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Archaeological Interpretation of Alluvial Gold Tailing Sites, Central Otago, New Zealand

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ABSTRACT

Tailings resulting from early alluvial goldmining ventures are significant site types in some areas of New Zealand. This paper outlines how the various tailing configurations were constructed by the miners in Central Otago and describes both their forms and value as archaeological sites and landscape features. Mining methods were strongly influenced by the topography and the availability of water, but human knowledge, regional patterns and in some instances ethnic preferences can be distinguished. The Otago miners had a wide cultural background, originating from the United States, Russia, Europe, China and Australia. Many had accumulated their mining experience in the western United States and Victoria, Australia. Detailed recording of alluvial tailing sites in the Upper Clutha district of Central Otago has shown that significant inter- and intra-regional patterns can be discerned. It is anticipated that regional patterning could be defined and gainfully analysed in other gold mining districts.
Keywords: GOLDFIELDS ARCHAEOLOGY, ALLUVIAL TAILING SITES, RECORDING, TYPOLOGY, INTERPRETATION.

INTRODUCTION

In the Upper Clutha area, extensive recording of predominantly historic sites has been undertaken over the past three years during the course of an archaeological programme associated with the Clutha Valley Development hydro-dam construction project (Ritchie 1979a). Over 1700 sites have now been recorded, including some 500 former mining sites. Several configurations of alluvial tailings, reflecting different mining techniques, are now recognised, and all such sites are now recorded by type. A typology is presented which, despite its regional origins, may have wider application.

No attempt has been made to place the various tailing patterns in a chronological or evolutionary order of development because, in the Upper Clutha area at least, there is no firm evidence of such trends. The potential for recovery of information by subsurface excavation within tailing sites is minimal except where there are associated habitations. Rather, their value lies in the fact that the various recognisable configurations are field evidence of how a particular area of ground was worked in the past. Accurate interpretation and assessment demands both an appreciation of the nature of gold deposition and an understanding of the mechanics of gold recovery (Gordon 1906). These factors are reflected in the morphology of mining sites, the most visible evidence being tailing deposits and mining scars.

ALLUVIAL GOLD DEPOSITS

Alluvial gold accumulates in gravel deposits in terraces and flats, the gravel being derived mostly from fluvial action and erosion in the adjacent mountain country. Gold is rarely evenly distributed throughout the whole of an alluvial deposit but tends to concentrate in layers or horizons termed leads, which form where more turbulent stream currents remove the lighter material and allow the heavier gravels and metallic substances to concentrate on or near the bed. Leads of gold-rich alluvium may run for considerable distances and be confined to only part of the course of both present and fossil river or stream channels.

The nature of a lead reflects varying hydraulic factors such as the current strength, imbricate layering of gravels, cut and fill bedding and scouring (MacPherson

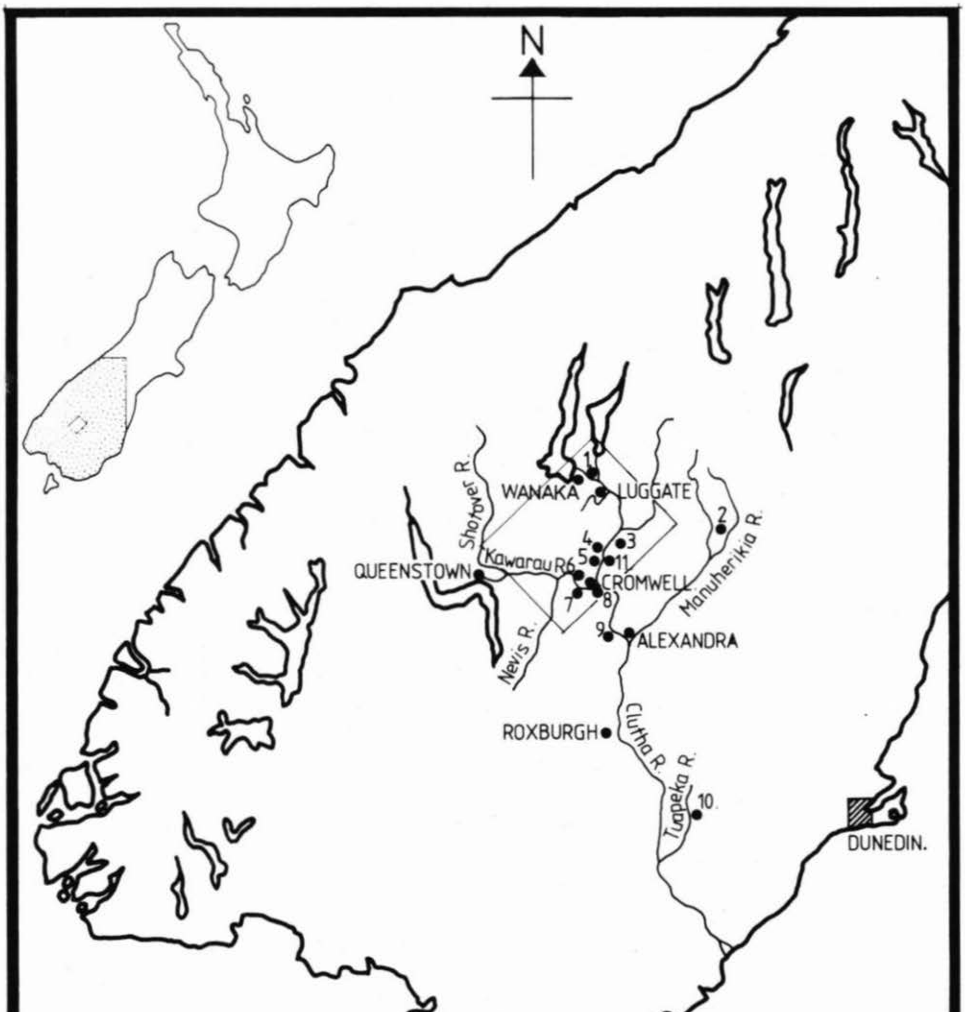

Figure 1: Map of southern New Zealand showing location of sites and localities mentioned in the text. The rectangle delimits the Upper Clutha-Kawarau area.

1. Albert Town
2. St Bathans
3. Bendigo
4. Smallburn
5. Lowburn
6. Kawarau River Tailings
7. Bannockburn sluice-faces
8. Cornish Point
9. Earnscleugh dredge tailings
10. Gabriel's Gully
11. Northburn Tailings

1933:262), and to a lesser extent physical factors such as the nature of the river or stream bed. Fluctuating water flows alternatively free and trap the gold so that river channels have acted as "natural sluice boxes" over thousands of year. The final extraction of the accumulated gold has required much human ingenuity.

A BRIEF OUTLINE OF TECHNOLOGICAL DEVELOPMENTS IN ALLUVIAL GOLD MINING

At the outset of gold mining in New Zealand it was possible for miners to earn a livelihood by working shallow alluvial deposits by panning, cradling or box-sluicing, i.e. agitating gold-bearing gravel in water-filled containers, resorting to tunnelling and shafting in deeper deposits. As the easily worked ground became exhausted, attention was directed towards labour saving devices, in particular the use of water to break down gold-bearing deposits.

Unpressurised water was used initially, the terrace margins being broken down by the action of the water flowing over them, aided by the use of bar and pick. This method was known as ground sluicing. However, these operations were generally short-lived due to difficulties in disposing of the eroded debris. Hydraulic sluicing, a technique using a stream of water directed under pressure against a terrace, was introduced into New Zealand by the Californian diggers. The water was conveyed to a working face by a pipeline and directed through a monitor (a movable nozzle). This method did away with much of the pick work necessary in ground sluicing, and was the only practical method to cope with the vast amounts of sub-economic gravel that often had to be removed to reach deep leads within terraces. Hydraulic sluice workings generally have steep working faces (compared to ground sluicing) because the water was directed upslope on to the face which was progressively cut down to the gold bearing strata.

In 1880 J. R. Perry, working in Gabriels Gully in the Tuapeka district, introduced hydraulic elevating (McIntosh 1906:212, Salmon 1963:226). Elevating enabled the working of deposits that were too deep to allow the disposal of washdirt and tailings by the means of gravity (Type 10, see below). The loosened material was lifted from the mining area to adjacent high land where it was run through sluice boxes; the tailings were then conveyed to dumping areas.

Water races were cut at elevations calculated to afford the necessary hydraulic energy to work gold deposits in many localities. The extent of terrace gold working was determined as much by the availability of water, as it was by the gold concentration in the ground. While sluicing was generally declining towards the turn of the century, the advent of dredging provided a yet more effective method for working river flat and river channel alluvial gold deposits. However, while sluicing technology had improved markedly, it was some years before problems in dredge design were overcome (Salmon 1963:231). The pertinent developments in dredging technology are outlined in the section headed Type 11. From an archaeological standpoint, the significant factor common to all these alluvial mining techniques is that they left distinctive marks on the landscape in the form of tailings and mining scars.

TAILINGS

The term "tailings" has a wide variety of accepted meanings (Thrush 1968:1116). In early mining usage it was used to describe sand, gravel, cobbles and other materials which "came out the tail end" after passing over the gold recovery riffles in the course of sluice mining. The clays, silts, sands and fine gravels were generally carried away from a site in a nearby creek or river (which often aggraded) or accumulated on lower ground as fans. Thus alluvial tailing sites are composed primarily of the visually obvious coarser material, the cobbles and boulders, which remain at a mining location. Tailings are also produced during hard rock mining in the form of waste or refuse rock dumped near mine adits and as accumulated spoil resulting from the washing, concentrating or crushing of ore (Thrush 1968:1117). The hard rock tailings are, however, beyond the scope of this paper.

An examination of the mining literature indicates that a considerable amount has been written on the hydraulic and engineering aspects of alluvial mining but, other than basic advice on such matters as the construction of sluice boxes and the paving of tailraces, very little appears to have been recorded on the specific placement of tailings.

In the following section various alluvial tailing configurations recognised in the Upper Clutha area are described, followed by an analysis of the tailing patterns.

TYPE 1: HERRINGBONE TAILINGS

Tailings of this type, if neatly stacked, are generally accepted as the most visually interesting form because of their symmetry. The characteristic "herringbone" pattern was produced by the hand stacking of cobbles and boulders uncovered within terrace gravels during sluice mining operations (Fig. 2). The stones were stacked in parallel lines at angles to a central tailrace, the working face encroaching from the lower end of a claim. This offered the minimum impediment to the sluice water flow which carried the gold bearing sediments down the tailrace to a sluice box where the gold was trapped in riffles or by some other means. The finer debris was washed through a sludge channel or tailrace into an adjacent river or formed fans below the workings. Cobbles and boulders tended to block the tailraces and trap the gold before it reached the riffles, so the stones were handstacked into rows to enable the system to work as efficiently as possible. Once a retaining wall was formed, cobbles and coarse gravels were forked behind the wall.

Herringbone tailing sites frequently consist of several herringbone compartments separated by ridges of largely unworked material along which the water was distributed. This type is often very extensive and represents a huge investment of human effort. The tailing areas may exceed one kilometre in length along a river bank and cut back into a river terrace over 100 metres.

Herringbone tailings are generally associated with ground sluice or low pressure hydraulic sluice workings into river terrace gravels. The excavations may exceed six metres in depth. Ground sluicing involved stripping ground downslope by means of a free flowing stream of water. This loosened the gravels, which were then washed through a sluice box (a trough with riffles) where the gold was recovered. The slope at the upper end of an area that has been ground sluiced is usually of moderate gradient.

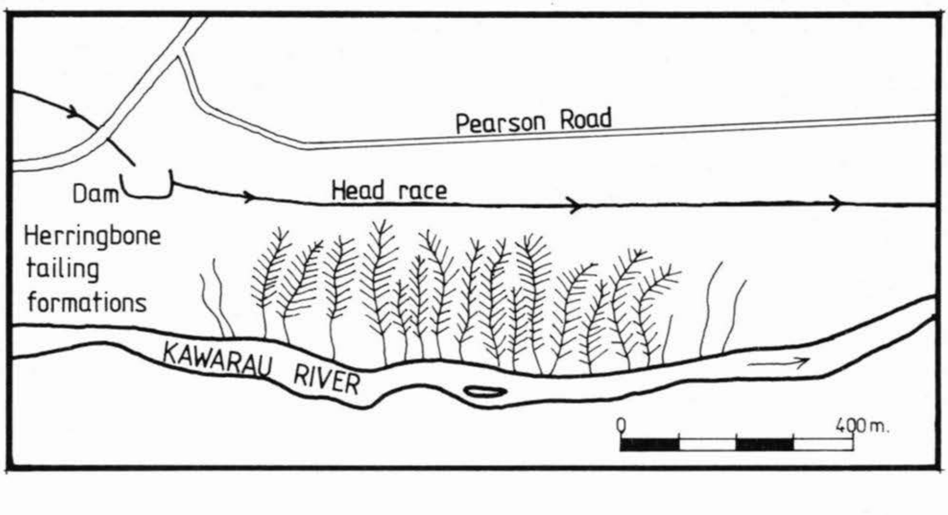

Figure 2: Plan view of a herringbone tailings site S133/426, Kawarau River.

Some excellent examples of this type of site are found in the vicinity of Cromwell at Deadman's Point, Northburn, and along the true left bank of the Kawarau River (S133/426) upstream of the Bannockburn Road bridge (Fig. 2). The workings depicted

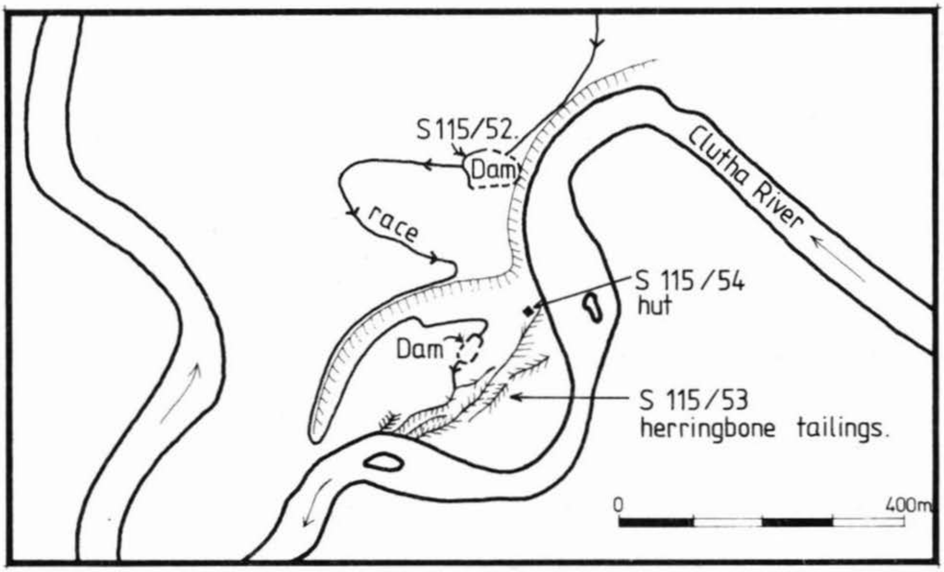

Figure 3: Diagram of herringbone workings (Site S115/53) Ah Wee's Point, Clutha River, within dams, races, and tailings complex (Sites S115/52–54).

in Figure 3 are believed to have been formed by a Chinese miner (Ah Wee) sometime prior to 1898 (Roxburgh 1957:117). Herringbone tailings and other neatly stacked tailings are commonly assumed to be the work of the Chinese miners. This is an unreliable assumption; many mining sites which have been worked only by European miners are equally tidy. Conversely, the tailings in some sites known to have been worked by Chinese miners are not neatly stacked.

TYPE 2: BLOW DOWN TAILINGS

Tailings of this type (Figs 4, 5 and 6) result from a system termed "blow down" sluicing by Park (1908:47). The method was first introduced by a Russian miner and has been used for the working of wide stretches of poor alluvial ground in Central Otago. Its greatest application has been in the Cromwell area where it was introduced before 1880 (Park 1908:47). The method differs from ordinary sluicing, whether ground sluicing or hydraulic sluicing, which began at the lowest point of the ground and worked forward on a rising bottom, the main tailrace being extended as the working face advanced.

In the blow down system a main tailrace was excavated across the base of the slope to be worked. A side gutter was then extended up one or both boundaries of the claim. Water was conveyed to the top of the claim by race or pipeline, and sluicing commenced by working downslope. A strip of ground about three metres wide was thus worked either side of the gutter which acted as a channel for the loosened material to be carried down through the tailrace. This process was repeated, so that the ground was cut away in parallel slices (Fig. 4).

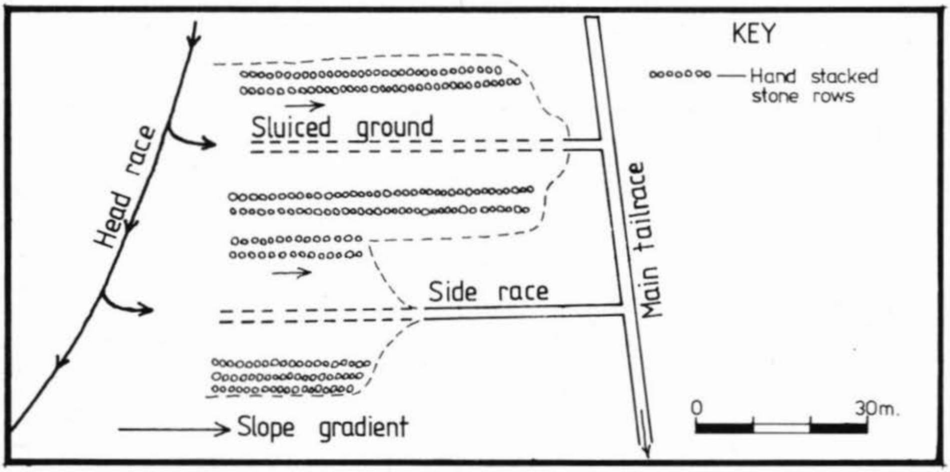

Figure 4: Diagram of blow down system of sluicing adapted from Park (1908:48).

This system could only be applied to the working of alluvial ground where (a) the wash lay on a sloping bottom having a gradient of not less than 1 in 3, (b) where the wash was shallow, that is to say not exceeding about two metres, and (c) where large stones were absent – that is, they could be handled by two men (Park 1908:47). Workings of this type near Cromwell are typically located along the old terrace risers (Fig. 5). The gold appears to have been lodged on the risers as a lag deposit whilst

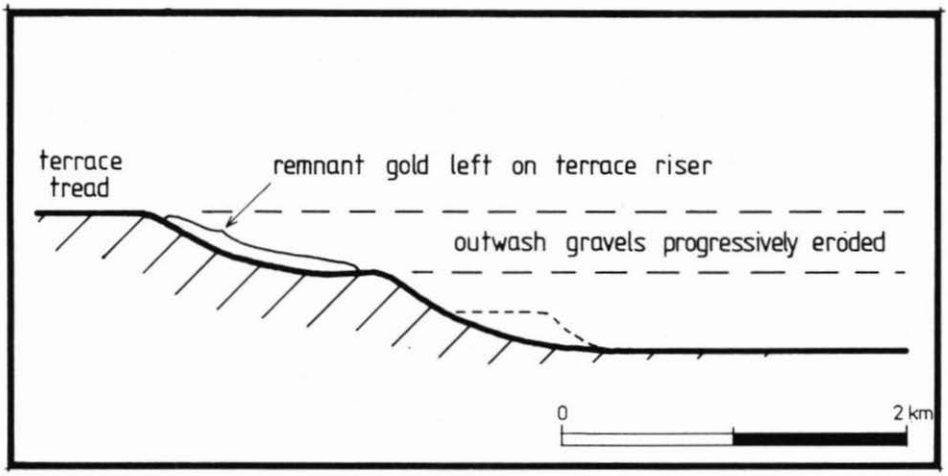

Figure 5: Cross section of terrace scarps showing locatin of blow down tailings.

the host outwash alluvium has been gradually eroded away (R. Thomson: pers. comm.). The typical configuration of blow down tailings consists of a series of parallel low stone rows running down a terrace scarp (Fig. 6). There are some excellent examples of this form of tailings in the Smallburn valley north of Lowburn township.

Workings of this type are locally quite extensive, individual mining areas being

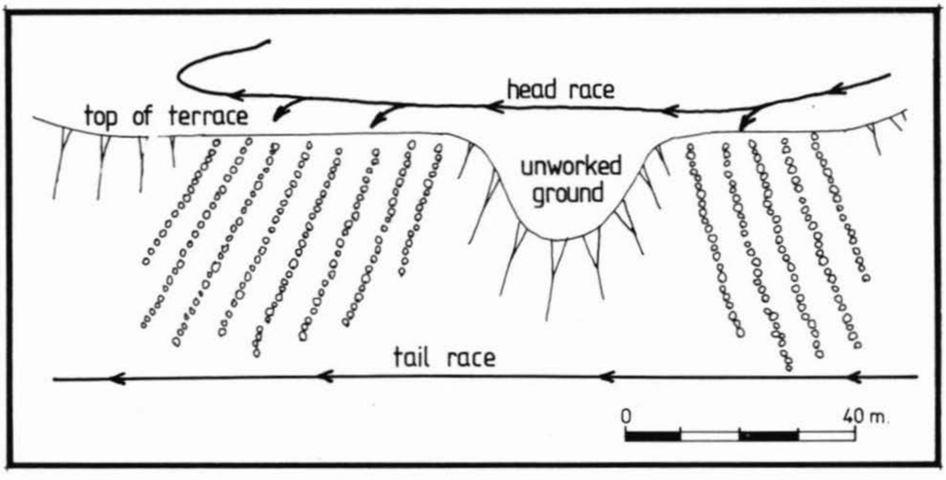

Figure 6: Blow down tailings. For key, see Fig. 4.

up to several hundred metres long and extending up the full height of a terrace riser. They are usually very shallow, seldom exceeding 1.5 metres in depth.

TYPE 3: PARALLEL TAILINGS

This is visually the simplest form of tailings, consisting of parallel rows of handstacked cobbles and boulders usually running at or near to right angles to a river or stream (Fig. 7). Sites of this type seldom exceed 100 × 150 metres in area and the stone rows are usually less than 1.5 metres high. They are frequently located right on the edge of a riverbank.

The mode of operation of parallel tailings can be compared to agricultural border

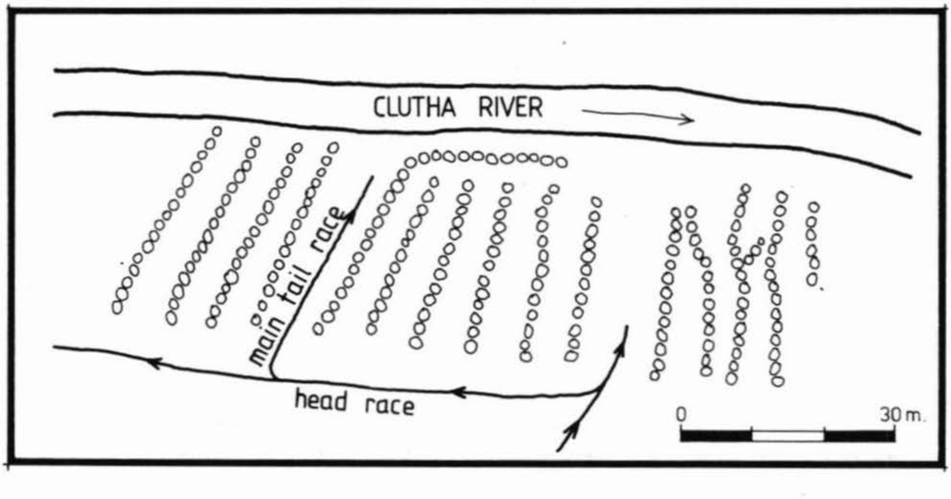

Figure 7: Diagram of S124/115 parallel tailings, Sandy Point, Upper Clutha River. For key, see Fig. 4.

dyking. In the latter case water is brought to the upslope perimeter of a field and channelled across it between rows of low earth walls. In the mining process associated with parallel tailings the working method was essentially the same, except that the gradient was steeper and the water flowed at a velocity sufficiently high to disaggregate and displace the gravels. The water was channelled into selected strips of ground by cutting short headraces from the main supply race. The heavy cobbles within the gravels were stacked on either side of the strip. This effectively contained the water and eventually the stacked stones formed parallel tailings.

As can be seen in Figure 7, riffles must have been placed between the mouth of nearly every row otherwise the gold-bearing sluice water could have washed over the riverbank. In some sites there is evidence that a stone barrier existed across the lower end of the rows. This would have contained a basal tailrace channel and thus simplified gold recovery. However, generally there is no evidence that any sort of barrier ever existed across the lower end of such workings; parallel tailings simply consist of straight rows of stacked cobbles usually located adjacent to a riverbank.

In some instances, the spaces between the rows are filled with cobbles, presumably dumped there in the course of working the adjacent row (Fig. 8).

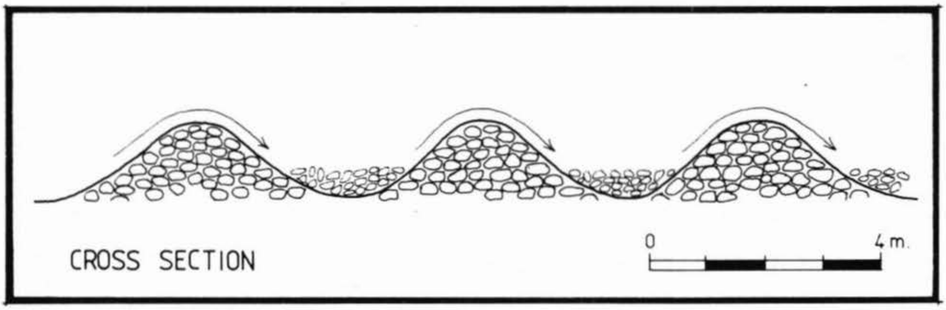

Figure 8: Cross section showing backfilling between tailings rows.

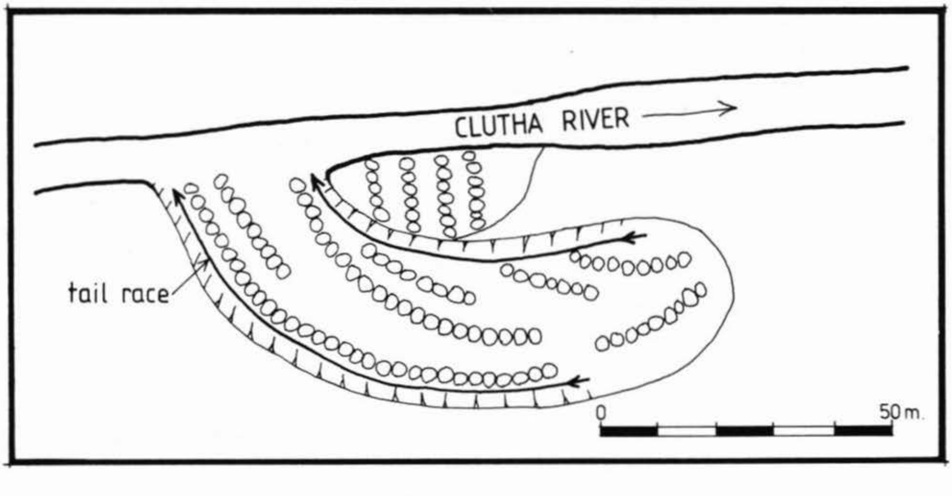

Figure 9: Diagram of site S124/112. Curved tailings, Upper Clutha River. For key, see Fig. 4.

TYPE 3a: CURVED TAILINGS

This form (Fig. 9) is a simple variant of the parallel tailings form and if expanded could result in the formation of "fan" tailings (Type 5). In curved tailings the rows of stacked stones are curved but they are still essentially parallel. Again, the spaces between the rows are often backfilled.

TYPE 4: BOX TAILINGS

This form of tailings is a variation of the parallel type, differing in that the rows of stacked cobbles are contained in a "box" which is formed by either unworked ground or, more usually, a row of stacked tailings across the lower (and frequently the upper) end of the workings (Fig. 10). The box arrangement would have been an improvement

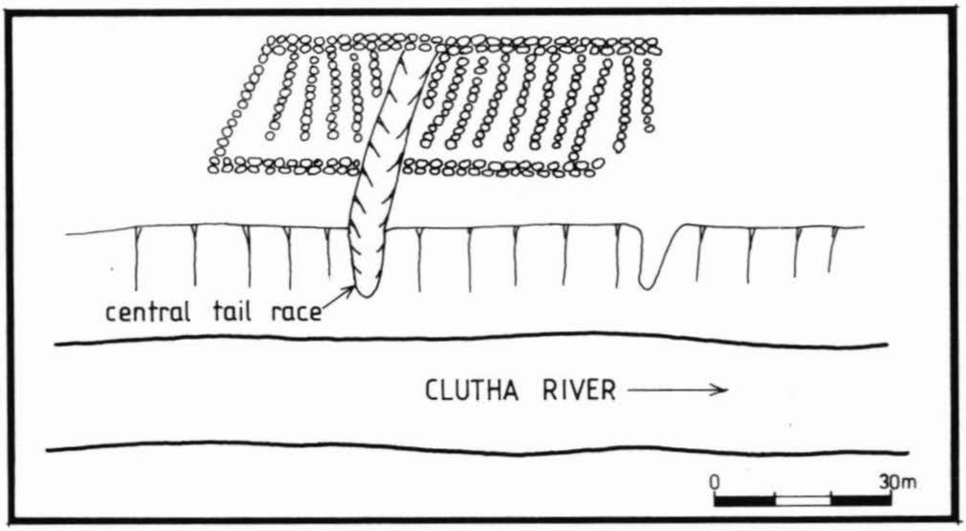

Figure 10: Box tailings, Upper Clutha River. For key, see Fig. 4.

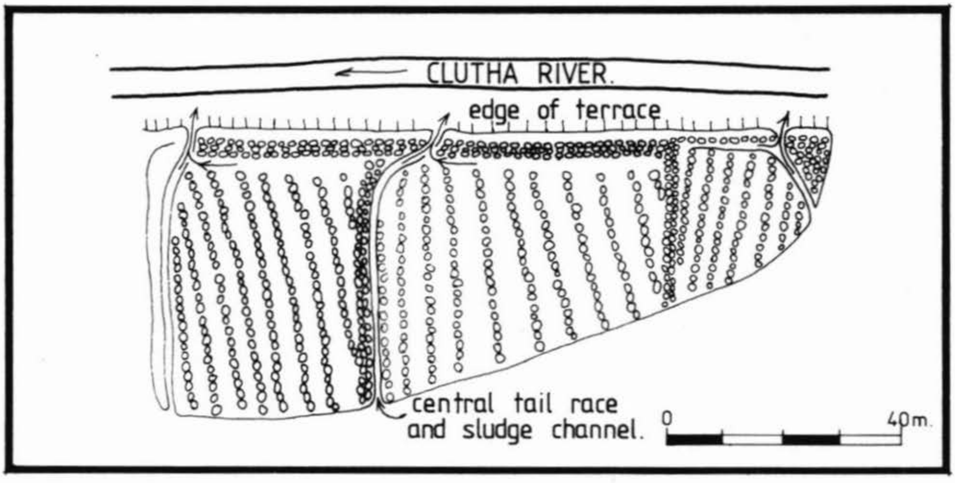

Figure 11: Site S115/32. Box tailings, Upper Clutha River. For key, see Fig. 4.

on the simple parallel method of working because all the gold bearing sluice water would have been channelled through one end tailrace.

This form of tailings is particularly common along the banks of the Clutha River between Albert Town and Luggate (Fig. 11). They are generally shallow workings and are found in similar riverside terrain to the parallel tailing formations. As with the parallel form the spaces between the rows are often backfilled with cobble debris from the adjacent row. Workings of this type seldom exceed 100 × 150 metres in area.

TYPE 5: FAN TAILINGS

This type is a cross between parallel tailings and the herringbone form. They were often constructed in ground which contained less coarse material than that in which the herringbone formations were frequently formed (Fig. 12).

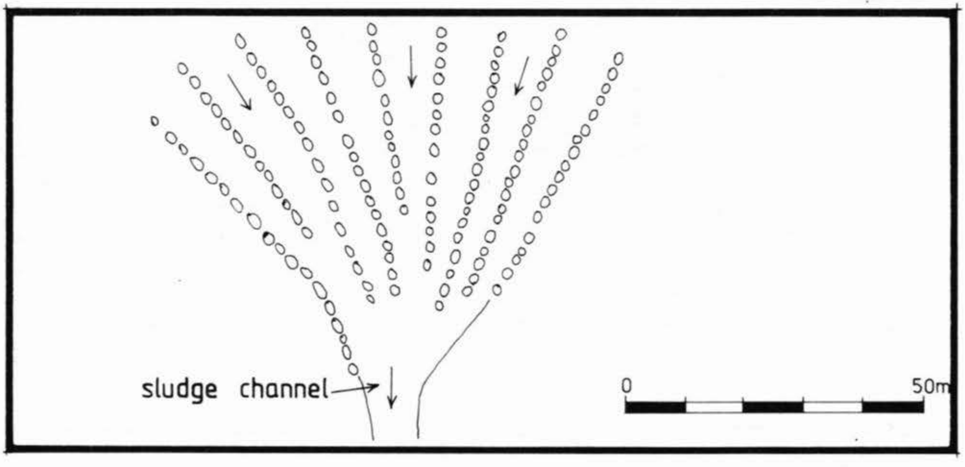

Figure 12: Diagram of a fan tailings site, S124 / 105, Luggate area. For key, see Fig. 4.

Fan tailings were derived from both ground sluicing and low pressure hydraulic sluicing. In the first instance a channelled stream of water was used to break down the consolidated gravels which were then directed down towards a central tailrace. An indication of downslope ground sluicing are leads from headraces running down unworked spurs.

The fan formations, formed as a result of ground sluicing or hydraulic sluicing, were created by the miners hand-stacking the cobbles and boulders (freed from the terrace gravels) in rows converging on a single point in the tailrace. Here riffles were located to trap the gold, whilst the spoil was washed on to lower ground or into a nearby river.

Superb examples of this type of tailings exist at Cornish Point opposite Cromwell. A good example of the type is depicted in Figure 12, it being part of an interrelated system of races, dams, and tailings sites (sites S124/103–107, Fig. 13).

TYPE 6: AMORPHOUS TAILINGS

Amorphous tailings are sluice tailings with no coherent patterning (Fig. 14). They are also described as hummocky tailings because of their appearance. This type is formed as a result of seemingly indiscriminate stacking of the cobbles during sluicing operations, but on closer examination winding tailrace channels threading between the mounds of stones can be discerned. Because of their lack of symmetry they often

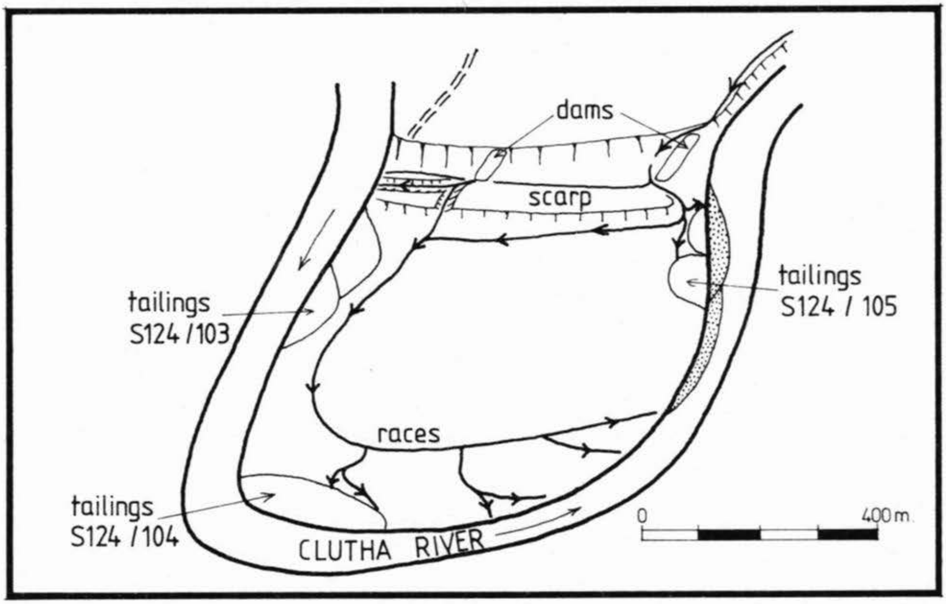

Figure 13: An interrelated races, dams and tailings system, near Luggate.

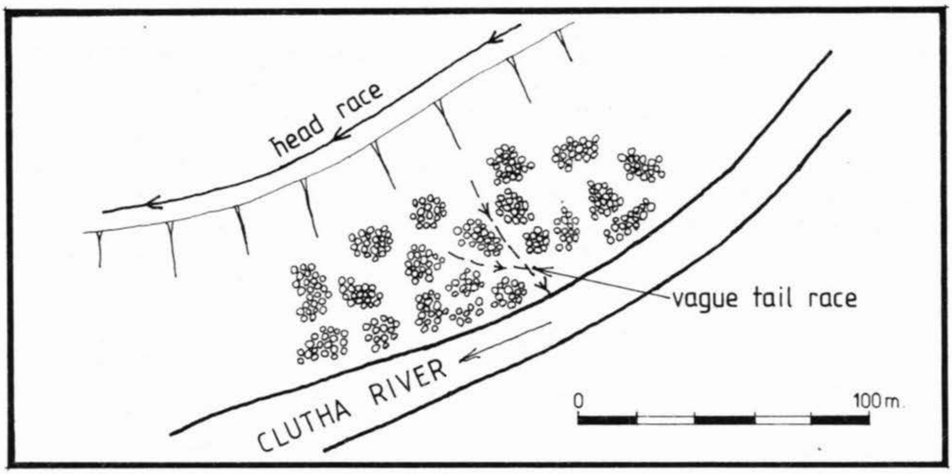

Figure 14: Diagram of an amorphous tailings site in the Luggate area showing typical hummocky mounds.

appear chaotic and disorganised, a factor which makes them difficult to interpret. In many instances, particularly in shallow drift deposits, the haphazard arrangement of amorphous tailings is caused by the uneven surface of the basal material or bedrock.

Amorphous tailings are typically located in ground with minimal fall, but are not unique to this type of terrain, since parallel and box tailings are found in similar topography. They are generally located on riverside terraces; many cases have been observed where they are sited on river flood plains and have been subsequently modified or buried under silt during high river flows. In some instances they were probably originally patterned tailings, i.e. Types 1–5, that have been disturbed beyond recognition. Amorphous tailings are relatively common. They vary in size from about 50 metres square to about 300 × 50 metres.

TYPE 7: SMALL CLAIM OR "POTHOLE TAILINGS"

The term "pothole mining" has been coined to describe the principle method of gold working during the early years of the nineteenth century goldrushes in Central Otago. During this phase the miners concentrated on working the stream and river beds, which were divided into individual claims measuring 24 × 24 feet (7.23 × 7.23 m). The miner dug into the gold bearing gravels with pick and shovel and raised the gravel with the assistance of a counterbalanced pole (termed a whip). The gravel was then panned or cradled. Typically the miners lived nearby in tents. The method has recently been described in detail by Higham and Vincent (1980:3, 103).

The resulting "pothole" tailings reflect the mining method. As a consequence the ground became dotted with hummocky circular and oblong mounds, occasionally separated by water channels. The tailings are often similar in appearance to Type 6 amorphous tailings, but are always found in stream bed or river flat locations, as opposed to the riverside terrace sites of the Type 6 tailings. Although individual working areas were very small (24 × 24 feet), when a number of such workings were established in close proximity, e.g. at Gabriels Gully, the aggregate was quite extensive. Excellent examples of this type can be seen in the flats of Bendigo Creek near Cromwell, a legacy of the 1862–65 rush. However, despite the fact that large tracts of alluvial creek beds were worked in this way during the early and usually ephemeral goldrushes, Type 7 tailings are relatively uncommon today. The former tailings have been obliterated by freshets or later mining ventures.

TYPE 8: PADDOCKING

Like many mining terms, "paddocking" has several meanings (Thrush 1968:787). In this instance, the term is used to describe the method of working a small area of alluvium by the excavation of the whole mass, leaving a large pit.

Although pothole tailings are arguably a small scale form of paddocking, both types have been classified separately because they are archaeologically distinguishable from one another. Pothole workings are generally located within river bed deposits, whereas evidence of paddocking ventures is found as excavated depressions on hillsides, river banks and terrace margins within outwash deposits. The former method tended to create hummocky relief, whereas in paddocking the washed alluvium was generally conveyed from the site leaving open pits or scars.

Sites of this type were generally small scale operations, the original "paddocks" only being enlarged if the returns proved satisfactory. Generally the pits tend towards square in form, measuring about 50 × 50 metres and seldom exceed two metres in depth. A nearby creek was used, or race constructed, in order to "wash the paydirt". Although paddocking was used extensively in the early days, a considerable number of unemployed men resorted to this method of mining during the depression of the 1930s, because it required little capital outlay.

TYPE 9a: SLUICING SCARS

Type 9a tailing sites consist of the scars or man-made gullies excavated in fine sediment or gravel river terraces during the course of sluicing operations (Fig. 15). Often very little visual evidence remains other than the gully which can sometimes be difficult to distinguish from natural erosion. In some instances, the remnants of stone revetting or a section of tail race are evident in the bottom of the gully, and a head race leading from a storage dam may be discernible entering the apex of the sluice scar.

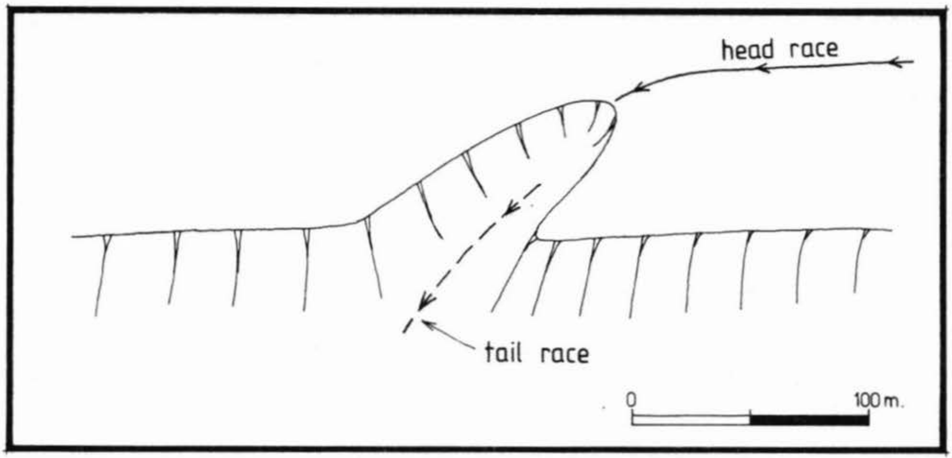

Figure 15: A sluicing scar site.

TYPE 9b: SLUICE FACES OR SCARPS

If enough sluicing has been undertaken along a terrace scarp, a "sluice face", i.e. a continuous series of sluice scars, may be produced (Fig. 16). Like scars they are characterised by a virtual absence of hand stacked cobble and boulder formations. These sites are often very extensive, the sluice face only representing the "back wall" of a vast area of terrace which may have been washed away during the mining operation. Often tall remnant pillars or islands of unworked ground survive as mesa-like features in front of the face. The Bannockburn sluice faces near Cromwell are undoubtedly among the best examples of this type of site in New Zealand.

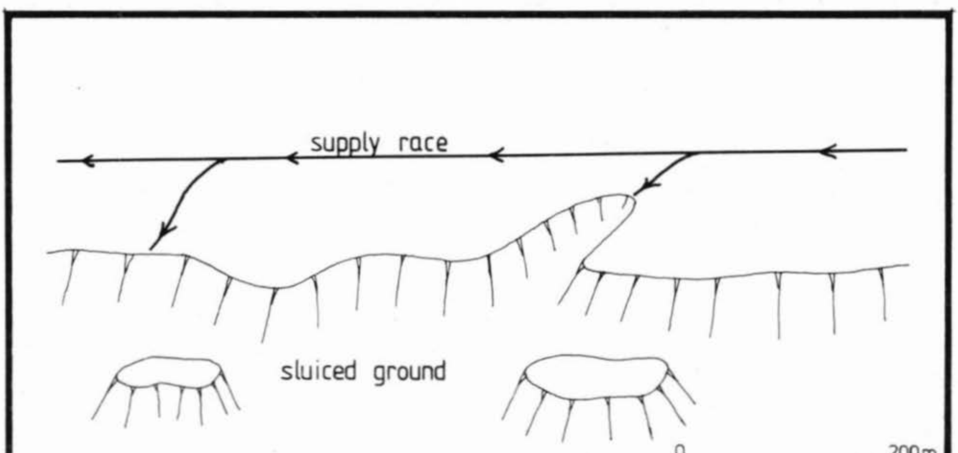

Figure 16: Diagram of a sluice face.

TYPE 10: HYDRAULIC ELEVATOR HOLES AND TAILINGS

This type of tailings results from the working of sluicing claims where there was insufficient fall, i.e. the ground being worked was too deep to allow the disposal of the tailings. Elevators (bucket and hydraulic) were frequently employed for working alluvium below the level of an adjacent river or stream. The hydraulic elevator used water pressure to convey the gravels to the ground surface. This was achieved by high pressure discharge of water from an inclined pipe through an internal nozzle which generated a suction that forced the gravels up the pipe and through sluices on the ground surface (Fig. 17).

Elevating sites typically consist of deep holes, filled with water, surrounded by low rounded mounds of tailings which have been dumped nearby after the gold has been recovered. In large scale operations the water-borne tailings were usually conveyed down on to low lying ground, often burying it under several metres of debris. The top of this deposit eventually forms a new ground surface. The tailings differ from the types previously described in that they have been totally deposited by water flow rather than hand stacked. Elevator dumps contain all the barren elevated solids, from silts to small cobbles.

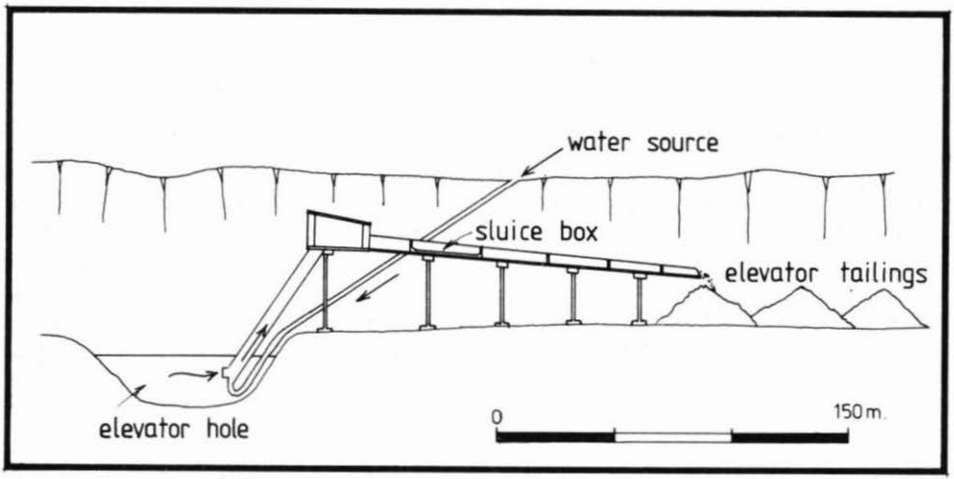

Figure 17: Simplified diagram of an hydraulic elevator in operation.

This type of workings is not common in the Upper Clutha Valley, although one site in Luggate Creek (S124/90) is a good example. Hydraulic elevating was a very important form of mining in Central Otago at several locations but most notably at St Bathans and on the Blue Spur in Gabriels Gully (Higham and Vincent 1980).

TYPE 11: DREDGE TAILINGS

The idea of recovering gold by dredging from the rivers in the Cromwell area was voiced within a year of the Dunstan goldfield being proclaimed in 1862 (Ritchie 1978). The initial spoon dredges were soon superseded by current wheelers which employed paddle-wheels to drive an "endless" chain of buckets. The first steam powered bucket dredge began operation on the Clutha River near Alexandra in 1881. Steam power enabled the dredges to work into the river banks and greatly expanded the potential of dredging operations. At this stage the major problem that had still to be overcome was the development of a system to prevent the excavated spoil from flowing back under the dredge and thwarting its operation. This difficulty was overcome by the invention of the tailings elevator (Fig. 17) by Cutten Brothers Engineering of Dunedin

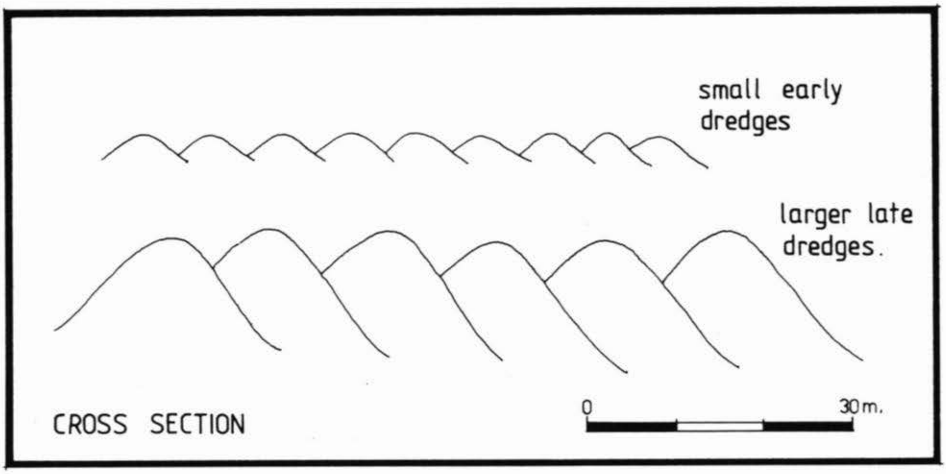

Figure 18: Diagram of dredge tailings in cross section.

in 1894. This innovation enabled the tailings to be stacked well clear of the stern of a dredge, in so doing created the distinctive dredge tailing configurations (Fig. 18). Like Type 10 tailings, dredge tailings were formed mechanically rather than by hand stacking. In general they are located along river banks and the adjacent river flats.

It is often difficult to determine which dredge may have created any particular set of tailings but some idea can be gained from the height and shape of the tailing mounds. Initially both the dredges and their tailing elevators tended to be fairly small and consequently the resulting tailings tended to form rows with a low mound-like appearance. The post World War One dredges were generally much larger, with elevators capable of stacking the tailings in very high piles aft of the dredge. Usually the tailings were deposited in gently curving bands as the dredge swung along a working face. Some good examples of dredge tailings, formed during the various mining phases between 1880 and 1960, can be seen in the Lowburn and Earnscleugh basins.

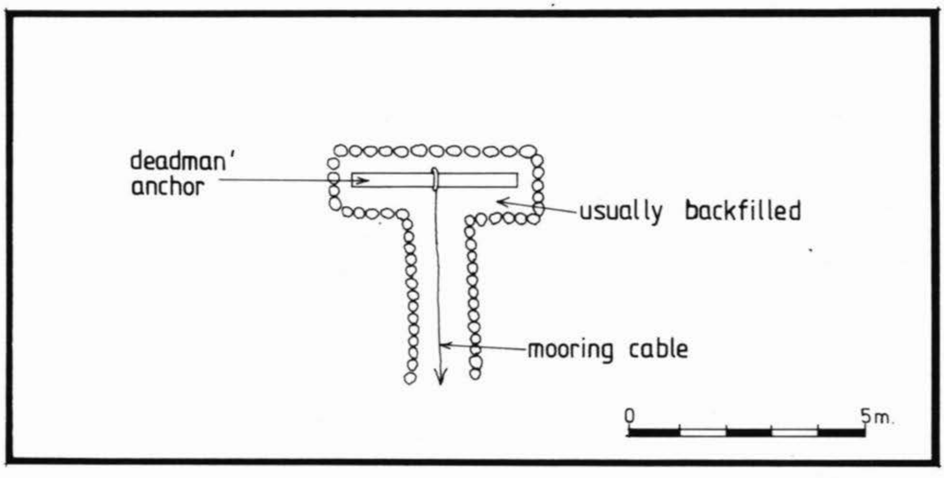

Figure 19: Dredge mooring anchorage.

Dredge tailings are frequently littered with dumps of bent and twisted dredge and elevator buckets discarded during routine maintenance on the dredges. Other features associated with dredge tailings are dredge ponds, tracks cut to facilitate fuelling of the dredges and mooring anchorages (Fig. 19). Dredge anchorages of the type illustrated consist of "T" shaped trenches which were designed to provide an anchorage for the dredge mooring cables. They were specifically used on poorly consolidated river banks, for example in outwash gravels, in the absence of firm anchoring objects such as a rock outcrop or large trees. The anchoring trenches were aligned in a downstream direction. The cross-trench contained a large log or beam which served as a "deadman" anchor to which the mooring cables were attached. The cross piece was then buried under rubble to hold it in place. Often rusting pieces of cable protrude today from the end of the cable trenches. Dredge (and punt anchorages) vary in size but they generally measure no less than three metres across the cross trench and five metres along the cable trench. The trenches are often totally or partially stone-lined.

DISCUSSION

The objectives of goldmining ventures were to maximise the throughput of gold-bearing material, whilst attaining the greatest afficiency in gold saving for the minimum cost in terms of time, labour and expense.

The various sluice-tailing patterns which are recognised in Central Otago today were presumably widely adopted because they were found to be the most efficient configurations for the working of different types of alluvial mining terrain. All the forms appear to have been tried and proven by 1880, and continued to be employed with only minor variations from the basic forms until the advent of the bulldozer and the mechanical excavator. Clearly there is a direct relationship between the resulting tailing configuration and the major physical variables; the topography, the nature of the substrate, the position of the paywash and the depth of overburden (Table 1). Fine grained deposits tended to be sluiced away completely leaving almost no recognisable tailings other than fan deposits, scars or man-made scarps; whereas the working of alluvium which contained a high proportion of cobbles and boulders necessitated stacking the stones in order to efficiently recover the gold and maximise throughput.

The depth of the paywash and the topographical location of a mining site were also important considerations in the selection of sluicing techniques. Some forms tended to be limited to certain types of terrain. For example blow down tailings were restricted to sloping terrace faces, amorphous tailings are generally found in areas with little natural fall and elevating was undertaken in areas below natural water level or within deep gravel terrace deposits.

The other major group of determinants were the hydraulic factors – the water supply, the available head, and its manner of application. The main variables here were the pressure of the supply and whether the water was applied up or down slope or by ground sluicing or hydraulic sluicing. The field evidence reflecting these hydraulic aspects was outlined earlier.

Besides the physical factors governing the selection of sluice mining methods, it is apparent that human preference or experience were important factors also. In some locations different tailing patterns have been produced virtually side by side in similar terrain, whilst in other areas there are clusters of similar types of tailing sites. As previously outlined, the ultimate type of tailing site was largely governed by the geological conditions, but a tendency to adopt the prevailing mining configuration can be distinguished. For example, along stretches of the Upper Clutha River above Luggate there are distinct concentrations of box tailings. The dominance of the technique that produced this type of tailings in this area appears to have been a deliberate choice because other forms, notably herringbone and parallel, are found in the same general area and terrain.

Occasionally individual sites exhibit evidence of more than one tailing pattern or slight variations on the "normal pattern", but, in the Upper Clutha at least, these

TABLE 1

ALLUVIAL TAILING CONFIGURATIONS

Associated Features	Herringbone	Blow Down	Parallel	Box	Fan	Amorphous	Pothole	Paddocking	Sluice Scarps	Hydraulic Elevating	Dredge
Typical Location:											
River flats/beaches							X			X	X
Riverbank			X	X	X	X		X			X
Terrace-edge	X				X			X	X	X	
Hillside/scarp		X						X	X		
Typical size range: (metres)	100×50 to 200×1000	300×100	100×50	50×50	200×100	200×100	200×200	extensive	extensive	extensive	extensive
Nature of substrate: f–fine m–medium c–coarse	m–c	m	m	m	m–c	m–c	f–m	f–m	f	f	f–m
Typical depth of working below ground surface (metres)	5–10	2	2	2	5–10	2	2	2	10–20	5–30	20

multiple configuration sites are relatively uncommon. If two or more forms are present in one site they are usually in separate compartments.

No specific studies have been undertaken to determine if there is any connection between the ethnic origin of miners and the type of sluice mining they preferred (and as a consequence the form of tailings they produced). Sluicing technology was first developed in the United States and introduced into New Zealand by the Californian miners. The basic methods were taken up by miners representing most ethnic groups involved in mining in this country, with new innovations being adopted as they were developed. According to Park (1908:47) blow down sluicing was first introduced by a Russian miner, but, as the method was used widely in Central Otago, it must have been readily accepted by miners of other nationalities. The field evidence used as the background to this paper indicates that the Chinese may have had some preference towards the herringbone form of tailings, but this pattern was also widely used by European miners. Confirmation of any ethnic preferences would require a detailed study of historical records, such as water and mining rights, compared with the archaeological evidence. Although it is widely recognised that the Chinese reworked abandoned claims, it has been found difficult to ascertain evidence of reworking from the surviving field evidence.

A notable feature of Chinese alluvial mining in Central Otago was the use of low vertically stacked stone walls (wing dams) to deflect the flow of the river or stream to one side of its channel. If the angle of the stone alignment was acute to the flow, this caused the opposite bank to be undercut. If, however, the structures were built at or near parallel to the flow they enabled the creek or river to be deflected to one side of the channel whilst the other side was dry-worked. Chinese wing dams in Central Otago were typically constructed of slabs of schist placed vertically in long lines in the described alignments. They are not defined here as tailings because they served principally as deflectors or retaining walls. In some instances the stone used in their construction was carried some distance to the mining site. Their durability is attested by the fact that many have survived massive floods and still exist intact today.

Many modern miners are finding wing dams, constructed by bulldozer and excavator, to be a cost-efficient method of working river gravels. The impounded areas are pumped dry after which the gravels are mechanically excavated and passed through a rotary screen and sluice-box in order to retrieve the gold. The unconsolidated gravels which form the modern wing dams are eventually washed away by high river flows.

CONCLUSIONS

Each mining location presented its own topographical and hydraulic obstacles. How these were overcome is reflected in the surviving field evidence – the tailing configurations and mining scars, and associated sites such as races and storage dams. Although these sites exist in large numbers in some mining districts in New Zealand, they are being modified and destroyed at a rapidly increasing rate by gravel removal, land development, dam construction and modern mining.

Detailed recording of tailing sites during site surveys in the Upper Clutha area of Central Otago and subsequent analyses of the recorded tailing configurations has shown that potentially significant inter- and intra-regional patterns of alluvial mining can be discerned. Comparable studies within other mining districts will further elucidate racial and behavioural patterns and areal differences. In turn this will contribute new information on both the historical and anthropological aspects of mining for those areas to which the described model is applied.

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