DEPARTMENT OF NATIONAL RESOURCES

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1979/8

CUMSEA 1979 -
Excursion Guide

by

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CRUST and UPPER MANTLE OF SOUTH EAST AUSTRALIA (CUMSEA) EXCURSION

INTRODUCTION

The aim of this excursion is to examine the field evidence used to elucidate the nature of the crust and upper mantle beneath the Lachlan Fold Belt. Some current models are biased towards the West Pacific marginal sea model involving Ordovician and Silurian oceanic crust and a mafic volcanic arc (e.g. Crook 1969, 1974). Other authors predicted a pre-Ordovician continental crust (Rutland 1973, White & others, 1976), while others (e.g. Scheibner 1973, 1974) a partly continental, partly oceanic substratum.

To date three major sources of evidence have been brought to bear on the problem; on this excursion we will examine all three.

1) Kimberlite nodules. These contain actual pieces of the crust and upper mantle sampled by the kimberlitic magmas during their intrusion.

2) Stratigraphic evidence. The oldest positively identified rocks in the Lachlan Fold Belt in New South Wales are Ordovician, although it has been postulated that some unfossiliferous sequences are Cambrian. Mafic rocks from the Ordovician and Silurian sequences have been used to support the West Pacific model, and the area through which the excursion passes contains one of the most comprehensive mafic volcanic sections in the Lachlan Fold Belt.

3) Granitoid evidence. The major problem which has emerged from geochemical study of granitoids is that for the majority of plutons the predicted source compositions cannot be matched with any known Ordovician or Silurian rocks. Evidently the crust is more complex than has been predicted by the stratigraphic evidence.

The route of the excursion is given in Figure 1. Kimberlites will be examined on the first half of day 1, and the stratigraphic evidence will be seen during the rest of Day 1 and early Day 2. The geological setting of the stops seen on the first half of Day 2 is shown in Figure 2. The remainder of the excursion will examine the granitoids. No detailed information on the granitoid section of the excursion is given in this guide as this is covered in I.G.C. excursion guide no 13-C (Chappell & White, 1976). Copies of this guide are available for CUMSEA members.

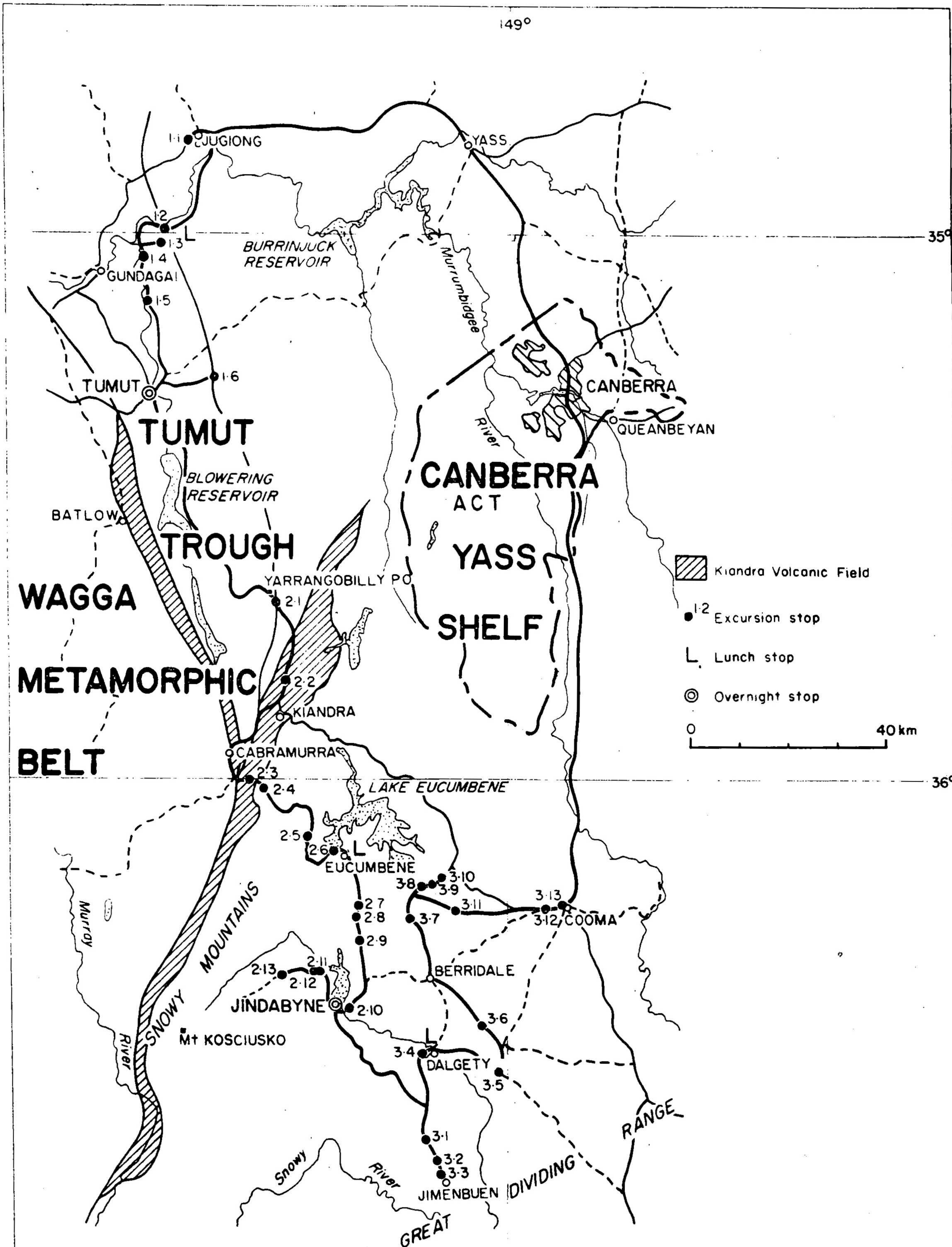

Figure 1
CUMSEA Excursion Route

N/B10-39A

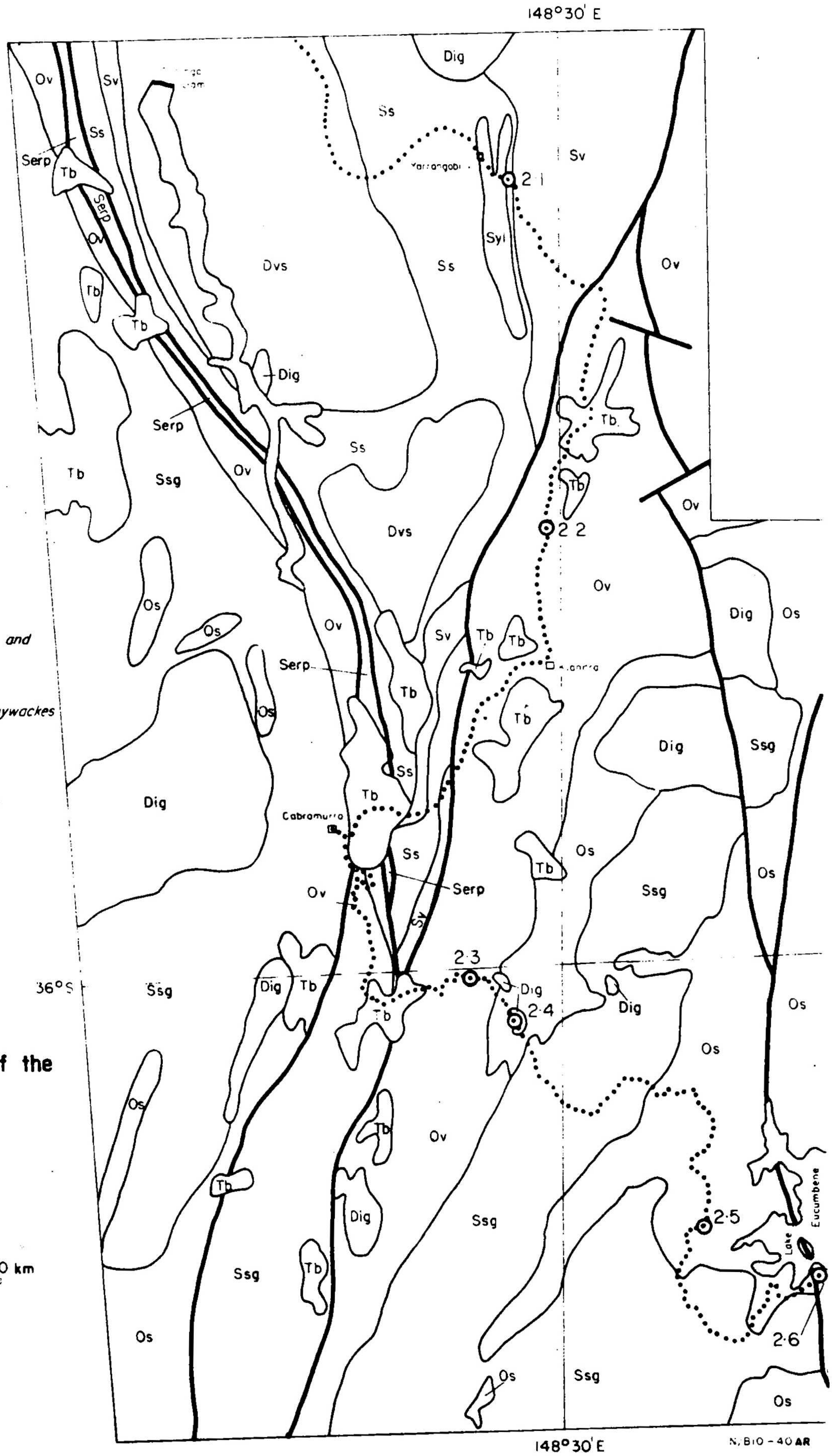

Figure 2

Generalised geology of the area traversed on the morning of Day 2

OUTLINE OF THE STRATIGRAPHY OF THE REGION

Ordovician

In the Lachlan Fold Belt the Ordovician sequence can be subdivided into volcanic (predominantly mafic) and non-volcanic sequences. The volcanic rocks are in one major north-trending belt, the Macquarie Volcanic Belt (Webby, 1976), which separates two troughs in which quartz-rich greywackes were deposited. On the excursion we will examine the most sourtherly part of this Belt, known as the Kiandra Volcanic Field (Webby, 1976), and the quartz-rich greywackes which were deposited to the east.

Volcanic rocks

The Kiandra Volcanic Field is a narrow, north-northeast trending belt which extends from at least the Upper Murray River northwards to beyond Kiandra (figure 1), and consists of lava flows, intrusive rocks, volcaniclastic deposits, and chert. On both margins, units of the Kiandra Volcanic Field intertongue and, in part, conformably overlie Ordovician quartz-rich greywackes; for this reason the mafic volcanics cannot be regarded as the substrata of an Ordovician marginal sea. All units of the Kiandra Volcanic Field have been regionally metamorphosed, and the isograds are continuous with those of the Wagga Metamorphic Belt to the west. This metamorphic event has been dated stratigraphically as lower Silurian (Wyborn 1977, Owen and Wyborn, in prep).

The magma types of the Kiandra Volcanic Field may be subdivided into three distinct chemical suites: The Jagungal Volcanics, the Nine Mile Suite and the Gooandra Suite. The other major unit of the Field the Temperance Formation is predominantly sedimentary, consisting of volcaniclastic rocks and tuffaceous chert.

The Jagungal Volcanics are very restricted in outcrop, and have been identified at only two localities, both of which are at the base of the volcanic sequence. They consist of high-titanium tholeiitic basalts, which have chemical characteristics analogous to both oceanic and continental tholeiites.

The Nine Mile Suite comprises the Nine Mile Volcanics, and the intrusive Geordies Spur Gabbro, Doubtful River Gabbro, and Leather Barrel Pyroxenite. These are on the eastern edge of the Kiandra Volcanic Field, and are in part faulted against the Gooandra Suite rocks, and in part separated from them by the Temperance Formation. The lavas are relatively unaltered, and consist of high - K basalts, basaltic andesites, and trachybasalts characterised by pale green clinopyroxene and primary K-feldspar and biotite- whereas the intrusives also carry abundant brown hornblende. Chemically the rocks of this Suite could be termed shoshonites. Jakes & White (1969), 1972) concluded that shoshonitic rocks overlie the deepest parts of downgoing slabs, but Arculus & Johnson (1978) suggested that, in general, such rocks appear to be developed in regions with a long history of plate interactions, and not necessarily in a back-arc environment.

The Gooandra Suite includes the Gooandra Volcanics, the Coppermine Creek Volcanics, and the intrusive Shaw Hill Gabbro, Windy Creek Diorite and Twins Creek Granodiorite. The Suite crops out on the western edge of the Kiandra Volcanic Field and is bimodal, consisting of felsic dacites, rhyolites, and granodiorites, and mafic basalts, basaltic andesites, and comagmatic intrusions. Felsic rocks are absent in the Jagungal Volcanics and Nine Mile Suite, but constitute up to 30 percent of the Gooandra Suite. Because of their abundance, the felsic rocks are unlikely to have been derived by fractionation from mafic rocks of the Suite, but could have been derived by partial melting of the lower crust.

The Temperance Formation contains volcaniclastic detritus derived from both the Gooandra Volcanics and the Nine Mile Volcanics. Cherts within this formation have ben regarded as deep water in origin (layer 1 of the ophiolite sequence) but they invariably contain a fine-grained volcaniclastic component, and frequently show evidence of deposition in shallow water.

The evidence of the origin of the Ordovician volcanic rocks in this region is inconclusive. They do not unequivocally support an island-arc model, and are equally compatible with a model which implies a thickened, possibly continental crust.

Sedimentary rocks

Ordovician quartz-rich greywackes are widespread throughout the Lachlan Fold Belt, and consist of greywacke, slate, and black graptolite-bearing shales. Conglomerate is rare and, calcareous and volcanogenic units are mainly found near the Macquarie Volcanic Belt. Widespread deformation and regional metamorphism have often obliterated most of the primary textures, but where preserved sedimentary structures include graded bedding, fine-scale laminations, convolute bedding, sole marks and small-scale cross-stratification.

The greywackes have a distinctive and uniform mineralogy, and consist of poorly sorted angular to sub-rounded quartz grains in a clay matrix. Feldspar (mainly albite, but some oligoclase and K-feldsapr) is present in minor quantities (2-6%). Rare rock fragments of chert, slate and fine quartz arenite are contained in a matrix of sericite and chlorite. Other detrital grains include zircon, tormaline, monazite, opaque oxides, apatite, and sphene.

When the chemistry of these sediments is plotted on Harker variation diagrams, distinct inverse linear relationships with SiO_2 are shown for all elements which remain in the clay matrix (e.g. Al, Mg, Fe, Ti, K, Rb) reflecting two-component mixing between quartz and matrix as the grainsize diminishes from sandstone to shale. Elements in detrital minerals such as feldspar (Ca, Na, Sr & Pb) zircon and apatite have a random distribution. CaO (0.8%) and Na_2O (2.0%) are very low in these sediments and it is this feature which makes it dubious that the S-type granitoids (Chappell & White, 1976) have been derived from these rocks.

Silurian

The Silurian geology of the Lachlan Fold Belt is more complex than that of the Ordovician. During the Early Silurian, extensional movements split the Ordovician rocks and produced a series of fault-bounded troughs, shelves, and highs. On this excursion we will look at the Tumut Trough (Lightner, 1977), a fault-bounded trough which formed by the splitting of the Kiandra Volcanic Field and the Canberra-Yass Shelf (Owen & others 1974) an area of waterlain to subaerial volcanics and shallow marine sediments ~~which occurs to the east of the Tumut~~ Trough.

The first sediments deposited in the Tumut Trough consist of extremely quartz-rich greywackes and quartz-poor greywackes, derived from Ordovician quartz-rich greywackes and mafic volcanics, respectively. In the Middle to Late Silurian abundant S-type dacites were extruded on the highs, whilst in the adjacent trough margins shallow-water sediments, limestones, and submarine volcanics were deposited. On the highs S-type granitoids were intruded; synchronously tholeiitic gabbros were emplaced (e.g., Micalong Swamp Basic Igneous Complex, Adelong Norite, Elkins Creek Gabbro, Snubba Range Gabbro). These tholeiitic melts are characterised by very low abundances of incompatible elements, and they plot in the ocean floor tholeiite field on most discriminant diagrams (e.g. those of Pearce & Cann 1971, 1973). However, field evidence shows conclusively that the tholeiites intrude metasediments and Silurian S-type granitoids, and volcanics, and that they cannot be regarded as representative of oceanic crust. Igneous activity on the highs thus consists of a bimodal suite of large volumes of crustal melts with minor tholeiitic intrusions. A similar bimodal suite is seen in the Basin and Range Province of the western United States where continental crust is undergoing extension.

Within the Tumut Trough there are numerous elongate mainly north-trending mafic volcanic units (e.g. Bullywyarra Schist, Brungle Creek Volcanics, Honeysuckle Beds, Jackalass Beds), as well as some ultramafic and mafic intrusions. The origin of these rocks is controversial and there are at least three possible origins:

1) they are Silurian and represent the oceanic basement of the Tumut Trough;

2) they are Ordovician and are remnants fo the Kiandra Volcanic Field, which was split by the Tumut Trough;

3) the mafic rocks in the Trough are coeval with the Silurian tholeiitic intrusions in the adjacent highs.

GRANITOIDS

The presence of both S and I-type granitoids in the region indicates that two distinct source layers in the crust have undergone partial melting. Wyborn (1977) and Wyborn & Chappell (1979) have shown that the Ordovician quartz-rich greywackes are too low in Ca, Na, Sr, and Pb to be the source of the majority of S-type granitoids. Nor can the granitoids, have been derived from the sediments plus mafic volcanics because other chemical inconsistencies result. A sedimentary layer of Late Precambrian to Cambrian age is postulated under the Ordovician quartz-rich greywackes. The layer contained at least 20 percent detrital plagioclase, and thus had undergone less sedimentary fractionation than had the Ordovician sediments. This layer has now mostly been removed by partial melting and upward migration of granitoids and volcanics, but the residue would consist mostly of cordierite and garnet-bearing granulites.

The I-type granitoids are usually younger than the S-types, and probably would have come from beneath the S-type source layer. The I-types form chemically distinct meridional suites (e.g. Griffin & others, 1977; Beams, 1979) in the Lachlan Fold Belt. A study of the changes in chemistry of these I-type suites provides valuable information on the lateral changes in the chemistry of the lower crust. To date, Sr has provided the best discriminant between I-type suites, and available data indicates that the zone of melting in the lower crust is high in strontium near the coast; strontium levels decrease gradually westwards to near Jindabyne, and then jump high levels in the vicinity of the Ordovician Kiandra Volcanic Field.

KIMBERLITIC INTRUSIVES IN THE JUGIONG AREA

Eight kimberlitic intrusives containing mantle and crustal nodules are found in the Jugiong area. Two of the intrusives penetrate Cainozoic basalts; nearby lavas give an age of 17.2 m.y. (Wellman & McDougall, 1974). Whole-rock Rb-Sr data (Stracke & others, 1977) also suggests Cainozoic ages for these kimberlitic intrusives. The fresh kimerlitic samples have the lowest $^{87}Sr/^{86}Sr$ ratios (just less than 0.705).

Two types of kimberlitic intrusives are found: The most common one is a massive, dark, fine-grained, porphyritic rock, but two of the seven intrusions are brecciated (equivalent to the diatreme-facies kimberlite of Dawson, 1971).

Massive kimberlitic rocks: These rocks fill necks (up to 40 m wide), and are present as narrow dykes up to 30 cm thick. Euhedral olivine and its pseudomorphs, form phenocrysts up to 1 mm across, and there are angular xenocrysts, up to 5 mm in diameter, of olivine, orthopyroxene, clinopyroxene, garnet and spinel (i.e., a lherzolite mineral assemblage). The very fine-grained groundmass contains aegirine, aegirine-augite, augite, richterite, orthoclase, magnesite and minor amounts of albite, analcite, chlorite, perovskite and magnetite. Some of these groundmass minerals are probably secondary. Serpentine, brown mica, and magnesite are abundant replacement minerals.

A notable feature of the rocks is the presence of spherical or irregular ocelli, up to 5 mm across. They are a little coarser grained and more felsic than the groundmass, and olivine is absent. There is a correlation between the compositions of the olivine phenocrysts, which range from Fo_{91} to Fo_{86} in different intrusions, and mineralogical variations in the groundmass and ocelli. In rocks with more magnesian olivine phenocrysts, the ocelli consist of magnesite, analcite and only minor augite. Where the olivine is less magnesian, clinopyroxene is more abundant and more sodic (aegirine), richterite appears, and orthoclase is the predominant felsic mineral. In the most fractionated rocks a brown mica is present, and richterite mantles xenocrystic pyroxene and olivine.

Xenocrystic olivine is usually Fo_{91}, but a few grains are Fo_{84}, and there is also a group between Fo_{86} and Fo_{88}. Orthopyroxene is consistently En_{91}, and spinel xenocrysts have molecular Al/Cr ratios of about 3. Rare composite fragments are also present - for example, an orthopyroxene host with olivine inclusions. Many of these xenocrysts have compositions identical to those of minerals in the lherzolite nodules.

Brecciated kimberlitic rocks. Brecciated (diatreme-facies) kimberlitic rocks are found in two intrusions which have a minimum depth of 200 m. These rocks contain nucleated autoliths (Ferguson & others 1973), and angular to rounded fragments similar to the lapilli found in kimberlites from the Kao pipe, Lesotho (Clement, 1973). Lapilli and lesser amounts of nucleated autoliths make up as much as 40 percent of the rock (by volume). The lapilli are characterised by a range of grainsize produced by a mixture of phenocrysts and xenocrysts, whereas the autoliths, typically 1-12 cm across, are more even-grained. The nuclei of the autoliths comprise mantle or crustal rock or mineral fragments, and rarely, kimberlitic lapilli.

Both crustal and mantle xenoliths are common. The crustal xenoliths are mostly granodiorite, with minor basalt and mafic granulite fragments and kaersutite crystals. Mantle rock inclusions include griquaites (mantle eclogites, Nixon, 1973), as well as garnet spinel, and garnet-spinel lherzolites (Ferguson & others, 1977). The occurrence of garnet-two-pyroxene granulites and plagioclase-garnet-clinopyroxenite is of interest, because they straddle the reaction zone between plagioclase-garnet-clinopyroxenite. they straddle the reaction zone between plagioclase and garnet-bearing assemblages a range of compositions, but differ from normal kimberlites in the relatively high SiO_2, Al_2O_3, and Na_2O, and lower MgO contents (Table 1). Some of these chemical features may be caused by the effects of CO_2-rich vapour phase during partial melting of postulated parent lherzolite, which would favour the production of liquids enriched in Al_2O_3, CaO, and alkalis (Boettcher & others., 1975). Most samples plot in the region of overlap of the melilite basalt and kimberlite fields on the Al_2O_3-MgO-FeO diagram. However, the most evolved samples plot well inside the melilite basalt field. Chemically, the Jugiong rocks quite closely resemble olivine analcitite from Murrumburrah, NSW (Irving & Green, 1976) and the olivine nephelinite from Delegate (Lovering & White, 1969), although most are slightly poorer in Al_2O_3, and contain considerable amounts of CO_2 (Table 1). There is also some similarity with ankaramite from the Lashaine volcano, Tanzania (Rhodes & Dawson, 1975), and with average South African olivine melilitite (McIver & Ferguson, 1977).

Magma equilibration pressures of about 20 kb may be deduced from CMAS projections, and the chemical variations may be explained in terms of only minor olivine and possibly orthopyroxene fractionation. Temperature estimates based on compositions of co-existing minerals in lherzolite and eclogite nodules, and the occurrence of unique garnet-spinel lherzolite inclusions falling on the quasi-univariant boundary between the garnet and spinel lherzolite fields, show that the nodules equilibrated at about 1240°C and 22 kb (Ferguson & others 1977). This is in good agreement with the data obtained for the host rocks, and suggests that the olivine nephelinite magmas were derived by partial melting of garnet lherzolite at depths of about 70 km. The abnormally high geothermal gradient implied by these data is higher than the calculated mean oceanic geotherm, and intersects the graphite-diamond stability curve at considerably higher temperatures and pressures than those indicated by the nodules. Thus diamondiferous kimberlites of Cainozoic age are unlikely to be present in this part of New South Wales.

STOP 1-1. 1 km west of Jugiong, and 200 m south of the Hume Highway is a brecciated kimberlite, about 100 m in diameter, which is cut by a 30 cm-wide massive kimberlitic dyke. In the brecciated kimberlite, lapilli and nucleated autoliths are very common. The nuclei of the autoliths at this locality comprise crustal or mantle rock or mineral fragments and rarely, kimberlitic lapilli. Fresh griquaites, as well as garnet and spinel lherzolites, are found here. Crustal nodules include S-type granodiorite and mafic granulites.

The dyke rock has olivine nephelinite affinites but has the mineralogy of the massive kimberlitic rocks; leucocratic ocelli are also present.

STOP 1-2. Approximately 3 km east of Gobarralong is the largest of the kimberlitic intrusives in the area, comprising a brecciated pipe measuring 635 x 425 m. Drilling has revealed that the pipe extends to a depth of at least 200 m. The rocks are weathered and contain abundant lapilli and nucleated autholiths, as well as crust and upper mantle nodules. Garnet and spinel lherzolites in which the orthopyroxene and olivine have been replaced by secondary minerals are present. A feature of this pipe is the abundance of kaersutite megacrysts a few centimetres long.

STOP 1-3. Honeysuckle Beds - 4 km east of Darbalara. Massive and pillowed basalts are well exposed in a gully 250 m south of the road to The Elms. The Honeysuckle Beds have been referred to as the oceanic substrate of the Silurian Tumut Trough (e.g. Scheibner 1973, Ashley, 1974). Here the basalts are faulted against the Coolac Serpentinite to the east, but further north layered gabbros (Franklin, 1979) separate the two units and a dyke complex has been mapped (Brown, 1979). Mangold (1978) believes the Honeysuckle Beds are at the top of the Tumut Trough sequence. The lack of exposure makes field relationships equivocal, but if Mangold is correct the arguments for an oceanic crust are weakened.

STOP 1-4. Bullawyarra Schist - 2 km south of Darbalara on the Tumut Road. Schistose basalt of the Bullawyarra Schist crops out in a gully east of the road and consist of albite-epidote-actinolite schist. These rocks together with the Jindalee Beds (basalt, chert, serpentinite, magnetite quartzite) constitute a deformed basement to the Tumut Trough, and may be as old as ~~Cambrian. They may be rifted blocks from the Kiandra~~ Volcanic Field, but have been little studied.

STOP 1-5. Gatelee Ignimbrite - Gundagai - Tumut Road at the Tumut River Bridge 4 km north of Brungle. This Early Devonian I-type volcanic unit unconformably overlies the Tumut Trough sequence. It is probably related to a number of high-silica I-type granitoids in the area.

STOP 1-6. This locality on the Bumbolee Creek Road 8.9 km east of the junction with the Tumut-Brungle Road was described by Crook & Powell (1976) as part of the ophiolitic substrate of the Tumut Trough. The stop traverses a largely schistose segment of the Coolac Serpentinite. The eastern margin of the serpentinite is an east-dipping mylonitised fault zone against the S-type Young Granodiorite. West of the serpentinite is a rather weathered exposure of the Honeysuckle Beds, presumably faulted against the serpentinite.

STOP 2.1 Goobarragandra Volcanics overlain by Kings Cross Shales in road cut 3 km southeast of Yarrangobilly Village. The Goobarragandra Volcanics are a thick sequence of subaerial ash-flow tuffs of remarkably homogeneous dacitic composition. The tuffs are composed of phenocrysts of partly resorbed B-quartz, plagioclase and minor biotite, orthopyroxene and cordierite in a devitrified glassy groundmass showing eutaxitic layering, perlitic structures replaced by quartz and chlorite, and rare unwelded glass shards. The volcanics have been dated by Rb/Sr whole-rock isochron at 429 $\pm$ 16 m.y. ($Rb^{87} = 1.42 \times 10^{-11}y^{-1}$). Rb/Sr on a biotite gave an age of 420 $\pm$ 12 m.y., using the initial ratio of 0.7095 $\pm$ 0.0009 obtained from the whole rock isochron. Total-rock analyses are very similar to those for the Young Granodiorite which intrudes the volcanic pile.

This locality is close to the westernedge of the Canberra-Yass Shelf, which in this region is thought to be a broad monoclinal flexure, in contrast to the major Mooney Mooney Thrust System to the north in the Tumut area. In the northern end of the roadcut the Kings Cross Shales crop out and consist of purple and green shales, with minor waterlain felsic tuffs. The Yarrangobilly Limestone crops out to the west, and the units are thought to be conformable.

STOP 2.2. Representative units of the Gooandra Suite - Snowy Mountains Highway 6 km north of Kiandra.

At this locality the Shaw Hill Gabbro (part of the Gooandra Suite) will be examined. Nearby, mafic and felsic lavas occur, and all have been regionally metamorphosed to greenschist grade.

1) Shaw Hill Gabbro: This unit crops out as a series of discontinuous lenses within the Gooandra Volcanics. It is medium to coarse-grained, and consists of colourless clinopyroxene enclosing random laths of plagioclase with rare primary brown amphibole. Metamorphic minerals include albite, actinolite, epidote, chlorite and biotite. Chemically this gabbro is the most mafic member of the Gooandra Suite. The ophitic gabbro from this locality contains over 12 percent MgO.

2) Gooandra Volcanics: a) mafic lavas. The Mafic lavas are common in this area, they are extensively altered, and frequently show pillow structures. No primary pyroxene is preserved; the original mafic minerals are replaced by chlorite and actinolite. All primary plagioclase is altered to albite and other minerals present include calcite, epidote, and biotite. b) Rhyolites and Dacites. The felsic lavas are extremely altered, and are mainly composed of albite laths with interstitial quartz, feldspar, epidote, chlorite, biotite, and minor actinolite. Primary phenocryst shapes have been preserved - mainly plagioclase (now albite) and anorthoclase (now K-feldspar and albite). Quartz phenocrysts are very rare. Chemically these felsic lavas show marked variation in Na_2O, K_2O, and Ba.

STOP 2.3. Temperance Formation-Happy Jacks Pondage.

The heterogeneous nature of the Temperance Formation is well illustrated at this locality. Fine tuffaceous cherts, predominate but there are also coarse volcaniclastics. The rocks have been regionally metamorphosed to biotite grade, and consist mainly of quartz, albite, chlorite, actinolite and epidote. Primary detrital clinopyroxene and amphibole is present in the volcaniclastics but not detrital quartz.

STOP 2.4. Dodger Diorite - Dodger Quarry, 4 km southeast of Happy Jacks Dam.

The Dodger Diorite is part of the Boggy Plain Suite, a group of early Devonian I-type granitoids in a north-trending belt west of the Jindabyne Suite. Chemically they are high in K_2O and Sr, and occur in the same area as the Ordovician high-K Nine Mile Suite. Other members of the Boggy Plain Suite include the Arsenic Ridge Quartz-monzodiorite, the Boggy Plain Adamellite, and the Crack Hardy Point Monzodiorite (formerly the Pollocks Gully Monzonite). In the field many members of this suite have a spotted appearance, with the ferromagnesian minerals (mainly pyroxenes) forming sub-rounded clusters in a matrix of quartz and feldspar.

The Dodger Diorite is heterogeneous and weakly zoned from an olivine - bearing porphyritic gabbroic diorite at the margins to a fine-grained diorite in the core. There are intrusive lenses of quartz monzonite, hornblendite, and aplite. Parts of the pluton are strongly altered.

STOP 2.5. Nungar Beds (Ordovician quartz-rich greywacke) - in the roadside exposure 400 m east of the summit of Bald Hill.

In this outcrop, sedimentary structures include parallel lamination, ripple cross-bedding, convolute bedding and graded bedding. These structures suggest rapid deposition by turbidity currents. Although the mineralogy is extremely mature, (detritus consisting of mainly quartz), these sediments are texturally immature as indicated by the high proportion of clay matrix, and poorly sorted, sub-angular to sub-rounded nature of the framework minerals. Their uniform mineralogy over large areas suggest that the quartz-rich greywackes have been derived from a source region which has already been through at least one sedimentary cycle.

For the remainder of the second day and the whole of the third day of the excursion the stops correspond to stops in the IGC excursion guide no. 13C (Chappell & White, 1976). Only a summary of these stops will be given here.

DAY 2

STOP	GRID REFERENCE	FEATURE	IGC GUIDE STOP
2-6	Berridale 456006	Eucumbene Dam Observation point	7-2
2-7	Berridale 499887	Hornblende-rich Round Flat Tonalite	7-3
2-8	Berridale 495872	Hornblende-poor Round Flat Tonalite	7-4
2-9	Berridale 498808	Bullenbalong Granodiorite	7-1
2-10	Berridale 458665	Jindabyne Tonalite	7-5
2-11	Berridale 418768	Surge Tank at Jindabyne pumping station	7-6
2-12	Berridale 414767	Kalkite Adamellite	7-7
2-13	Berridale 347748	Mowambah Granodiorite at Rennix Gap	7-8

DAY 3

STOP	GRID REFERENCE	FEATURE	IGC GUIDE STOP
3-1	Numbla 627414	Numbla Vale Adamellite	6-10
3-2	Numbla 653368	Finister Granodiorite	6-11
3-3	Numbla 658342	Buckleys Lake Adamellite (Jimenbuen phase)	6-12
3-4	Numbla 620573	Dalgety Granodiorite	6-9
3-5	Numbla 769549	Maffra Adamellite	6-14
3-6	Berridale 746634	Buckleys Lake Adamellite at Buckleys Lake	6-13
3-7	Berridale 605861	Leucogranitoid	6-5

DAY 3 (cont.)

STOP	GRID REFERENCE	FEATURE	IGC GUIDE STOP
3-8	Berridale 634924	Tara Granodiorite	6-2
3-9	Berridale 644927	Hornblende-free inner phase of Tara Granodiorite	6-3
3-10	Berridale 665940	Namungo Adamellite	6-4
3-11	Berridale 693872	Cootralantra Granodiorite	6-1
3-12	Cooma 876875	Migmatites	5-3
3-13	Cooma 902876	Cooma Granodiorite Nanny Goat Hill Lookout	5-1

TABLE I

ANALYSES OF KIMBERLITIC ROCKS FROM THE JUGIONG AREA.

	1	2	3	4	5	6	7
SiO_2	36.13	35.83	41.93	40.30	38.30	37.41	42.99
TiO_2	3.18	2.93	1.96	2.22	2.10	2.07	0.17
Al_2O_3	9.86	8.14	8.69	6.94	6.33	6.25	2.64
Fe_2O_3	11.38	7.74	11.21	10.21	9.76	4.66	2.10
FeO		6.11				5.42	6.34
MnO	0.15	0.16	0.16	0.14	0.12	0.17	0.15
MgO	9.64	16.83	15.26	12.38	12.73	18.51	37.50
CaO	14.51	5.00	10.29	11.32	11.70	9.68	3.00
Na_2O	3.11	2.14	2.16	1.36	1.21	2.56	0.37
K_2O	0.91	1.32	1.99	1.11	1.09	0.91	0.22
P_2O_5	1.33	1.04	0.92	0.93	0.82	0.81	0.03
H_2O+	4.15	4.62	2.70	2.05	2.65	2.44	1.25
H_2O-	0.76	5.27	0.66	3.75	3.71	0.66	0.18
CO_2	5.05	2.24	3.65	6.0	8.65	7.65	2.46
Total	100.16	99.37	101.58	98.71	99.17	99.20	99.40

Trace elements in parts per million

	1	2	3	4	5	6	7
Sc	27	20	23	20	17	19	19
V	160	141	95	151	143	159	61
Cr		670				910	2530
Co		98				82	129
Ni	115	1090	737	692	803	820	2080
Cu	87	44	49	45	51	47	18
Zn	100	112	104	87	95	94	67
Ga		16.0				9.5	3.0
Rb	66	61	46	49	48	43	6.8
Sr	1400	447	955	835	1050	840	42
Y	30	23	24	23	28	20	3
Zr	310	248	222	223	230	196	13
Nb	174	164	96	95	102	84	2
Ba	1910	645	1210	729	902	845	35

TABLE I (cont.)

	1	2	3	4	5	6	7
La	100	61	68	68	58	59	1
Ce	163	127	117	113	115	106	4
Pb		15				7	3
Th	18	24	18	16	20	15	0.4
U		2.4				2.2	0.2

1) Olivine nephelinite lapillus

2) Olivine nephelinite lapillus

3) Olivine nephelinite

4) Olivine nephelinite autolith

5) Olivine nephelinite lapillus

6) Olivine nephelinite dyke

7) Garnet-spinel lherzolite nodule

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