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METALLOGENIC EPOCHS AND TECTONIC CYCLES IN NEW ZEALAND

(Figs. 4)

Abstract: The time distribution of metallic mineral deposits (metallogenic epochs) in New Zealand corresponds with the successive Tuhua (Early to Mid Paleozoic), Rangitata (Late Paleozoic to Mesozoic) and Kaikoura (Late Cenozoic) tectonic cycles. Gold is the dominant metal in all three cycles. The tectonic cycles have resulted from a history of almost continuous interaction of lithospheric plates along the mobile margins of Gondwana and the Pacific Ocean throughout the Phanerozoic. This is reflected by a dominance of mineral deposits formed by tectonic related concentration processes. Much gold has been recycled into Cenozoic deposits as a result of the Kaikoura tectonic cycle being superimposed on gold-bearing rocks of the Rangitata und Tuhua orogenic zones.

Резюме: Распределение металлических минеральных месторождений по времени (металлогенических эпох) на Новом Зеланде соответствует последовательным тектоническим циклам Тугуи (с раннего до среднего палеозоя), Рангитаты (с позднего палеозоя до мезозоя) и Кайкоуры (поздний кенозой). Во всех трех циклах господствующим металлом является золото. Тектонические циклы следует из истории почти непрерывного взаимодействия литосферических плит вдоль подвижных краев Гондваны и Тихого океана в продолжение фанерозоя. Это отражено в преобладании минеральных залежей образованных во время процессов концентрации в отношении к тектоническим. Много золота было перециркулировано в кенозойские месторождения вследствие кайкоурского тектонического цикла наложенного на золотоносные породы орогенических зон Рангитаты и Тугуи.

Introduction

Considering its relatively small 269,000 km^2 area, the New Zealand landmass contains a wide variety of metallic minerals and is particularly well endowed in gold with lesser associated silver. The total recorded production of gold is 852 tonnes. There are also extensive titanomagnetite and ilmenite beach sands. The "Economic Geology of New Zealand" by Williams (1974) describes most of the metallic deposits.

The New Zealand microcontinent (Fig. 1) consists of three main structural elements: firstly, a Lower Paleozoic orogenic zone called the Tuhua Orogen, which occupies the west side of the South Island; secondly, Carboniferous to Lower Cretaceous "geosynclinal terranes" of the Rangitata Orogen, comprising the basement rocks of the North Island and eastern South Island; and thirdly, Cretaceous and Cenozoic sediments and volcanics which cover a large part of the country. In the South Island the Tuhua Orogen and part of the Rangitata

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Orogen are divided into two segments by 480 km of right lateral shift along the Alpine Fault.

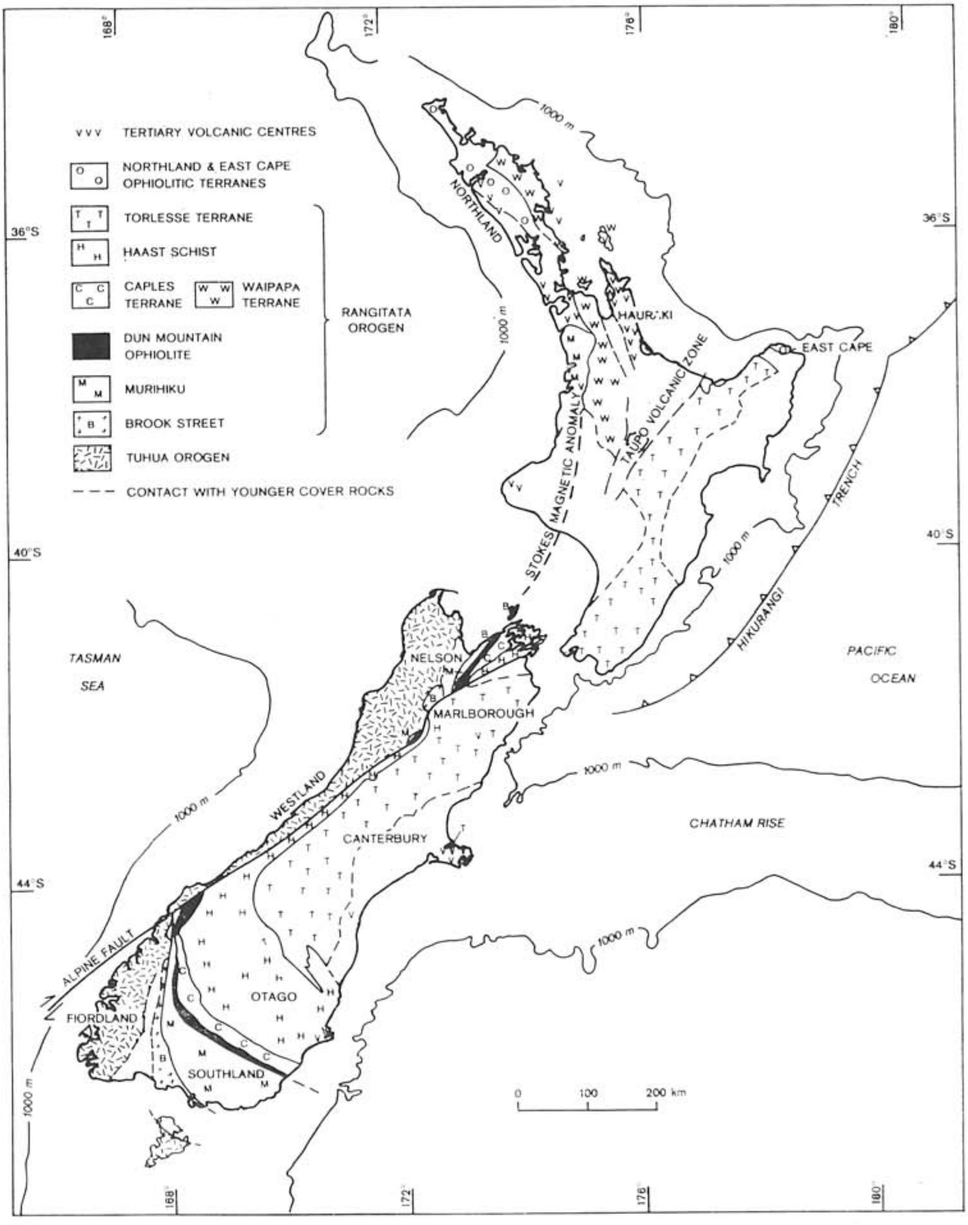

Fig. 1. Geotectonic map of New Zealand showing structural elements. Cretaceous and Cenozoic sedimentary cover rocks are without symbols.

The arrangement of the structural elements has resulted from present and past interactions of major lithospheric plates along the mobile margin of the Pacific Ocean. These interactions have produced a geological history of almost continuous, and at times intense, tectonic activity throughout Phanerozoic time. The geological history is subdivided into three tectonic cycles: the Tuhua in the Early to Mid Paleozoic, the Rangitata during the Late Paleozoic to Mesozoic, and the Kaikoura through the Cenozoic to the present day. Tectonic cycle is used here in the sense of a plate tectonic cycle and includes the pre-orogenic as well as the main orogenic phases. The effects of orogenies belonging to the three cycles have been superimposed to a considerable extent, thus giving New Zealand geology a complex structural pattern (Grindley, 1974).

Each of the tectonic cycles has brought about well defined metallogenic epochs (Pirajno, 1980) with characteristic mineral deposits which are geographically clustered in metallogenic zones. The metallogenic zones generally correspond with, or form part of, major geotectonic units which relate to specific plate tectonic settings.

Mineral deposits formed by tectonic related concentration processes are predominant. Metamorphic-hydrothermal gold-quartz lodes were probably formed during orogenic phases of the Tuhua and Rangitata cycles. Extensive Late Cenozoic gold placers and ilmenite beach sands have been concentrated from large volumes of source rocks as a result of rapid tectonic uplift of mountain ranges. Subduction related volcanism has led to the formation of epithermal gold-silver fields and has produced the andesitic source rocks of titano-magnetite beach sands.

Tuhua tectonic cycle

The Tuhua Orogen (Fig. 2), also known as the Western Province (Cooper, 1979), originally joined with Antarctica and southeast Australia on the eastern margin of the Gondwana supercontinent. It is made up of a number of metamorphosed sedimentary belts of Lower Paleozoic age that are intruded by Paleozoic and Mesozoic granitoids.

In west Nelson a central belt of Cambrian volcanics and sediments were probably deposited in a volcanic island arc setting (Grindley, 1978). This central belt is allochthonous and is in thrust fault contact with a western belt of Cambrian to Ordovician flysch type sediments. The central belt is host to: stratabound gold in a chert-volcanic sequence, nickel sulphides and asbestos in a synvolcanic mafic-ultramafic complex, and to stratabound scheelite in marble lenses. Other mineralisation of this early phase of the Tuhua cycle includes stratiform zinc and copper hosted by metasediments and metavolcanics in Fiordland. Economically important gold-quartz lodes occur in greywacke or black slate sequences of the western belt. The gold-quartz lodes are localised in dilatant shear zones along fold axes or limbs. The lodes are considered to be metamorphic-hydrothermal in origin and may be related to a lower greenschist facies metamorphic event, K-Ar dated as Silurian.

The main orogenic phase of the Tuhua cycle took place in the Devonian and was accompanied and followed by intrusion of granitoid batholiths of predominant ilmenite series/S-type character (Tulloch, 1983).

Greisen type deposits, the majority with tungsten (usually as scheelite) and a few with tin, are associated with leucocratic granite bodies intruding quartzose greywackes of the western belt (e. g. Pirajno—Bentley, 1985). Synorogenic mafic intrusions of probable Devonian age carry magmatic nickel--copper sulphides and magnetite-ilmenite segregations in Nelson and Fiordland.

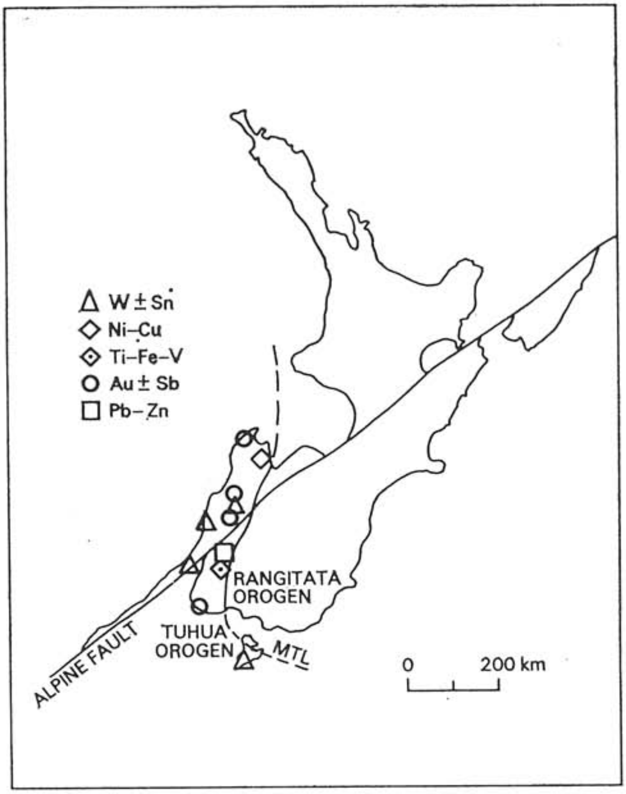

Fig. 2. Distribution of the principal metallic mineral deposits of the Tuhua cycle. The post-Cretaceous right lateral shift of 480 km along the Alpine Fault has been reversed.
Explanations: MTL = Median Tectonic Line, the boundary between the Tuhua Orogen and the Rangitata Orogen.

Rangitata tectonic cycle

The Tuhua Orogen is bounded on the east by the Rangitata Orogen, which is made up of an assemblage of discrete tectonostratigraphic terranes (Bishop et al., 1983) that vary and overlap in age from Carboniferous to Early Cretaceous (Fig. 3). These separate terranes include: an island arc-fore arc basin assemblage of the Brook Street and Murihiku Supergroups, the Dun Mountain

Ophiolite Belt, moderate P/T regional metamorphics of the Haast Schist zone, and extensive quartzofeldspathic and volcaniclastic greywackes of the Torlesse and Caples — Waipapa Terranes. These terranes are believed to have been accreted onto the pre-existing Gondwana margin during the Triassic (B i s h o p et al., 1983). The different terranes have distinctive metallogenic characteristics.

The Permian to Jurassic volcanics and sediments of the island arc-fore arc basin assemblage are poorly endowed with mineralisation. A layered mafic-

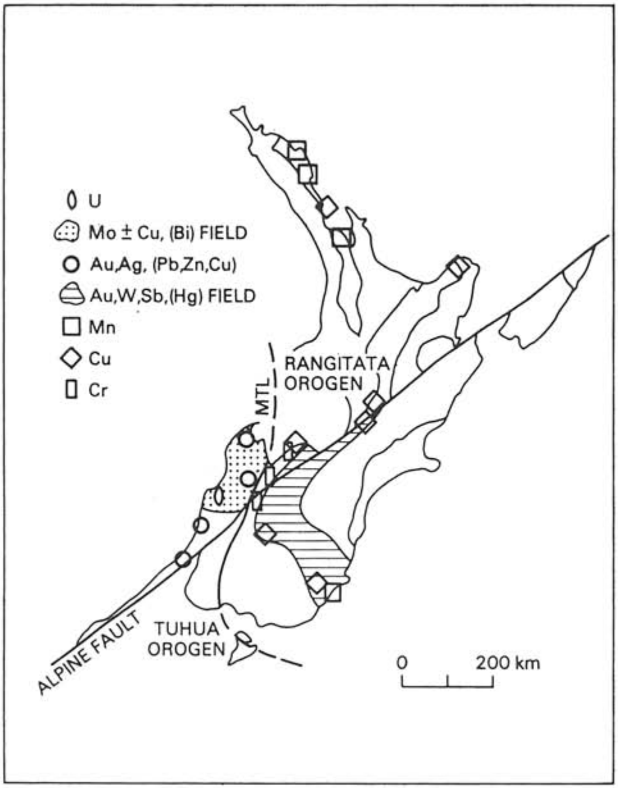

Fig. 3. Distribution of the principal metallic mineral deposits of the Rangitata cycle. The post-Cretaceous right lateral shift of 480 km along the Alpine Fault has been reserved.
Explanations: MTL = Median Tectonic Line, the boundary between the Tuhua Orogen and the Rangitata Orogen.

-ultramafic intrusion (Longwood Complex) in the root zone of the island arc is a source of alluvial gold and platinum.

The Dun Mountain Ophiolite Belt is an extensive belt of ultramafics, gabbros and basalts with minor associated felsic intrusives (C o o m b s et al., 1976; D a v i s et al., 1980). At Dun Mountain in the Nelson segment of the belt, podiform type chromite deposits are localised at the top of a protoclastic harzburgite zone and small pyrrhotite-chalcopyrite segregations occur in serpentinite above the podiform chromite (Johnston, 1981). Chrysotile asbestos deposits are localised around the margins of peridotite-dunite blocks at Red Mountain in the Otago segment of the belt (Babcock, 1981). The asbestos fibre zones have formed within dilational shear zones late in the Rangitata cycle.

The Permian to Triassic Caples Terrane consists mainly of volcanoclastic greywacke. In the North Island the Waipapa Terrane occupies a similar structural position, though it is mainly Jurassic in age. In the Waipapa Terrane, lenticular units of chert and pillow lava are hosts to syngenetic manganese deposits and, in one place, to a pyritic copper deposit that is comparable to the Besshi type of Japan.

The Haast Schists form a zone of regionally metamorphosed quartzofeldspathic schists with subordinate greenschist metavolcanics and manganiferous metacherts. Lithologic units of both Caples and Torlesse rocks pass with increase in metamorphic grade into the Haast Schist Zone, which may therefore represent the metamorphosed amalgamation of parts of two separate terranes. The amalgamation, together with early folding and metamorphism, possibly took place in the Triassic by collision of the Torlesse Terrane with the Caples Terrane (Bradshaw et al., 1980). The pre-metamorphic metallogeny of the Haast Schists is represented by small, pyritic copper lenses that are associated with greenschists. Quartz veins carying gold, scheelite, or stibnite are widely distributed in chlorite grade schists. The lodes are associated on a regional scale with manganiferous metachert, and mafic volcanics and tuffs. The mineralised quartz veins are thought to have formed from hydrothermal fluids generated by dehydration of the sedimentary pile during metamorphism (Henley et al., 1976; Paterson 1982).

The Torlesse Terrane is the most extensive terrane in New Zealand. Its sediments are characterised by thick sequences of quartzofeldspathic greywacke and argillite of original plutonic-metamorphic provenance. Spilitic lavas, chert and limestone are minor components. The Torlesse Terrane is barren of mineralisation, except for a few stratiform copper deposits, chert-associated manganese occurrences, and gold-quartz lodes, similar to those in the Waipapa Terrane and the Haast Schist Zone.

Rangitata granitoids

Late in the Rangitata cycle, the Tuhua Orogen was intruded mainly along its eastern side by extensive granitoids, mostly of magnetite series/I-type character. Calcalkaline granite, granodiorite and trondhjemite stocks that intrude the Karamea Batholith in west Nelson are associated with low-grade porphyry molybdenum mineralisation (Eggers—Adams, 1979). Also associated with Mesozoic granitoids are various gold, silver and polymetallic sulphide-bearing quartz vein deposits. A muscovite granite of probable Cretaceous age is a likely source for sandstone-type uranium mineralisation in arkosic sandstone and granite breccia in Westland.

Late Cretaceous to Mid-Tertiary rifting phase

Between the end of the Rangitata cycle in the Mid-Cretaceous and the onset of the Kaikoura Orogen in the Mid-Tertiary, an extensional tectonic phase, related to the rifting of the New Zealand microcontinent away from southeast Australia and Antarctica, is characterised by rift basins and intraplate type igneous activity. Some of the rift basins contain gold-bearing fanglomerates as at Gabriels Gully in Otago. The intraplate igneous products include alkaline mafic-ultramafic intrusions which are host to occurrences of copper-nickel sulphides and ilmenite-magnetite in Marlborough.

Northland and East Cape ophiolitic terranes

In northern New Zealand a different tectonic pattern is shown by the Cretaceous to Mid-Tertiary succession of Northland and East Cape (Fig. 4). Slabs of submarine basalt, dolerite and gabbro (Tangihua Volcanics and correlatives) are associated with stratigraphically disordered sediments that were emplaced as allochthonous sheets in the Early Miocene (Ballance—Sporli, 1979; Brothers—Delaloye, 1982). The Tangihua and correlative volcanic formations contain elements of an ophiolite suite, though ultramafics are present only at North Cape. Many of the slabs contain younger (Eocene—Miocene) lavas and intrusions, commonly alkaline in composition, that Brothers—Delaloye (1982) ascribe to later phases of seamount volcanism built on pedestals of Cretaceous ophiolitic ocean crust. Small pyrite-chalcopyrite lenses, similar to Cyprus type deposits, are associated with Cretaceous basalt of the ophiolitic slabs.

Kaikoura tectonic cycle – orogenic phase

The still continuing orogenic phase of the Kaikoura cycle commenced in the Miocene and is manifested by arc volcanism in northern New Zealand, and by growth of compressional mountain ranges induced by major strike-slip faulting (Fig. 4). In central and southern New Zealand the Alpine Fault system represents the boundary between the Indian and Pacific plates. Fault-controlled, non-marine basins in Otago and eastern Southland accumulated Miocene coal measures and quartz conglomerates that are host to numerous gold placers.

Beginning in the Late Miocene and still continuing, large regional uplifts, particularly along the Alpine Fault system, have resulted in the growth of mountain ranges. The rapid erosion and Late Quarternary glaciation of these ranges have produced large volumes of fanglomerates, and fluvial and fluvioglacial gravels, some of which were derived from gold-bearing Rangitata and Tuhua rocks. Repeated fluvial reworking of the gold-bearing conglomerates and gravels, coupled with further erosion of primary gold, has resulted in the formation of extensive and locally rich Late Tertiary and Quaternary gold placers, particularly in Late Quaternary river bed and terrace gravels. The gold placer fields of Westland and Otago have been classed as "giant placers" by Henley—Adams (1979).

Extensive Late Quaternary, heavy mineral beach sands occur along the west coast of both North and South Islands. The heavy minerals are concentrated by the dominant westerly winds and ocean currents acting on a long northerly trending coastline receiving an abundant sediment supply. On the west coast, North Island, large deposits of titanomagnetite blacksands occur in dune and beach sands at intervals along 480 km of coastline. The titanomagnetite is derived from erosion of Late Quaternary andesite volcanoes located near the coast. In the South Island, ilmenite-garnet blacksands, commonly carrying economic gold concentrations, are found at intervals along 320 km of the west coast. The ilmenite and garnet are largely derived from the Haast Schist of the Southern Alps.

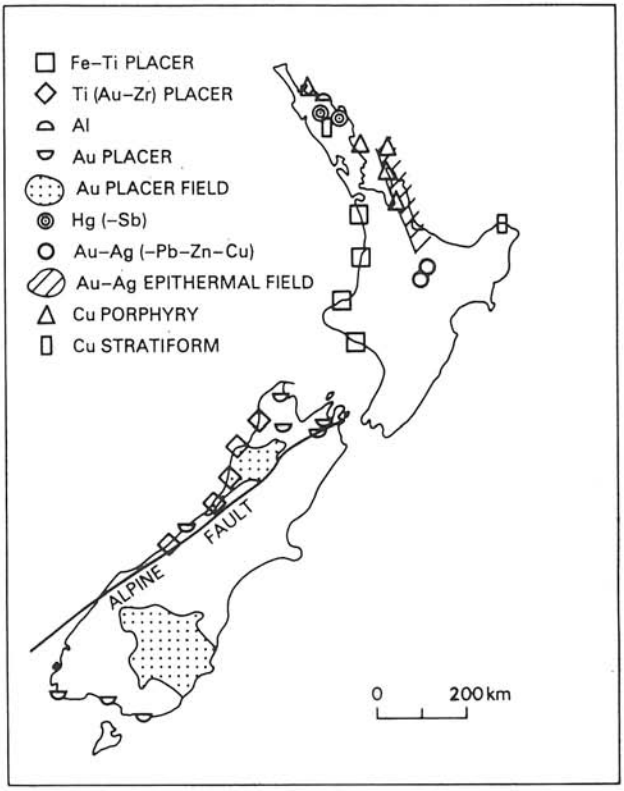

Fig. 4. Distribution of the principal metallic mineral deposits of the Kaikoura cycle.

Kaikoura tectonic cycle — volcanic zones

Commencing in the Early Miocene and continuing today series of volcanic zones in northern New Zealand are products of magma generation above westerly dipping subduction systems along the convergent boundary of the Pacific and Indian plates, though different configurations of the volcanic--subduction zones are proposed (Ballance, 1976; Cole—Lewis, 1981; Brothers, 1984) (Fig. 4).

The orogenic volcanic and associated minor intrusive rocks group into four main regions: western Northland, eastern Northland, Hauraki, and Taupo Volcanic Zone. There is a general decrease in age southeast from Northland to the still active Taupo Volcanic Zone. In western Northland the volcanics are of Miocene age and consist mainly of submarine calcalkaline basalt. No significant mineralisation is known.

The Miocene activity of eastern Northland and Hauraki is represented by subaerial andesite-dacite volcanism. Erosion has exposed a few high-level diorite stocks which are associated with low-grade porphyry copper mineralisation and polymetallic sulphide quartz veins. During the Late Miocene to Early Pliocene, rhyolite-dacite volcanism was extensive along the east side of the Hauraki region. This segment contains the major epithermal gold-silver metallogenic zone of the Hauraki Goldfield. The recorded production of the field is 1369 tonnes of gold-silver bullion with a gold: silver ratio of approximately 1 : 3.4. Gold and silver, predominantly as electrum, are contained in polymetallic sulphide-bearing quartz veins surrounded by extensive zones of hydrothermal alteration. The veins are mainly hosted by andesite and dacite, though some are in rhyolite or the greywacke basement.

Pliocene and Quaternary hydrothermal activity in Northland has produced epithermal mercury, antimony and silver mineralisation that appears to be related to alkaline and peralkaline rhyolites (Smith et al., 1977). The rhyolites are closely associated with alkaline to tholeiitic basalt lavas and are located well back from the modern subduction system.

The active Taupo Volcanic Zone was established less than 2 m. y. ago as the volcanic expression of the northwesterly dipping Taupo — Hikurangi subduction system (Cole—Lewis, 1981). The volcanic products comprise extensive ignimbrites, numerous rhyolite domes, large andesite stratovolcanoes, and minor dacite domes and basalt scoria cones. At least 20 active geothermal systems occur within the Taupo Volcanic Zone and some of these contain and are still making, native sulphur, gold-silver-antimony-arsenic and zinc-lead--copper deposits (Weissberg et al., 1979; Henley—Ellis, 1983).

In terms of value of metal produced the Kaikoura metallogenic epoch far exceeds the Tuhua and Rangitata epochs. Some 80 % of the total yield of gold and most of the silver has come from placer and epithermal deposits of Late Tertiary and Quaternary ages, though much of the placer gold has been inherited by recycling from lode deposits of the Tuhua and Rangitata epochs. The greater metallogenic productivity of the Kaikoura epoch is therefore, to a large extent, attributable to the superposition of the Kaikoura Orogen on the older Tuhua and Rangitata Orogens.

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