall is about 200 mm per annum and not so low as to create areas without plant cover. Rain can be received both from the relics of tropical cyclones which have come in from the sea off the north-west coast, or from an extension of the late summer-autumn rainfall regime of the Murchison region to the south. In both cases rainfall is very erratic, and long droughts are known to occur.

Vegetation

The vegetation of the area has been mapped at a scale of 1:1,000,000 by Beard (1974,1975) with explanatory memoirs, and there are sections on the Little Sandy Desert in Beard (1969, 1990). Broadly, the whole country is covered by Hummock Grassland formed by species of *Triodia*, spiny grasses growing in isolated clumps, with scattered shrubs and small trees. Hills are generally very rocky so that vegetation is sparse. There are small trees about 4.5 m of the mulga *Acacia aneura* with shrubs of *Grevillea, Hakea* and *Thryptomene* but there are also areas of hummock grassland consisting of both *Triodia basedowii* and *T .melvillei.* Scattered larger trees of *Eucalyptus camaldulensis* occur here and there. The gullies have *E. microtheca* and *Callitris glaucophylla.* The sandplains carry spinifex country of *Triodia basedowii* with numerous tall shrubs, principally of *Hakea suberea* and *Acacia* spp. with *Hakea rhombale.* On sand ridges the general cover is of *Triodia schinzii* with the ericoid shrub *Thryptomene maisonneuvii* sharing dominance on the flanks of the dunes. The desert bloodwood *Eucalyptus chippendalei* occurs as scattered trees along the dune crests with shrubs of *Acacia ligulata* and *Grevillea stenobotrya.* Groves of the desert oak, *Casuarina decaisneana*, may occur in depressions between the sandhills.

Geology

The geological setting of the Lake Disappointment catchment is shown in Figure 2. In simple terms, the geology of Western Australia (excluding the Kimberley) can be interpreted as a central massif of Proterozoic and Archaean age, bordered on the north, west and east by sedimentary basins. More detailed mapping shows the Shield divided into two cratons, the Pilbara Craton in the north and the much larger Yilgarn Craton in the south, divided by a belt known generally as the Capricorn Orogen which can be further subdivided into Proterozoic basins and orogens. The Little Sandy Desert which largely corresponds to the Lake Disappointment catchment is situated at the north-west corner of the Shield, and is underlain geologically by the Savory (geological) Basin (Williams 1990) and the Paterson Orogen (Williams & Myers 1990), both containing Late Proterozoic rocks. These are bounded on the north by the Canning Basin and on the east by the Officer Basin, both containing Phanerozoic sediments.

The Savory Basin mainly comprises gently east-dipping medium to coarse-grained sandstone and pebbly conglomerate. For the most part bedrock is poorly exposed and limited to marginal ranges such as the Robertson Range or to scattered rocky hills such as the Poisonbush Range. In general the topography is monotonous and obscured by linear sand ridges. The surface sand which covers most of the Little Sandy Desert in this way is considered to have been derived from the underlying sandstone. A very detailed description of the sand dune formations in the area was included by Williams (1995) in the geological survey report on the map sheet Bullen. It is thought that the dunes were formed by wind action during the last glacial maximum at 13–25 Ka, most likely during the intense phase at 15–18 Ka.

The Paterson Orogen consists of a belt of metamorphic and igneous rocks with a long and complex history of multiple deformation and metamorphism (Williams & Myers 1990) which form a series of low rocky ranges trending NW to SE. These will be found on the map in Figure 3 as the Throssel and Fingoon Ranges, the Connaught Hills and the Harbutt Range, rising to heights of 450 to 550 m, with a relief of 100–200 m. The age of these rocks is estimated as Proterozoic, and rather older than those in the Savory Basin. The geological history shows that this topography is of long standing, since there are former valleys filled locally with Permian glacial sediments. One can envisage that during the ice-age conditions of the Sakmarian stage of the Permian there were glaciers flowing off the Western Shield to the Canning Basin, where Permian sediments are widely distributed. While interesting, this history has no bearing on modern conditions.

The Disappointment Palaeoriver

This portion of the Lake Disappointment system has been described in a previous paper (Beard 2002) from which some of the conclusions are repeated here. The channel leading north into the lake was named the Disapointment Palaeoriver by van de Graaf *et al.* (1977) who connected it to Lakes Carnegie and Wells. Beard's (1973) map had shown this drainage, south of the confluence with the Keene Palaeoriver which comes in from the north-east, as flowing originally to the south and finding an outlet to Lake Throssel (outside Figure 3 to the south-east). Van de Graaf *et al.* (1977) agreed with this as the original alignment but considered that the

system north of Lake Wells had been reversed to the north at a later stage. A notable feature of this drainage line is that it is situated along the geological boundary between the Archaean and Proterozoic rocks of the Western Shield and the Phanerozoic rocks of the sedimentary basins to the east. Beard (2002) suggested that this drainage line was originally formed after the end of an Early Cretaceous transgression by rivers which continued to discharge eastward off the Western Shield and were impounded at the break of slope at the former shore line. It is probable that flow took place partly to the north and partly to the south.

Examination of the maps shows a valley floored here and there by salt lakes and pans extending south from Lake Disappointment. From the lake bed the valley trends uphill to the 400 m contour in 100 km (0.75 m km^{-1}) and then at a lower grade to Lake Burnside at 425 m in another 90 km (0.28 m km^{-1}) – (Fig. 4). South of lake Burnside the alignment continues uphill to Lake Bedford at 443 m and beyond to a source on high ground at about 480 m. Beard's evidence from the mapping showed clearly that this valley represented the Disapppointment Palaeoriver, that the tributary Keene River joined it, but that there is not and has never been any outflow from Lake Carnegie to Lake Disappointment. Lake Carnegie was shown to have discharged to the south via Lake Wells. On the other hand the south-westerly alignment of the Keene Palaeoriver suggests that it originally had an outlet to the south and Beard (2002) suggested that it had originally found its way into Lake Carnegie at its north-western end, but was later diverted by tectonic movement northward into Lake Disappointment.

The drop at the north end of the palaeoriver into Lake Disappointment is much steeper than the grade higher up in the catchment, so much so as to suggest a downwarp at the site of the lake. However the opposite may also have been the case, *i.e.*, uplift of the upper part of the catchment. Beard's (2002) study of the geomorphology of the Gibson and Great Victoria Deserts showed that these had been subject to repeated tectonic movements from the early Cretaceous onward with alternating periods of uplift and depression coinciding with such movements in the Eucla Basin. These movements apparently weakened towards the north and while the southern part of the Disappointment Palaeoriver was evidently included, the northern part and the Lake itself were not. A profile of the Disappointment Palaeoriver is included here based on the 2002 paper (Fig. 4).

On the west side a substantial palaeoriver came in to join the Disappointment Palaeoriver, but downstream of the Keene river, and hence not affected by the same tectonic movement. This is the Ilgarari Palaeoriver, usefully named, described and mapped by Williams (1995) in the revised edition of the geological survey of the map Buller. This begins as a combination of small creeks rising like Savory Creek in the Central Watershed of the Western Shield, and terminating in salt lakes on reaching sandhill country. These include the Ilgarari Creek itself which penetrates as far as Terminal Lake and the Nanyerinni and 477 Creeks which empty into the Beyondie-Ten Mile Lake system. Strings of disconnected salt lakes and patches of valley calcrete connect and continue these drainages to the east eventually to join the Disappointment Palaeoriver.

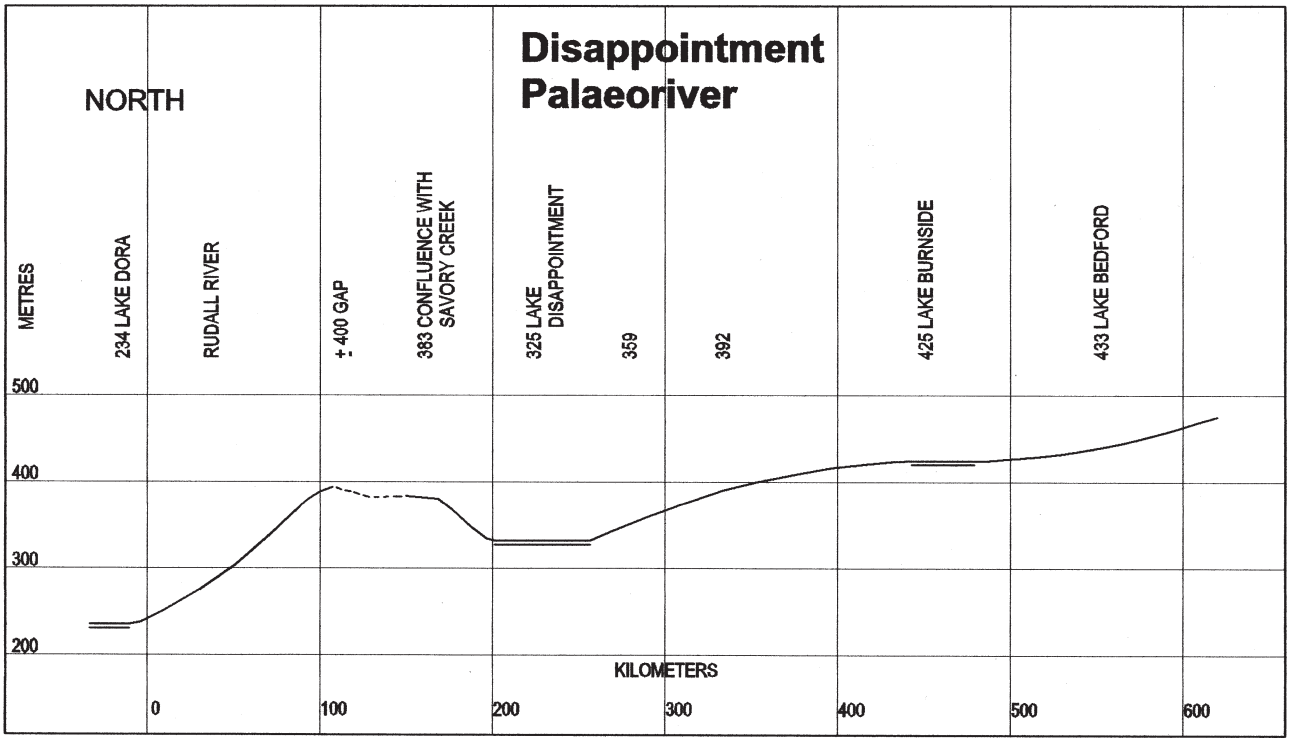

Figure 4. Profile of the Lake Disappointment Palaeoriver based on Fig.5A in Beard (2002) extended further to the north to include line of suggested former outlet joining the lake to the Percival Drainage System at Lake Dora, now obstructed by tectonic movement.

Savory Creek

Savory Creek has features which differ from other tributaries in this system and deserves special mention. It is unique for the area in being a still active river. The origin of the name is given in a note in Fieldbook 43 of A.W.Canning in 1904 when he was on a reconnaissance for the later Canning Stock Route, saying that it was named after a Mr.Savory who held a pastoral lease in the area. From its source to the lake, Savory Creek is 320 km in length and flows mostly through sandhill country. It rises in the Central Watershed of the Western Shield at a spot height of 646 m and after quickly levelling off at about 600 m it flows for the next 260 km at a steady grade of about 1 m per km, heading first east and then north-east. Along this stretch it has a well-defined branching channel incised to a depth of 20 m in places, and containing thick vegetation and pools of relatively fresh water. On reaching what is evidently a flat area at a spot height of 383 m where flood-out conditions prevail, the Creek turns to the east and divides into several widely separated saline channels up to 10 m deep, which support little vegetation apart from samphire communities (Williams & Williams 1980). After 20 km these channels unite and reach Lake Disappointment in another 30 km. This behaviour suggests strongly that Savory Creek at one time continued to flow to the north through a gap in the ranges, round the western end of the McKay Range to reach the Rudall River. Calcrete deposits are evidence of former drainage lines along this route but at the present time the slopes head south-east towards Lake Disappointment. This calcrete is shown as a surface deposit in the geological survey (Bagas *et al.* 2000) and is not in inverted relief which would be evidence of greater age. Intermittent drainage comes in to Savory Creek from the north at the point where it takes its turn to the east. This comes from a small lake some 10 km to the north, and above this there are calcrete deposits probably representing palaeochannels which head to the southeast from the direction of the Poisonbush Range. However these could have been formerly picked up by Savory Creek on its way to the Rudall River and later reversed by tectonic movement.

In the geological survey report (Williams & Williams 1980) it is suggested that the salt lakes are migrating to the east. Fresh bedrock occurs on the eastern side of Lake Disappointment whereas extensive kopi and sand-buried lake deposits fringe the western margin. Low breakaways also occur on the western side of the McFadden Ranges. This behaviour is contrary to that observed in the southern part of the State.

Outlets from Lake Disappointment

Figure 5 has been designed to show the area north of the lake in more detail. Previous authors (Williams & Williams 1980, Crowe & Chin 1979) have shown the lake with an outlet to the Percival Palaeoriver in the Canning Basin, connecting at Lake Winifred south of Lake Auld, which has an elevation of 261–263m. These are about 65 m lower than Lake Disappointment but there is no obvious palaeochannel between the two. A line of lakes and pans leads to the east from the north-east corner of Lake Disappointment, but without any indication of an outlet to the north to Lake Winifred. In any case a col 30 m higher than the lake stands in the way of this outlet. It is equally possible that the line of lakes and pans represents former drainage of tributaries from the east into the lake. It seems logical to conclude that in the distant past the lake or the river which preceded it must have had an outlet to the Percival System at some point which could have been as described above or via Savory Creek to the Rudall River. The Percival has in the past been the major drainage outlet for this whole area. It seems less likely that the lake basin has existed as an interior basin since a geologically early date and this question cannot be resolved until borehole data may become available to reveal the depth and dates of accumulated sediments.

The 1999 geological map of Western Australia (Anon 1999) clearly shows the Percival Palaeoriver, named as such, by showing lakes and channels in blue and by mapping of alluvial bottom-land deposits. It rises far to the east at Wilson Cliffs on high ground near the State boundary at lat. 22° 00'S, long. 127° 30'E, and heads to the west for 300 km, then turning to the south along the length of Lake Auld for 140 km., with heights of 261–263m. Turning then to the SW through the smaller Lakes George and Winifred it swings to the NW along Lake Blanche (254m) to Lake Dora (234–229m), a distance of 90 km. From Lake Dora in a NW direction the channel heads for Lake Waukarlykarly (233m), 140 km away. There are no more lakes and pans but the alignment is shown as a valley by the contours, floored by calcrete deposits. It passes north of Telfer Mining centre between the Malli Hills 331m and Kaliranu Hill 334m. There is very little fall along this stretch. The channel leaves Lake Waukarlykarly in a westerly direction for 40 km, then bears to the NW for 100 km, where it unites with the Oakover River north of the Isabella Range. Although thus reduced to the status of a tributary to the Oakover and de Grey active rivers of the Pilbara, the Percival is one of the most substantial drainage lines in the State with a length of 800 km.

Discussion

It seems clear that Lake Disappointment was originally formed by being impounded when outlets were obstructed by various means, possibly obstruction by dunes, deflation or tectonic movement. This last seems the most probable. Such movements on the fringes of the Western Shield have been reported elsewhere (Beard 1999,2000,2003). In this case the shape and situation of the lake suggest the sinking of a basin which received flow from the Disappointment Palaeoriver when it was active, and accumulated sediment from that source. The sinking of this basin evidently affected Savory Creek also, diverting the flow into the lake. It seems likely that drainage from the east was drawn into the lake in the same way. It seems likely also that tectonic movement was not confined to the sinking of the basin, but involved some uplift of the ranges in the Paterson Orogen. These are arranged north-west to south-east along the flank of the Western Shield but there is only one substantial river, the Rudall River, draining them towards the Percival system. Why is this? There seems to be no reason why the Connaught Hills should have given rise to such a stream when the other ranges have not. The Rudall River is aligned with Savory Creek and it is suggested here

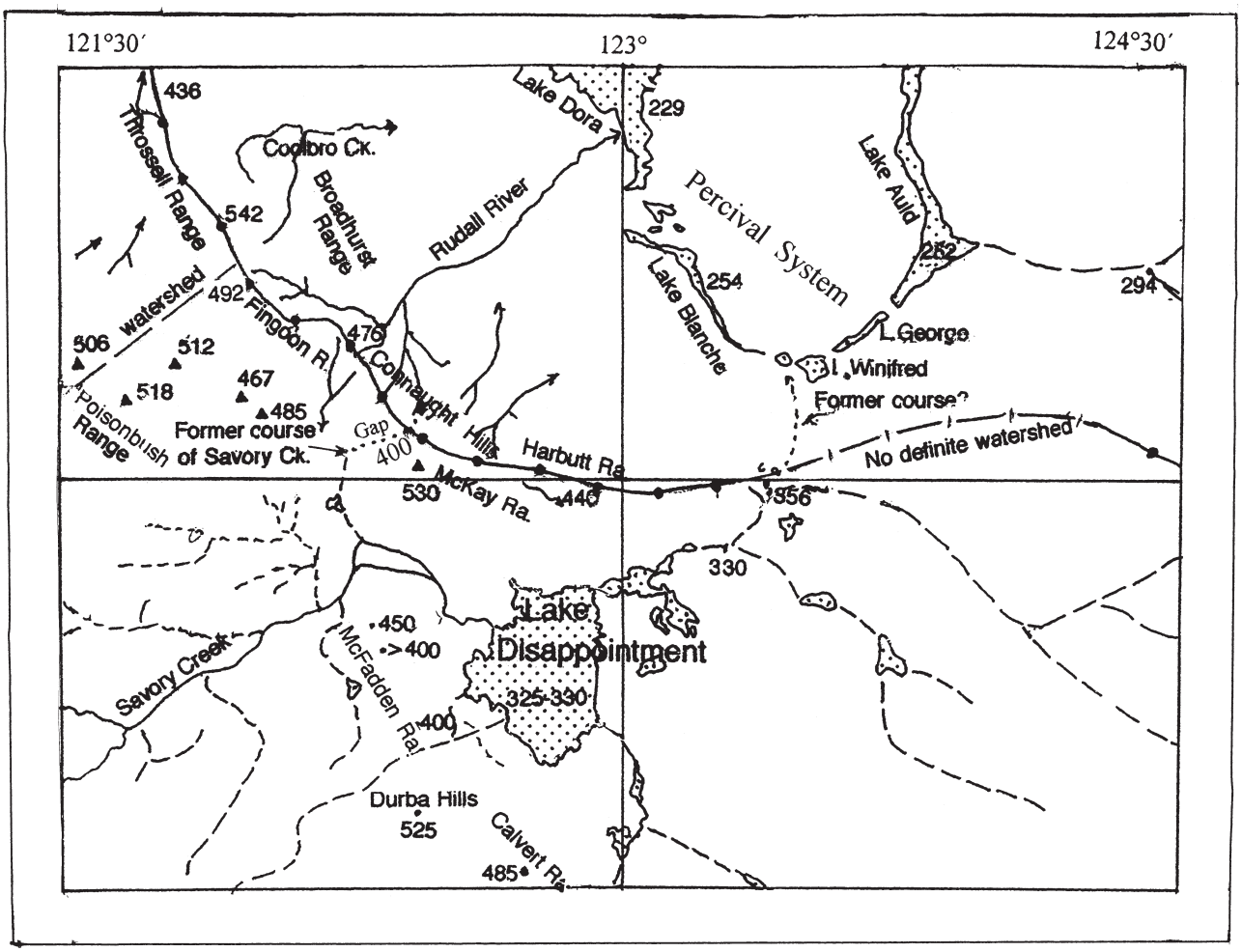

Figure 5. Larger scale map of the area between the Disappointment and Percival Systems where former outlets were located.

that Savory formerly continued to the north, so that the Rudall is the remnant of its lower course. The highest point today on the probable course joining the two, where "Gap" is marked on the map in Figures 3 & 5 is at about 400 m. If Savory Creek continued to this spot at the same grade as it maintains for 100 km upstream from where the 400 m contour is marked on the map, the height would be about 350 m. It is therefore concluded that an uplift of about 50 m occurred, reversing the upper Savory into Lake Disappointment. It seems probable that the same thing happened north-east of Lake Disappointment where drainage flowing to the north from the Gibson Desert plateau to join the Percival system below Lake Winifred was diverted into the lake. While this seems to show that there has been tectonic uplift affecting the Connaught Hills and associated ranges, there would appear also to have been down-warping of the lake area, because the point where Savory Creek turns to the east towards the lake is some 60 m higher than the lake surface, and the actual lake bed, filled with sediment, is lower still. On the other hand, if we look at the profile of the Disappointment Palaeoriver in Figure 4 which extends the original diagram in Beard (2002) to include the suggested outlet to the Rudall River, and draw a straight line from Lake Burnside to Lake Dora, it is found that the line passes through the north end of the Lake. This suggests that there has been relatively little subsidence of the lake bed compared with the uplift of the Connaught Hills and other ranges, which would be of the order of 100 m.

Some evidence for the dating of this event can be derived from the fact that the rivers concerned were already losing their erosive capacity. If a tectonic barrier is raised across a major drainage system as the Savory-Disappointment system must have been early in the Tertiary, then the river can keep pace with uplift and carve an antecedent gorge. There is no sign of this, so that a later date of Miocene is suggested.

Conclusions

For final conclusions to be drawn about the development of this area it would be necessary to have borehole data from the bed of the Lake to show the thickness and nature of sediments and their age, and these are not at present available. It is tentatively concluded that the Rudall River was originally the lower course of Savory Creek which continued to flow to the north through the Connaught Hills but has been diverted into Lake Disappointment by a combination probably of uplift of the ranges in the Paterson Orogen and of sinking

of a basin on the site of the Lake. Prior to that event the Disappointment Palaeoriver flowed to the north-west across the present site of the lake to unite with Savory Creek and Rudall. While not conclusive, the data do appear to show that tectonic movement occurred. It is impossible at present to date this event accurately but a date of Miocene is suggested.

Acknowledgment: I am indebted to Prof. C.D. Ollier for critically reading this paper while in production.

References

Anon 1990. Geology and mineral resources of Western Australia. Geological Survey of Western Australia, Perth. Memoir 3.

Anon 1999. Western Australia Atlas of Mineral Deposits and Petroleum Fields. Geological Survey of Western Australia, Perth.

Bagas L, Williams I R & Hickman A H 2000. Explanatory Notes on the Rudall geological sheet, revised edition. Geological Survey of Western Australia, Perth.

Beard J S 1969. The natural regions of the deserts of Western Australia. Journal of Ecology XX: 677–711

Beard J S 1973. The elucidation of palaeodrainage patterns in Western Australia through vegetation mapping. Vegetation Survey of Western Australia Occasional Paper No.1. Vegmap Publications, Applecross.

Beard J S 1974. The vegetation of the Great Sandy Desert area. Vegetation Survey of Western Australia 1:1 000 000 Series No.2. University of Western Australia Press, Nedlands.

Beard J S 1975. The vegetation of the Pilbara area. Vegetation Survey of Western Australia 1:1 000 000 Series No.5. University of Western Australia Press, Nedlands.

Beard J S 1990. Plant Life of Western Australia. Kangaroo Press, Sydney.

Beard J S 1998. Position and developmental history of the central watershed of the Western Shield, Western Australia. Journal of the Royal Society of Western Australia 81: 157–164.

Beard J S 1999. Evolution of the river systems of the south-west drainage division, Western Australia. Journal of the Royal Society of Western Australia 82: 147–164.

Beard J S 2000. Drainage evolution in the Moore-Monger System, Western Australia. Journal of the Royal Society of Western Australia 83: 29–38.

Beard J S 2002. Palaeogeography and drainage evolution in the Gibson and Great Victoria Deserts, Western Australia. Journal of the Royal Society of Western Australia 85: 17–29.

Beard J S 2003. :Palaeodrainage and the geomorphic evolution of passive margins in Southwestern Australia. Z.Geomorph.N.F. 47: 273–288.

Beard J S & Sprenger B S 1984. Geographical Data from the Vegetation Survey of Western Australia. Vegetation Survey of Western Australia Occasional Paper No.2. Vegmap Publications, Applecross.

Canning A W 1904. Field book no.43, pp.15. Unpublished.

Crowe R W A & Chin R J 1979. Explanatory notes on the Runton geological sheet. Geological Survey of Western Australia, Perth.

Donaldson M & Elliott I 1998 (eds). Do Not Yield To Despair. Frank Hann's exploration diaries in the Arid Interior of Australia 1895–1908. Hesperian Press, Perth.

Giles E 1995. (reprint edition) Australia twice traversed. Hesperian Press, Carlisle, W.A.

Hill J G 1905. The Calvert Scientific Exploring Expedition (Australia 1896). London & Liverpool.

Steele W & C 1978. To the Great Gulf: the surveys and explorations of L A Wells. Lynton Publications, Blackwood, South Australia.

Van de Graaf W J E, Crowe R W A, Bunting J A & Jackson M J 1977. Relict early Cainozoic drainages in arid Western Australia. Z. Geomorph. NF 21: 379–400.

Williams I R 1990. Savory Basin. *In*: Geology and Mineral Resources of Western Australia. Western Australia Geological Survey, Memoir 3, pp.329–334.

Williams I R 1995. Explanatory notes on the Buller geological sheet (revised edition). Geological Survey of Western Australia, Perth.

Williams I R & Myers J S 1990. Paterson Orogen, *in* Geology and Mineral Resources of Western Australia. Western Australia Geological Survey, Memoir 3, pp 274–286.

Williams I R & Williams S J 1980. Explanatory notes on the Gunanya geological sheet. Geological Survey of Western Australia, Perth.