NEW ZEALAND ARCHAEOLOGICAL ASSOCIATION NEWSLETTER

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THE DEFINITION, DISTRIBUTION, AND SOURCING OF CHERT IN NEW ZEALAND

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SUMMARY

Use of the term "chert" has not been consistent in the past. To avoid further confusion it is suggested that both archaeologists and geologists adopt a single definition, encompassing all "chert-like" siliceous rocks. The distribution of chert-bearing formations is outlined, and some specific chert deposits are described. Chert is shown to be widely distributed, but particularly common in Northland, east coast North Island, and Marlborough. Few sources known to have been exploited by the Maori have so far been identified.

Methods already applied, or which could be applied, to the sourcing of chert artefacts are reviewed, and their application to the sourcing of New Zealand cherts is discussed. Trace element analysis appears to be the most promising sourcing method, but other methods may be useful in some cases. Two different approaches to the sourcing of chert in New Zealand are discussed.

INTRODUCTION

The study of lithic materials (or stone) recovered from archaeological sites has, in the last few years, gained considerable momentum, and advances overseas have often been followed by research in New Zealand. It is not surprising, therefore, to find that recent work on the differentiation of chert (or flint) sources in Western Europe in particular, has aroused some interest among New Zealand archaeologists.

Chert is undoubtedly one of the most important rock types exploited by the Maori, yet little is known about its natural or cultural distribution, or its use. This is perhaps understandable firstly because only in recent years have rapid and accurate analytical techniques such as X-ray fluorescence (XRF) and neutron activation been developed, thus providing a more efficient means of differentiating chert sources, and consequently artefacts derived from those sources; and secondly, the geology of chert occurrences in New Zealand has been virtually ignored, even though interest in semi-precious stones in in recent years has added considerably to the list of localities for chert and other microcrystalline quartz varieties. The archaeologist, then, faces a field of investigation which, although sadly lacking in basic data, should provide valuable information on the movement of man and lithic materials in prehistoric New Zealand.

This paper sets out to find the most acceptable definition for chert, one that can be used widely and without confusion; to show the distribution of chert-bearing formations, and location of some specific chert deposits; and to review methods which have already been applied, and which could be applied, to the sourcing of chert artefacts. The intention is not to present an exhaustive account of the subject, but rather to stimulate further research and promote better understanding of the nature and occurrence of the material.

THE DEFINITION OF CHERT

The controversy over the definition of chert has been raging for many years, and even today some geologists and archaeologists do not entirely agree on terminology. Use of the terms 'chert' and 'flint' has been reviewed elsewhere (Keyes 1970; Walls 1971), and little would be gained from a lengthy discussion here, but some comment on these terms is necessary in order to point out anomalies, and difficulties with their use.

Both chert and flint consist of the same material, silica (SiO_2). Crystalline silica is termed quartz, tridymite, or cristobalite; quartz is the common form, but small amounts of cristobalite can occur in opal (a constituent of chert). Chalcedony is the micro- or cryptocrystalline variety of quartz, consisting of minute fibrous crystals with numerous submicroscopic pores (Deer *et al*. 1963). Both flint and chert are impure varieties of chalcedony, and various features have been used to distinguish them, including colour, fracture, lustre, opacity, mode of occurrence, and whether or not they were used in stone tool manufacture. Suffice to say they are essentially the same, though differences in some features can be observed in *in situ* deposits.

Use of the two terms causes real problems when attempting to describe archaeological material. As Wilkes and Scarlett (1967) have pointed out, it is very difficult to decide whether a flake of impure chalcedony in an archaeological assemblage should be called flint or chert, because in such a situation we don't know if the material originally came from a nodular or bedded deposit. (Flint has generally been considered to occur only in nodular form, and chert in extensive beds). In addition, as the term 'flint' is often applied to the darker coloured, grey or black, varieties of chalcedony, samples showing alternate light and dark banding, or complex intermixing of light and dark colours, pose considerable classification difficulties. Thus, because of its genetic connnotation (i.e. occurrence only in nodular form), restricted colour range, and other variable or doubtful characteristics, the term 'flint' should be dropped, a recommendation previously made by others (e.g. Pettijohn 1957; Walls 1971).

Having discarded the term 'flint', we must then define the term 'chert' to include those characteristics previously considered to be restricted to flint. The definition probably accepted by most New Zealand geologists is that of the American Geological Institute (Glossary of Geology 1972, p. 122), which is as follows:

"Chert - a hard, extremely dense or compact, dull to semi-vitreous, cryptocrystalline sedimentary rock, consisting dominantly of cryptocrystalline silica (chiefly fibrous chalcedony with lesser amounts of micro- or crypto-crystalline quartz and amorphous silica (opal); it sometimes contains impurities such as calcite, iron oxide, and the remains of siliceous and other organisms. It has a tough, splintery to conchoidal fracture, and may be white or variously coloured grey, green, blue, pink, red, yellow, brown, and black. Chert occurs principally as nodular or concretionary segregations (chert nodules) in limestones and dolomites, and less commonly as areally extensive layered deposits (bedded chert); it may be an original organic or inorganic precipitate or a replacement product. The term flint is essentially synonymous, although it has been used for the dark variety of chert (Tarr, 1938). Syn: hornstone; white chert; silexite; phthanite".

Some recent workers (e.g. Sieveking et al., 1972; Ward and Smith 1974) have tended to consider chert an exclusively marine deposit, ignoring deposits associated with sub-aerial volcanics, such as those in Coromandel Peninsula.

Such chert deposits are clearly included in the above definition through the words "original inorganic precipitate" and "replacement product". As an example of replacement Fuchtbauer (1974 p. 328) records that surface silicification (replacement by silica), particularly of carbonate rocks, can occur in desert environments. Although such a case does not apply to any known deposits in New Zealand, it does illustrate the point that not all chert is of marine origin.

If we accept the definition of chert given by the AGI, then it is possible to include other impure varieties of quartz or chalcedony, and chert-like rocks, under the one broad term. Thus we could describe jasper, jasperoid, jaspillite, some porcelanite, and highly silicified volcanic and sedimentary rocks (e.g. silicified tuff, cherty limestone) as "chert". There is some advantage in this, because in an archaeological assemblage it will often be difficult to distinguish, without detailed analysis, chert-like material obtained from in situ deposits of different origin. "Chert" flakes of similar appearance could, for example, be obtained from outcrops of siliceous clay baked by lava flows or burned-out coal seams, or from chert beds in greywacke terrain.

The suggestion of using "chert" as a lump term appears to be the most practical solution for New Zealand archaeologists. This is because most amateur and professional archaeologists in New Zealand do not have a geological background, and therefore should not be expected to try and decide whether a siliceous flake is a chert, flint, jasper, porcelanite, or silicified limestone. Also, because chert-like material could be (and almost certainly was) obtained from a wide variety of geological deposits in New Zealand it is better to use a broad term, which can be refined after detailed analysis, rather than a specific term which is wrong.

DISTRIBUTION

Good, flake-quality chert occurs in three main areas in New Zealand - Northland-Coromandel (Fig. 1), East Coast North Island (Fig. 2) and Marlborough. The thickest and most extensive deposits are associated with multicoloured shales (or mudstones) in Northland, and siliceous limestone (the Amuri Limestone) in Marlborough; highly siliceous beds and nodules in these sedimentary formations have generally been called "flint".

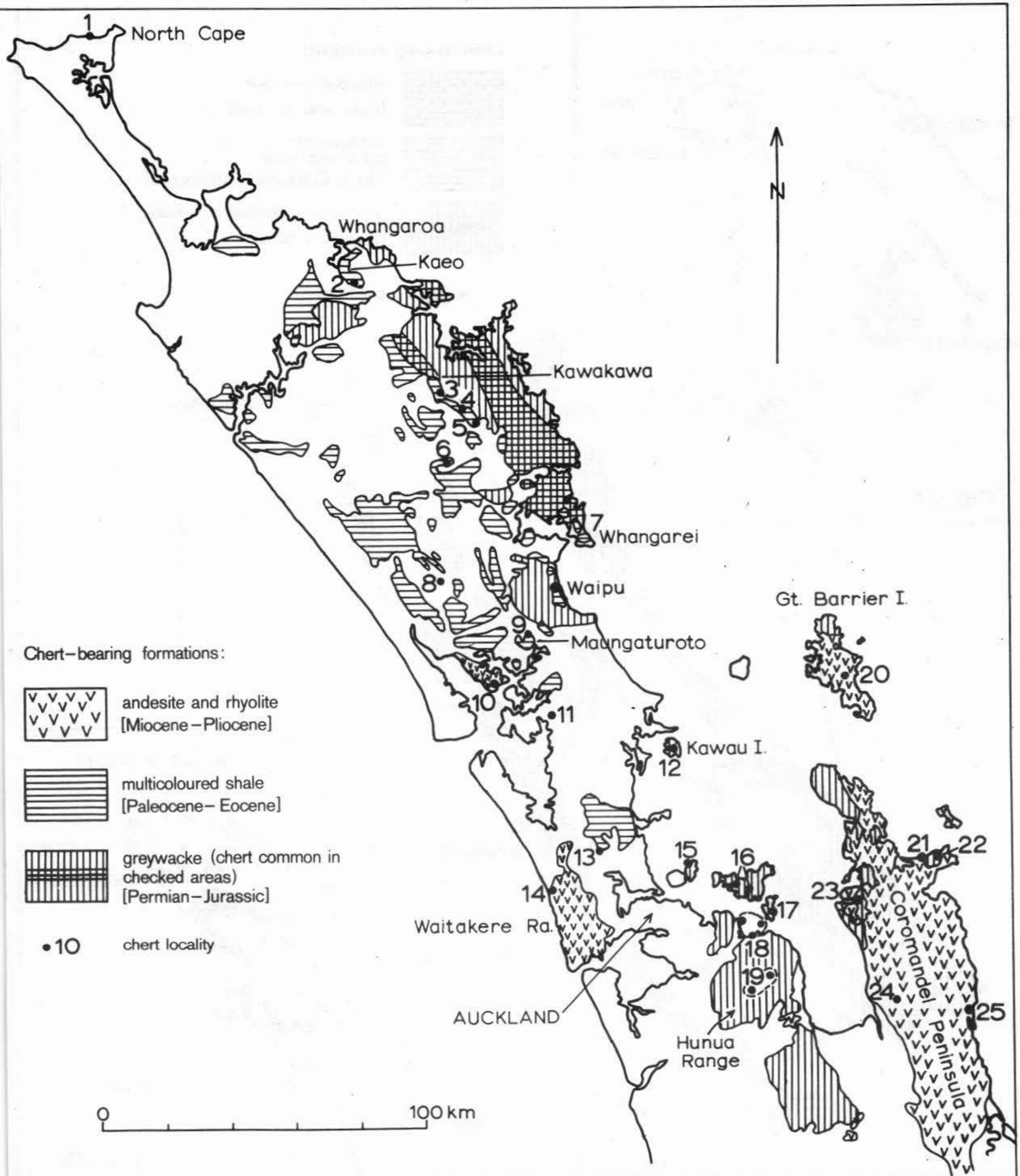

Fig. 1 - Distribution of chert-bearing formations in the Northland - Auckland - Coromandel region.

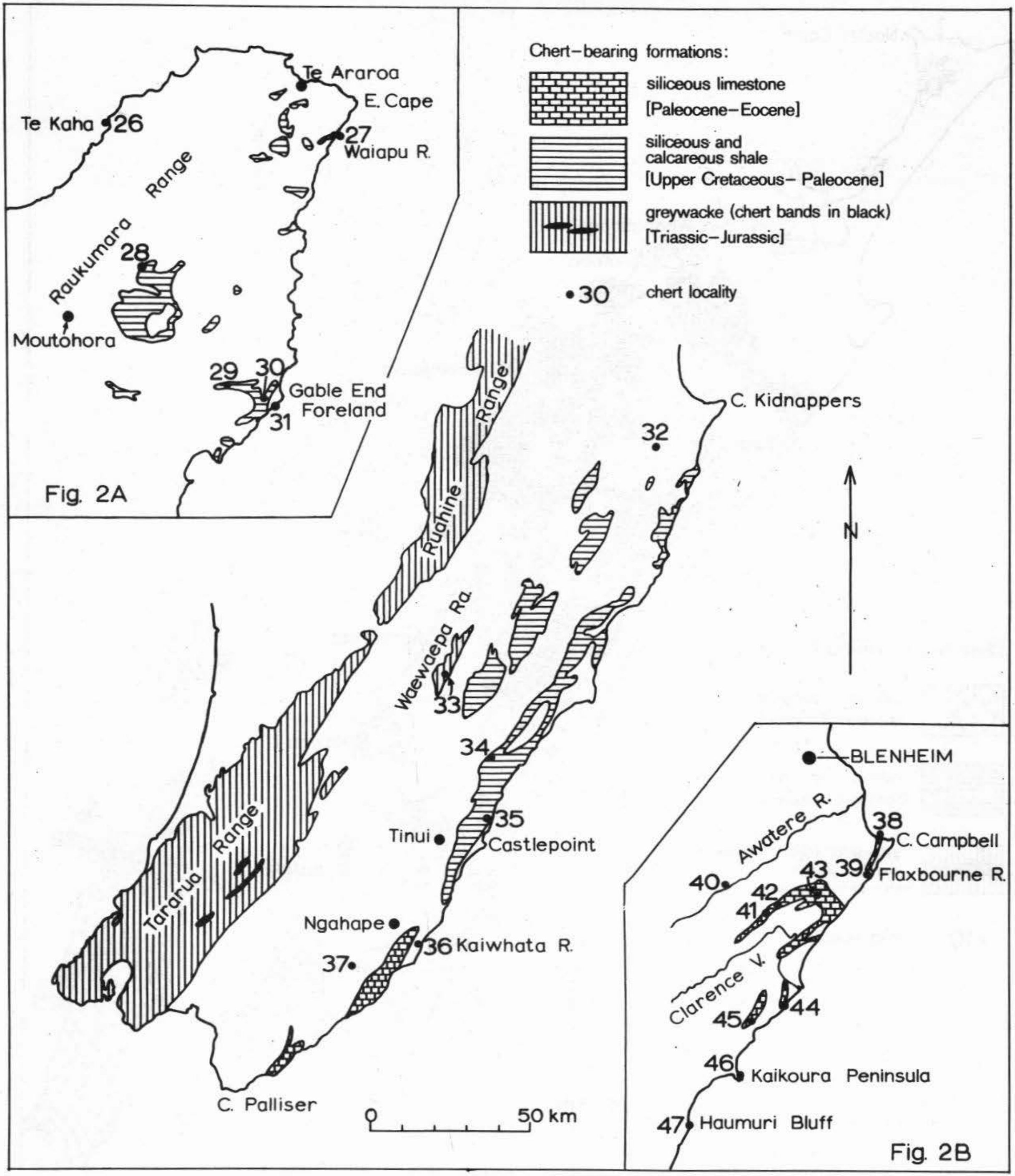

Fig. 2 - Distribution of chert-bearing formations in the East Cape, Southern Hawke's Bay - Wairarapa, and Marlborough areas.

TABLE 1: Geological time-scale, showing ages and distribution of chert-bearing formations.

Million years	Period	Epoch	N.Z. Stage	Distribution, and formation
	QUATERNARY			Pebbles in terrace gravels, in river beds, and on beaches.
2	TERTIARY	PLIOCENE		Coromandel Peninsula, Gt Barrier Is., associated with acid volcanics (rhyolite, etc.) of the Whitianga Group.
8		MIOCENE		Northland, Auckland, Coromandel Peninsula, Otago associated with rhyolitic-dacitic, andesitic, and occasionally basaltic volcanics.
25		OLIGOCENE		Otago, associated with basic volcanics (Deborah Volcanics).
38		EOCENE	Runangan	Otago, associated with basic volcanics (Waiareka Volcanics).
			Kaiatan	
			Bortonian	Northland (Opahi Group).
			Porangan Heretaungan Mangaorapan Waipawan	Northland (Waiomio Group).
55		PALEOCENE	Teurian	Northland (Mangakahia Group), East Cape (Mangatu Group), Wairarapa (Whangai Formation, Mungaroa Limestone), Marlborough (Amuri Limestone).
65	CRETACEOUS	Upper	Haumurian	
			Piripauan	
			Teratan	
			Mangaotanean	
			Arowhanan	
			Ngaterian	Minor occurrences in Northland, E. Cape and Wairarapa, associated with basic volcanics in greywacke-type beds. Canterbury foothills associated with rhyolite-andesite (Mt Somers Volcanics).
		Lower	Motuan	
			Urutawan	
			Korangan	
160	JURASSIC TRIASSIC PERMIAN			Northland (Permian-Jurassic), Auckland (Jurassic), Ruahine & Tararua ranges (Triassic-Jurassic), and eastern South Is. & Southern Alps (Triassic-Jurassic), associated with volcanic bands in greywacke.
	CARBONIFEROUS			Central Otago and Southland, associated with schist?
350				

Some thick chert beds are also found in the "greywackes' of the main ranges, particularly in eastern Northland, Auckland, and the Ruahine and Tararua ranges, associated with submarine volcanics. Small deposits of chert are commonly associated with rhyolitic, andesitic, and sometimes basaltic rocks, particularly in Northland, Coromandel Peninsula, and east coast South Island. And finally, minor quantities of chert are found in gravels, reworked from older rocks, and in some sandstones and metamorphic rocks.

The four main chert-bearing formations - siliceous limestone, shale, greywacke, and volcanics - are, in most cases, of very different geologic age, and since age may be an important factor in distinguishing cherts from different sources (see later), it is useful to differentiate between the four rock types (see distribution maps, Figs 1-3). Within major rock types e.g. the shales of Northland, chert may occur at different horizons, each of different age, so that even finer age distinctions can be made. Table 1 shows the age (based largely on fossil determinations) of important chert-bearing formations in relation to New Zealand Stages (of time), and gives some idea of the distribution of cherts of roughly equivalent age.

NORTHLAND - AUCKLAND - COROMANDEL PENINSULA (Fig. 1)

This large area contains a wide variety of chert deposits, both in appearance and age. The main chert-bearing formations are the multicoloured shales of Northland (mapped as the Mangakahia, Waiomio, and Opahi Groups), the "greywackes" of eastern Northland and Auckland (the Waipapa and Waiheke Groups), and the andesitic and rhyolitic rocks (Beeson's Island Volcanics and Whitianga Group respectively) of Coromandel Peninsula. Fig. 1 shows the distribution of chert-bearing formations, and the location of some recorded chert deposits; numbered localities are described in Table 2.

Sedimentary formations

Areas of multicoloured shales, locally containing chert, are wide-spread in central Northland. The shales are of Lower Tertiary age (Teurian to Bortonian, Table 1) and have been mapped as part of the Mangakahia, Waiomio and Opahi Groups (Hay 1960; Kear and Hay 1961).

The older Mangakahia Group contains shale with interbedded lenses and bands of chert or siliceous claystone (Kear and Hay 1961); no specific chert deposits are mentioned. In the Mangakahia Subdivision Hay (1960) recognised two chert-bearing multicoloured shale formations, the Long Hill Shale (Waiomio Group; Waipawan-Porangan age) and Aponga Shale (Opahi Group; Bortonian); chert in the former formation is recorded from south of Kawakawa (Loc. 3, Fig. 1) and from the latter formation, near Kaeo (Loc.2). Cherts in the Aponga Shale are described (Hay 1960, p. 40) as forming lensoid bands up to 0.3 m thick, of a mauve or chocolate colour when fresh, but weathering to green or white.

Because the Onerahi Chaos-breccia of Northland (a sedimentary formation accumulated by gravity sliding; Kear and Waterhouse 1967) contains sediments of the Mangakahia, Waiomio and Opahi Groups, outcrops of this formation will also yield chert. A large body of "Chaos" north of Auckland is probably the source of some isolated chert boulders found in that area (e.g. loc. 13).

The oldest rocks in Northland - greywacke and argillite (often just called "greywacke") of the Waipapa Group (Permian - Jurassic) - contains a wide belt of commonly red or brown-coloured chert that extends from Whangaroa in the north to Whangarei in the south (Kear and Hay 1961; Thompson 1961). Occurrences are also reported from west of Waipu, and on Kawau Island. In the Auckland area, similar greywacke (mapped as Waiheke Group; Jurassic) contains numerous chert lenses, some of which are radiolarian (Schofield 1967). (Radiolaria are plankton with siliceous skeletons; their remains form thick deposits of ooze on parts of the ocean floor).

Volcanic rocks

Volcanic rocks which have a relatively high silica content, such as andesite and rhyolite, often contain small deposits of chert, silicified sediments, silicified wood, and other varieties of silica. In Northland, the andesitic Wairakau Andesites and rhyolitic-dacitic Parahaki Volcanics are likely to contain minor chert deposits. Some chert has also been observed in the basic (e.g. basalt) Wangakea Volcanics of North Cape, and Hay (1960 pp. 49-50) records minor radiolarian and green chert in the Tangihua Volcanics of the Mangakahia Subdivision. Some green and black chert is also associated with basic volcanics in the Tupou Formation (Early Cretaceous; Hay 1975).

In the Auckland area, isolated chert occurrences have been reported from Manukau Breccia of the Waitakere Range, and in south Auckland, from the Kiwitahi Volcanics. In Coromandel Peninsula, the andesitic Beeson's Island Volcanics and rhyolitic Whitianga Group are well-known as a source of chert and other varieties of silica, and most large streams and many beaches yield good specimens (although some deposits have now been virtually "worked out" by rockhounds). Some rocks on Great Barrier Island also contain chert deposits.

EAST CAPE REGION (Raukumara Peninsula) (Fig. 2A)

Unlike the Early Tertiary shales of Northland, sediments of similar age and lithology in the East Cape region do not contain extensive chert deposits. Only a few occurrences have been recorded but this probably partly reflects the very complex geology, and paucity of good exposure. Some red and green chert is associated with Mangatu Group rocks (Teurian age) in the Te Araroa area (Chaproniere 1969 p. 15), and these beds are the likely source of chert (mata Waiapu) found in the Waiapu River. Siliceous shale of similar age extends all along the southern side of the Raukumara Range but appears to contain only rare chert (e.g. Te Rata Stream); west of Moutohora no chert has been observed in this unit. Some, however, has been collected further south from outcrops near Gable End Foreland (locs 29-31).

Chert also occurs in Early Cretaceous greywacke-type rocks, for example at Te Kaha, and as pebbles in Cretaceous conglomerates. Minor chert could be associated with the basaltic Matakaoa Volcanics, as very similar rocks in Northland (Tangihua Volcanics) contain chert.

SOUTHERN HAWKE'S BAY - WAIRARAPA (Fig. 2)

Cropping out in many areas between Cape Kidnappers and Cape Palliser is a widespread, distinctive sedimentary formation of Haumurian-Teurian age (Table 1), which has been variously termed the Whangai Shale, Whangai Argillite and Whangai Chert - most geologists refer to it simply as "Whangai". Although highly siliceous (silica content up to 90-95%), the rock does not show the typical features of chert (e.g. conchoidal fracture) and is better termed a siliceous mudstone or siltstone. Chert nodules, some very large, are common in this unit, though in parts of southern Wairarapa the Whangai lacks chert.

The main chert-bearing formation in the south-eastern part of Wairarapa is a siliceous limestone often called the Mungaroa or Kaiwhata Limestone; it is essentially a northern equivalent of the Amuri Limestone of Marlborough. Chert localities have previously been recorded by Keyes (1970) and Walls (1971), and some trace-element analyses were obtained by the latter worker. The chert, mostly black or grey, occurs as nodules and lenses in the limestone, and never as extensive beds such as are found in Marlborough.

Some chert, often red or brown in colour, is also associated with basic volcanics (basalt and spilite) within Early Cretaceous greywacke-type beds, particularly in the Opouawe-Awhea valleys, in SE Wairarapa, and near Tinui. Green chert, along with agate, is also found in younger (Haumurian) basalts near Ngahape. To the west, in greywacke of the Tararua and Ruahine ranges, red chert occurs in extensive bands associated with altered volcanics. Splinter greywacke ranges, such as the Waewaepa Range, contain similar chert bands.

MARLBOROUGH (Fig. 2B)

While multicoloured and siliceous shales are the most important chert-bearing formations in the North Island, it is the distinctive, hard, well-bedded limestone - the Amuri Limestone - of Marlborough that is the single most important chert-bearing formation in the South Island. The formation, which extends from Cape Campbell in the north to the Waipara district, North Canterbury in the South, not only contains chert nodules and lenses, but in many places also grades down into a thick, bedded chert unit.

The chert beds and lenses associated with the Amuri Limestone have been described in detail by Thomson (1916), and their distribution is shown in Fig. 2B. The greatest development of the basal chert beds, distinguished as a separate formation - the "Flint Beds" - by Suggate (1958), is in the Coverham area (mid Clarence Valley) where the unit is over 300 m thick, but the chert thins rapidly to the southwest along the Clarence Valley and is absent in the Dart River (McKay 1890 p. 161). The basal chert unit also becomes much thinner to the west, in the Awatere Valley, and to the northeast, between the Flaxbourne River and Cape Campbell.

To the south it is not found beyond the Hapuku River (Thomson 1916 p. 52), and at Kaikoura Peninsula and Haumuri Bluff chert occurs only as nodules and lenses within the limestone (McKay 1890 p. 162).

The base of the Amuri Limestone ranges in age from Teurian to Waipawan (Lensen 1962; Table 1), so that much of the basal chert unit is probably of Teurian or uppermost Haumurian age. In fact, at Woodside Creek, the Cretaceous-Tertiary boundary lies about 50 m above the base of the chert (Dr P. Strong, pers. comm.). However, there are also some slightly older chert beds, as Thomson (1916 pp. 52-3) records deposits 12 m below the main chert unit in Isolated Hill Creek, and 300 m below in Nidd Stream, Coverham. The age of the uppermost chert occurrence is unknown, but the limestone itself ranges into the Eocene.

Sporadic chert deposits have been recorded from the adjacent greywacke ranges by Lensen (1962). Some siliceous rocks are also likely to be associated with basaltic volcanics of the Gridiron and Cookson formations, of Early Cretaceous and Oligocene age respectively.

OTHER AREAS

North Island

All of the main chert-bearing formations in the North Island have been considered above, but there is one deposit worth special mention. This is a river terrace gravel near Purangi, Taranaki which contains pebbles and cobbles of a dense green "chert", probably a silicified tuff. The occurrence has previously been described by Keyes (1971), and to the writer's knowledge this locality is the only source of chert that has been recorded in Taranaki. Although further work could reveal other sources, the pebbles are almost certainly derived from conglomerates within the Tertiary Urenui Siltstone, and as such conglomerates are probably fairly rare, the chances of finding similar important chert-bearing gravels elsewhere in Taranaki seem remote. The only other area where chert pebbles might be found is along the coast near Marakopa, because Triassic conglomerates there may have been the original source of the wide variety of pebbles that occur in the terrace gravel.

Further south, in the Wanganui district, some chert pebbles may occur terrace gravels but none, to my knowledge, have been recorded. To the west, some chert pebbles would be expected to be present in rivers draining the west side of the main range, such as the Rangitikei and Manawatu.

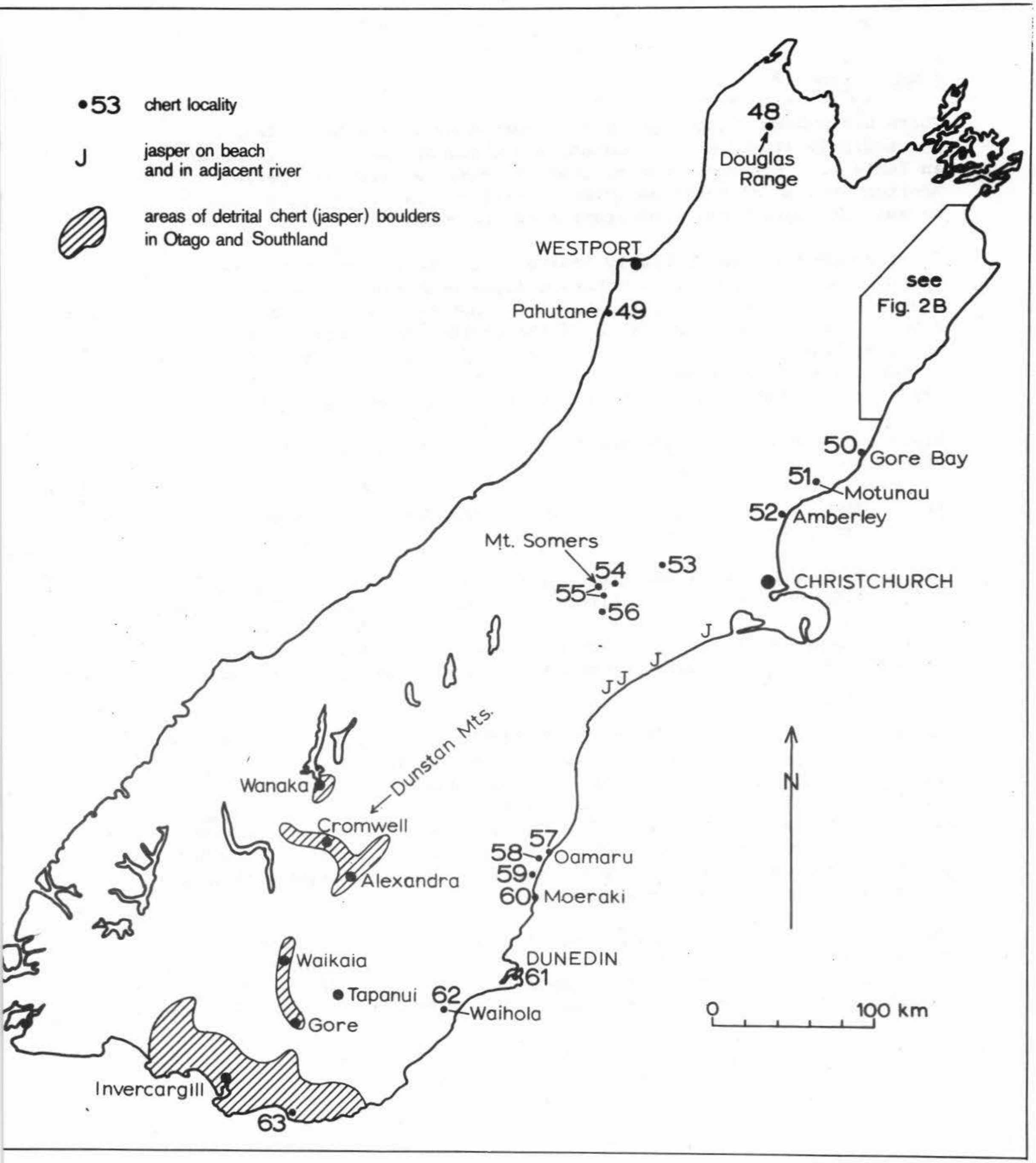

Fig. 3 - Chert localities in the South Island, excluding Marlborough.

South Island (Fig. 3)

There are numerous isolated chert occurrences in the South Island, particularly along the east coast, and these are described in detail in Table 2. However, some of these occurrences require special mention because of their association with certain rock types, and because of their known exploitation by the Maori.

Chert sources are particularly scarce in the Nelson and West Coast regions, but one source, at Pahutane (near Westport), is known to have been exploited into European times (Heaphy 1862). Heaphy records that Taramakau Maoris used the chert from Pahutane for drilling holes in greenstone. The age and nature of occurrence of the chert is not known but geological maps of the area (Henderson 1917) show terrace gravels overlying Miocene marine sediments.

Along the east coast of the South Island, chert deposits are associated with three main rock types:

(1) Basic volcanics within Jurassic greywacke e.g. near Gore Bay, and in the Canterbury foothills.

(2) Early Cretaceous andesitic-rhyolitic volcanics (Mt Somers Volcanics) e.g. at Mt Alford, Mt Somers, and Gawler Downs, and

(3) Eocene to Pliocene age basic volcanics at various localities in Otago, such as Oamaru, Otepopo, Moeraki, Dunedin, and perhaps Waihola.

Volcanic bands in greywacke of the Canterbury foothills are the probable source of red chert (or jasper) found in the Rakaia, Ashburton, Rangitata, and Orari rivers south of Christchurch (Tricker and Niethe 1968), but as the catchment of these rivers also includes andesitic-rhyolitic volcanics (Mt Somers Volcanics), some of the chert pebbles could be derived from these rocks. Chert found at Amberley, Leithfield, and Motunau is almost certainly derived from volcanic bands within the greywacke, as is the case near Gore Bay.

The younger Mt Somers Volcanics may have been an important source of chert in pre-European times, as Orchiston (1976) has recently documented the use of a hard, pale green silicified rhyolitic tuff from Gawler Downs. It is possible that similar deposits nearby e.g. at Mt Alford, were also exploited.

Some chert also appears to be derived from the extensive schist terrain of Central Otago, odd occurrences having been reported from areas such as the Dunstan Mountains (Liversidge 1877) and Tapanui (Cox 1882). Vaughan (1970) has shown that jasper boulders are reasonably common in some areas of Otago and Southland (Fig. 3), and that many of Southland's gravel beaches contain chert pebbles.

The only other major source of "chert" is from porcelanite deposits associated with burned-out lignite seams in Otago and Southland. These are currently being investigated by Mr G.M. Mason of Otago University.

Chatham Islands

Recent archaeological investigations on the Chatham Islands have revealed the existence of several chert deposits (Mr H. Campbell, pers. comm.). One sample has been dated as Heretaungan (Table 1) on the basis of fossils, but as yet no sedimentary formations of this age have been mapped on the Chathams; it is possible that Heretaungan sediments have been almost entirely removed by erosion, only the chert remaining.

SOURCING OF CHERT

In the last few years, the well-known prehistoric flint mines of Great Britain and Western Europe have been the subject of intensive study by archaeologists and geologists in attempts to differentiate the raw material sources by chemical means (e.g. Sieveking *et al.*, 1970, 1972; Aspinall and Feather 1972; de Bruin *et al.*, 1972). Various methods of trace element analysis combined with statistical treatment of data have been successfully employed. However, it should be emphasised that these workers were dealing with a small number of *known* sources, all related to a single geological formation (the Cretaceous Chalk); in New Zealand we are dealing with a large number of potential sources (i.e. not definitely known to have been exploited), related to geological formations of widely differing age and rock type.

While most of the analytical equipment employed by European workers is available in New Zealand, no major attempt has yet been made to differentiate the various chert sources. Samples from some areas have been analysed by conventional X-ray fluorescence (Walls 1971; Ward and Smith 1974), and by a new "low-power" XRF analyser (Leach 1976), but while the results are encouraging, they are not yet of practical value.

In the following section it is proposed to review methods already applied by overseas workers (mainly in Europe) to the "sourcing" of chert (or flint), and to look at other methods which may be useful in differentiating New Zealand chert sources. The latter, to my knowledge, have not yet been applied to sourcing studies.

Sourcing methods

Most of the major sourcing methods employed depend upon minor constituents or impurities in the chert sample. Impurities such as clay minerals, heavy minerals and fluid inclusions (pure chalcedony contains 1-2% water) are the most likely source of minor (or "trace" as they are commonly called) elements such as aluminium, iron, manganese, strontium, and the "rare earths", and these are the basis for trace element analysis. Clays and water also provide the basis for heat treatment methods such as differential thermal analysis (DTA). Petrographic methods depend on textural differences in the chert, on the forms of silica (i.e. opal, chalcedony or quartz) and on other minerals present. Finally, marine cherts may contain microfossils such as Foraminifera and Radiolaria which can be used to indicate geologic age.

(1) Trace element analysis

A detailed discussion of the various methods employed in trace element analysis of chert is beyond the scope of this paper, but it is worth noting some of the problems and limitations of these methods, particularly in relation to New Zealand. Some of the different techniques that have so far been applied to sourcing studies are:

- (a) emission spectroscopy (e.g. Sieveking *et al.*, 1970)
- (b) atomic absorption spectroscopy (e.g. Sieveking *et al.*, 1972)
- (c) X-ray fluorescence spectrometry (e.g. Walls 1971; Ward and Smith 1974)
- (d) neutron activation (e.g. Aspinall and Feather 1972; de Bruin *et al.*, 1972).

In Britain, initial results from emission spectroscopy were found to be somewhat unreliable (Sieveking *et al.*, 1970 p. 253) and this method was soon superseded by the more accurate and faster atomic absorption method by which up to 26 elements could be determined (Sieveking *et al.*, 1972 p. 160).

However, the advantages of neutron activation analysis were quickly appreciated (Aspinall and Feather 1972; de Bruin et al., 1972), especially since it is a non-destructive technique and is capable of handling a large number of elements, including the "rare earths".

Because of variations in concentration of elements both within a single chert sample, and in different samples from the same chert deposit (de Bruin et al., 1972 pp. 56, 59), all of these methods require large numbers of samples to be analysed. In addition, statistical treatment of data is necessary in order to show up differences between sources. Thus, even for a small number of sources within a single geological formation, as is the case in Britain and Western Europe, a considerable number of analyses are required.

In New Zealand, X-ray fluorescence is the only trace element technique that has so far been applied to the sourcing of chert. While Walls (1971) has shown differences in the Rb/Sr concentrations of cherts from Wairarapa and Wairau Bar, these differences are likely to become less significant once more cherts from the same formation are analysed. Cherts from some volcanic environments may have very low concentrations of some trace elements compared to sedimentary cherts, as suggested by Ward and Smith (1974), but so far only a few elements have been analysed. Leach (1976) has recently conducted a pilot study to assess the potential of a new "low power" XRF analyser, and has analysed a number of samples from archaeological assemblages and natural chert occurrences.

The large number of potential sources in New Zealand, and scarcity of known exploited deposits, means that very large numbers of samples will have to be analysed; rapid, accurate and non-destructive techniques such as neutron activation are therefore the most attractive methods of analysis. But while it may be possible to distinguish between some individual chert deposits it might not be possible, because of destruction of many sources (i.e. by removal of material, or burial), to say that a particular chert artefact came from a particular source. Trace element analysis should, however, be able to indicate the general area (e.g. Coromandel) from which a chert flake could have come.

The foregoing discussion has been confined to reviewing methods by which large numbers of minor elements are generally analysed. However, while Aspinall and Feather (1972, p. 52) have noted that it is "doubtful whether a comparison of concentrations of a single element .... is sufficient to characterise (British) prehistoric flint mine sites ....", the more varied origins for chert in New Zealand make such an approach worth considering.

Even within the rather uniform Amuri Limestone, Thompson (1916, p. 54) records flints in Isolated Hill Creek, Marlborough with high magnesium values (5-10% MgO probably resulting from dolomite) yet chert at Mororimu Creek, 35 km to the south (Wellman 1945) and Amuri-type limestone in Wairarapa contain less than 1% magnesium. The analysis of a single element, therefore, may be useful in eliminating certain possible sources for a particular chert sample, or perhaps in indicating the type of geologic formation from which a chert artefact may have come.

(2) Petrographic methods

The petrological microscope has already been used in identifying stone sources in New Zealand e.g. Simmons and Wright (1967), Best (1975), but to the writer's knowledge has only been applied to chert in one instance. In a study of 12 thin sections, Walls (1971) has shown differences between chert samples from SE Wairarapa and Wairau Bar, particularly in veining, grain size, and organic remains. While these differences could become less significant once more chert samples are studied, Thomson (1916) has noted three features in Marlborough cherts which may be useful in distinguishing some of these cherts from those in other areas:

(a) the absence of siliceous microfossils such as Radiolaria and diatoms (p. 56)

(b) the occurrence of dolomite (calcium-magnesium carbonate) crystals in some flints (pp. 54-55)

(c) in basal flint beds at Sawpit Gully, Coverham, a large amount of detrital quartz (i.e. sand) and other minerals (p. 55).

Walls (1971 Plate 8) illustrates one thin section of a Wairarapa chert containing abundant detrital grains, so this latter feature (c) is not confined to Marlborough chert. However, if other factors (trace element analysis) indicate a Marlborough source for a sample, cherts from Coverham may be able to be distinguished, on this basis, from those in other areas of Marlborough.

The production and study of thin sections is time-consuming and relatively expensive, and it seems unlikely that this method could ever play a major role in the sourcing of chert. The method may, however, be very useful in distinguishing cherts in an archaeological assemblage which originate from very different geologic environments i.e. from siliceous limestone, greywacke, or volcanics.

(3) Dating by fossils

In reviewing some of the methods applied to chert sourcing in Europe, Sieveking et al. (1972 p. 151-2) noted that attempts to identify sources of flint using fossils did not prove very successful. The reason for this failure is that all the main chert occurrences in Britain and Europe are of roughly the same age. A similar situation exists in New Zealand, in the main Northland and East Coast occurrences, and even though there are some differences in age within these regions (Table 1), both Thomson (1916 p. 56) and Walls (1971 p. 36) have reported the virtual absence of siliceous organisms such as Radiolaria and diatoms in Marlborough and Wairarapa cherts. The calcareous tests of Foraminifera seem to be the only identifiable fossils preserved.

The occurrence of radiolarian cherts has previously been mentioned in discussing "Distribution", and to the writer's knowledge these deposits are confined to greywacke-type rocks ranging in age from Permian to Lower Cretaceous (Table 1). Theoretically it would be possible to extract Radiolaria (by dissolving in hydrofluoric acid) and identify them, and this has been done with some Cretaceous cherts, but generally poor preservation and difficult identification means that any age determinations would be very crude. It is probably better to look for other ways of distinguishing between radiolarian cherts.

There is some hope, however, for the limited use of fossils in sourcing. Chert samples that contain small pockets of the original limestone matrix may yield abundant microfossils, and in the case of one Chatham Island chert sample, these provided a reliable age determination. Thus, while the method of dating by fossils is cumbersome and imprecise, it may be useful in dealing with odd chert assemblages, and as a last resort if other methods of sourcing fail.

Potential sourcing methods

The three potential methods of sourcing chert discussed here are all dependent on the heat treatment of samples, and information is drawn almost entirely from Purdy (1974).

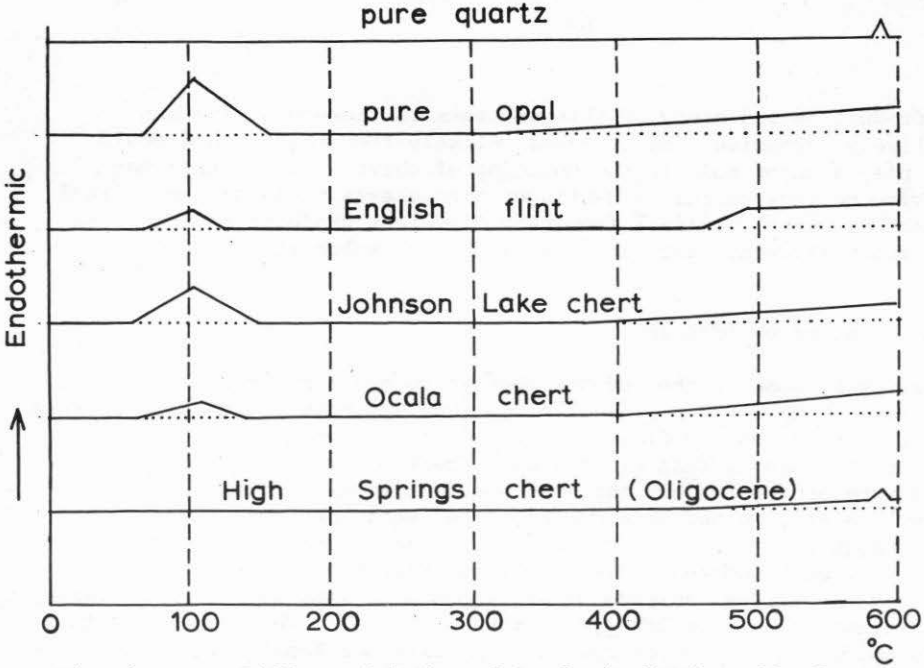

Fig. 4 - Differential thermal analysis (DTA) graphs for some Florida cherts compared with standards. After Purdy (1974).

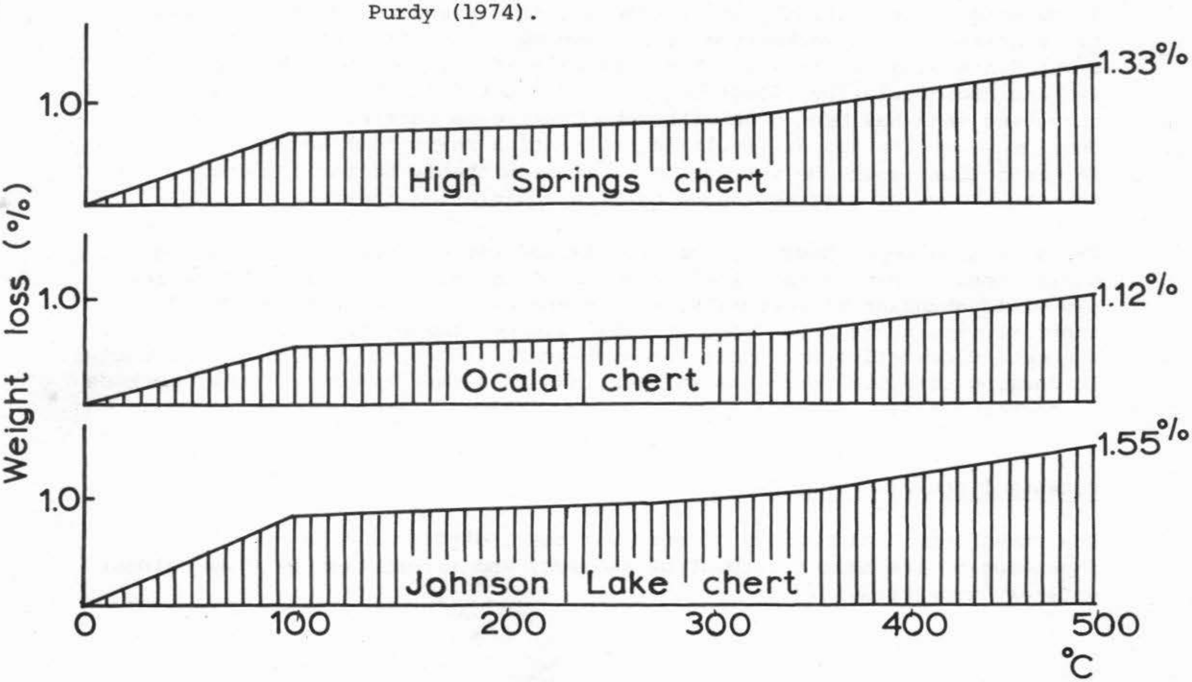

Fig. 5 - Weight loss on heating of some Florida cherts. After Purdy (1974).

Although Purdy's investigations were related to the American Indian's use of thermal alteration of silica minerals in order to produce better flaking qualities, her methods are certainly applicable to the sourcing of New Zealand cherts. In fact, because two out of the three methods are non-destructive (although the odd explosion occurs on heating), and do not require very sophisticated equipment, they hold considerable promise.

The first two methods described - differential thermal analysis (DTA) and weight loss - depend on the fact that cherts contain a certain amount of water, both adsorbed on the surfaces of crystals and chemically bound. Fuchtbauer (1974 p. 328) states that chalcedony contains 1-2% water, and opal 8-10%, so that the quantity of water in a chert must partly reflect the forms of silica present. The third method mentioned depends on the amount of iron present, and may be particularly useful in distinguishing sources of iron-rich cherts.

(1) Differential thermal analysis (DTA)

The DTA analysis of some American cherts, English flint, and two standards, is shown in Fig. 4. The graphs represent the water lost from the chert on heating, an endothermic (heat gain) peak at 112°C representing the loss of adsorbed water, and a further endothermic trend at between 350-450°C representing the loss of chemically bound water. It can also be seen that two of the American cherts (age unknown) closely match the pure opal graph, while an Oligocene chert shows no peak at 112°C, but instead one close to pure quartz. Thus DTA not only shows water loss but also identifies the forms of silica present. This method, therefore, could have considerable potential in sourcing, particularly in determining the geologic age of chert artefacts, because as Pettijohn (1957 p. 437 Table 1), points out, the quantity of both water and opal in chert decreases with time (or increasing geologic age). Fuchtbauer (1974 p. 330) also notes that amorphous silica (opal) is transformed into quartz at different rates, and that the duration of transformation depends on the thermal history of the rock. Thus, it may even be possible to distinguish between chert deposits of the same geologic age, because various parts of a formation may have been subjected to different degrees of deformation or stress (and therefore temperature).

(2) Weight loss on heating

The weight (water) loss on heating of three Florida cherts is illustrated in Fig. 5. These graphs show that at 100°C there is a large weight loss due to the removal of adsorbed water, and a further, slow weight loss beginning around 350°C, when chemically bound water is removed. Comparison with Fig. 4 shows that the High Springs chert, although containing little or no opal, contains a large quantity of water. This is explained by the fact that chert can readily gain or lose water depending on the humidity. Thus, while total weight loss on heating may not be a very reliable parameter for distinguishing different chert sources, measurement of chemically bound (fixed) water could be.

(3) Colour change

Purdy (1974 p. 46) found that in Florida cherts a colour change took place on heating to 240-260°C, and that the resulting colours depended on the amount of iron present. Therefore, in samples containing considerable quantities of iron (1 000 - 5 000 ppm), as probably many New Zealand cherts do, colour change on heating may prove to be of some value in the initial sorting (into "source") of chert assemblages.

DISCUSSION

Having a large number of widely distributed chert occurrences, so few of which are known to have been exploited by the Maori, is the one outstanding problem facing archaeologists involved in the sourcing of chert. The number of potential sources is undoubtedly several times greater than that of many other rock types (e.g. obsidian, quartzite, greenstone) and as a result, the sourcing of chert must be approached in a slightly different way. Two suggested procedures are outlined below. The first could perhaps be described as a local or intraregional approach, with minimal use of analytical techniques; and the second, an inter-regional approach, with greater reliance on detailed physical and chemical analysis.

(1) As most chert was probably obtained from rivers and beaches, rather than from primary (in situ) sources, there is unlikely to be much direct evidence of exploitation remaining. Evidence of exploitation of a source or sources must come, therefore, from archaeological sites close to the area of chert occurrence. This means that all chert occurrences close to sites would have to be located and sampled, so that chert flakes from these sites could be matched with samples from potential sources. Only in this way would it be possible to say, without resource to extensive analytical work, that a particular source was definitely exploited, though tradition or historical records might also provide evidence of exploitation in some cases.

Of course, it may not be possible to locate all sources, even major ones, because erosion and landslides will have removed or buried some. (At the same time others, not exposed in pre-European times, could have been uncovered). In some areas in particular, aggradation of rivers has been so great in post-European times that important secondary (i.e. river gravel) chert deposits could have been completely buried. A more recent problem is that of total removal of some deposits by rockhounds. Thus the chances of being able to match all chert flakes from a site with a particular source (or sources) do not seem very good.

(2) On the other hand, it may be reasonably safe to assume that sites located in or close to a major chert-bearing region such as Marlborough will contain material obtained almost exclusively from within that region (though there are certainly well-documented cases for other rock types e.g. obsidian, where this is not so). So in major source areas, what would the matching of a chert flake with a particular chert outcrop tell us? Perhaps nothing. However, it is important to know whether a piece of chert recovered from a site within a chert-bearing area did definitely come from that locality, and even more important for a site well-removed from any chert source (e.g. central North Island), to know from which general area a chert artefact came. As a first priority then we should perhaps be looking for major differences in chert from different regions, and analysing chert assemblages from sites well-removed from any major source area; such an approach might give some idea of the overall exploitation and dispersal of chert.

There is obviously considerable scope for amateur participation here, because both approaches to chert sourcing will require detailed field surveys, and considerable reliance on local knowledge. There is scope, too, for co-operation between the archaeologist and amateur geologist (or rockhound), because both have a common interest - the search for siliceous deposits. Thus the successful sourcing of chert artefacts in New Zealand will probably depend largely on the combined efforts of the professional and amateur archaeologist and geologist, together with a fair amount of luck.

CONCLUSIONS

In order to facilitate easier communication between those involved in the study of chert, it is recommended that both archaeologists and geologists adopt a single, broad definition for the term. The suggested definition for use is that of the American Geological Institute (Glossary of Geology 1972).

It has been shown that chert is widely distributed in New Zealand and that it varies considerably in its mode of occurrence and age. Several methods are available which have been, or could be, used to differentiate chert from different sources, but it is unlikely that any one method will provide all the answers. Finally, two approaches to the sourcing of chert are outlined, both of which will require detailed field studies and sampling. It is concluded that the successful sourcing of chert in New Zealand will depend upon:

(a) the location, sampling, and analysis of all major chert formations, and any known exploited sources

(b) determination of the total range in composition of each chert formation, and of each known exploited source, and

(c) the use of a variety of analytical techniques.

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TABLE 2 - Description of numbered localities shown on Figs 1, 2 and 3.

Information is largely drawn from published material (in which case the original descriptions are given), and observations by the writer.

NORTHLAND - AUCKLAND - COROMANDEL PENINSULA (Fig. 1)

<u>Northland</u>

1. West end of Tom Bowling Bay (pers. obs.); minor chert in volcanics.

2. Near Kaeo, grid ref. N11/327691 (Hay 1960 p. 41).

3. Several localities near Waiomio, approx. 6-7 km south of Kawakawa (Hay 1960 p. 36); on ridge between east and west branches of Waiomio Stream; and between Waiopitotoi Stream and the foot of Long Hill (residual flints resting on Waipapa Group). These are probably the localities mentioned by McKay (1884 pp. 125-8).

4. On the slopes of Ruapekapeka (Ferrar *et al* 1925 p. 35); boulders of banded flint.

5. Hukerenui (Ferrar *et al* 1925 p. 37); banded flint beds in claystone.

6. Near Purua (Thompson 1961); multicoloured shale with flint (Waiomio Group).

7. Whangarei, several localities. Liversidge (1877 p. 495) records variegated grey and white flint from the Heads; Hector (1892 p. 117) notes the occurrence of flint in diatomaceous earth; and brown flinty chert is recorded by Tricker and Niethe (1968 p. 8) from the north side of lower Whangarei Harbour.

8. Curnow's Road, in the upper Manganui Valley, grid ref. N23/c. 590675. This area, containing a variety of cherts, has recently been set aside for use by rockhounds.

9. Maungaturoto (Morgan 1927). Tricker (1970 p. 13) records "moss agate" from green and chocolate shales a few kilometres north of Maungaturoto.

10. Hukatere Peninsula (pers. obs.); several chert localities, and silicified wood near Tinopai.

11. Between Port Albert and Tauhoa (Cox 1881 p. 18); flints in chalk-marls.

Auckland

12. Kawau Island (Thompson 1961); chert in greywacke.

13. "Sergeants Creek", draining the NE side of Red Hill, grid ref. N38/c. 120770 (Bartrum 1924 p. 145); boulders of impure jasper.

14. Muriwai; chert, plasma and silicified wood, associated with volcanics.

15. Administration Bay, Motutapu Island (pers. obs.).

16. Waiheke Island, several localities (Schofield 1974).

17. Ponui Island (Schofield 1974).

18. Coast between Maraetai and Orete Point, several localities. Also on McCallum's Island (Schofield 1967, 1974).

19. Hunua Range, several localities (Schofield 1974).

Coromandel Peninsula

20. Kaitoke Valley, Great Barrier Island (pers. Obs.); chert which is probably mainly silicified rhyolite and tuff.

21. Rings Beach, near Kuaotunu (pers. Obs.); variety of siliceous pebbles.

22. Black Jack (Tricker 1968 p. 6). Also in stream at west end of Otama Beach (pers. obs.).

23. Manaia, grid ref. N43/c. 979618 (pers. obs.); mostly dark grey or bluish-grey chert, often with plant remains.

24. Kaueranga Valley; a well-known collecting area for chert and silicified wood.

25. Whitipirorua (R.C. Green, pers. comm.).

EAST COAST NORTH ISLAND AND MARLBOROUGH (Fig. 2)

East Cape region (Fig. 2A)

26. Te Kaha (pers. obs.); red to brown chert in greywacke.

27. Waiapu River (Prickett 1975 p. 46); source of mata Waiapu.

28. Te Rata Stream (pers. obs.); light grey chert.

29. Upper Waimata Valley (Henderson and Ongley 1920 p. 34); small pieces of flint in fault zone.

30. Quarry at junction of Panikau Road and main highway, grid ref. N 98/597525 (T.L. Grant-Taylor, pers. comm.); light grey chert.

31. Gable End Foreland (Prickett 1975 p. 46); beach pebbles.

Southern Hawke's Bay- Wairarapa

32. Along the axis of the Elsthorpe Anticline near Kahuranaki (pers. obs.); grey to brown chert. See also McKay (1879 p. 73).

33. Waewaepa Range (pers. obs.); red chert in greywacke.

34. Quarry at Mara, grid ref. N154-5/680977 (pers. obs.); nodules of black, banded chert in complexly folded Whangai argillite.

35. Whakataki, in streams along coast to north (pers. obs.); light grey, black, and dark brown chert.

36. Kaiwhata River (Prickett 1975 p. 47).

37. Junction of the Wainuioru and Pahaoa rivers (Keyes 1972).

Marlborough (Fig. 2B)

38. West of Cape Campbell (McKay 1877b p. 188); black, grey and flesh-coloured flint.

39. Mouth of the Flaxbourne River (McKay 1890 p. 161).

40. Awatere River (McKay 1890 p. 161); interbedded limestone and flint.

41. Swale Stream (McKay 1890 p. 161); flint beds.

42. Mead Stream (Thomson 1916 p. 53); flint beds with intercalated limestone.

43. Isolated Hill Creek (Thomson 1916 p. 52); flint beds.

44. Waipapa Point and Bay (McKay 1890 p. 161; Wellman 1945); light-coloured and black flint.

45. Hapuka River (McKay 1877a P. 176); flint nodules in shale.

46. Kaikoura Peninsula (McKay 1890 p. 162); layers and nodules of yellow and grey chert.

47. Haumuri Bluff (McKay 1890 p. 162).

OTHER SOUTH ISLAND AREAS (Fig. 3).

Nelson

48. Douglas Range, near Lake Stanley (Grindley 1971); chert in Balloon Formation (Cambrian).

West Coast

49. Pahutane (Heaphy 1862 p. 169); flint. The geological bulletin (Henderson 1917) covering this area makes no mention of flint.

Canterbury

50. North of Gore Bay (Niethe 1968 p. 12); golden brecciated chert associated with basic volcanics in Jurassic greywacke.

51. Motunau (Tricker and Niethe 1968 p. 12).

52. Amberley and Leithfield (Tricker 1971 p. 7); spotted jasper.

53. Malvern Hills (Haast 1866 pp. 256-7); jasper and chert.

54. Mt Alford (P. Oliver, pers. comm.); pink and white silicified tuff.

55. Mt Somers, various localities. Cox (1882 p. 388) records black and grey flint, and jasper. Baked porcellanous tuff has also been located north of Mt Somers (P. Oliver, pers. comm.).

56. Gawler Downs (Haast 1866 pp. 256-7); plasma, probably silicified tuff. Orchiston (1976) records a Maori quarry in green silicified rhyolite tuff near the Surrey Hills homestead, grid ref. S81/886312.

Otago and Southland

57. Chelmer Street, Oamaru (Niethe 1969 p. 22); brown to green chert.

58. Waiareka Valley (McKay 1877c p. 62); black flint, associated with limestone?

59. Otepopo (Cox 1882 p. 387); jasper.

60. Moeraki (Liversidge 1877 pp. 494-5); grey flint with brown and dark blue-grey streaks; green jasper, variegated with reddish-brown streaks.

61. Portobello - Little Papanui (Tricker 1971 p. 7; Prickett 1975 p. 50); opal-jasper.

62. Waihola (Liversidge 1877 p. 495); yellowish chert.

63. Waipapa - Tokanui mouth (Prickett 1975 p. 50).