

ATLAS OF NORTH PILBARA

Geology and Geophysics

1:1.5 Million scale



AGSO Record 2000/04

By R.S. Blewett, P. Wellman, M. Ratajkoski & D.L. Huston



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R.S. Blewett, P. Wellman, M. Ratajkoski & D.L. Huston

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Cover photograph:

View south-southeast along a central Pilbara chert ridge interpreted as a silicified and folded shear zone located east of the McPhees mining centre on the Wodgina 1:100 000 Sheet area (photograph by Doug Thost).



AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Chief Executive Officer: Neil Williams

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INTRODUCTION

The early to mid Archaean Pilbara Craton is one of the best exposed and least dismembered granite/greenstone terrane in the world, and is an excellent study area of early earth evolution. The Pilbara Craton records successive greenstone sequences (>3515 Ma to 2950 Ma) deposited on a gneissic (tonalite-trondhjemite-granite) crust (<3650 Ma) in a series of synclinal troughs that envelope large (> 100 km diameter) composite ovoid granitoid complexes (3650 Ma to 2850 Ma).

The mineral potential of the Pilbara Craton has been generally down played by industry and the area has thus not received the intense exploration industry focus seen in the Yilgarn Craton (especially the Neo-Archaean Eastern Goldfields) to the south. The Pilbara Craton differs fundamentally from many other granite/greenstone terranes in terms of its tectonic evolution and metallogenesis. The metallogenetic characteristics of the Pilbara Craton are:

- 1.......... The presence of some of the oldest mineralising systems (VAMS, epithermal gold, PGEs in layered mafic-ultramafic intrusions etc) in the world
- 2....... The presence of multiple mineralising events over a period of 800 Ma (e.g. four VAMS events and five orogenic gold events)
- 3....... The presence of Phanerozoic-like characteristics for some deposit types (e.g. the presence of significant Pb and barite in VAMS deposits and the association of some of these deposits with calc-alkaline volcanic rocks).
- 4...... An abundance of mineral deposit types such as Sn-Ta pegmatites, porphyry Mo-Cu deposits and possibly adularia-sericite epithermal Au deposits that are better known in Proterozoic or younger rocks.
- 5...... Differing regional controls on mineralisation, even along strike in apparently the same system.
- 6...... A general lack of craton-wide shear zones in the Pilbara Craton (cf. Eastern Goldfields and Superior Provinces).
- 7....... A crustal architecture significantly different to that found in Neo-Archaean Provinces (e.g. the greenstone belts and granitoids that they envelope extend to greater depths (>10 km) in the Pilbara Craton).

The Australian Geological Survey Organisation (AGSO) and Geological Survey of Western Australia (GSWA) have been compiling data in the Pilbara Craton as part of a joint National Geoscience Mapping Accord Project (1995-2000). This atlas has been produced at 1:1 500 000 scale from coverages derived from the North Pilbara project GIS. These are only a selection of the datasets compiled by AGSO and GSWA that best display the geological richness of the Pilbara Craton.

The frame for most of the datasets (except airborne gamma-ray spectrometric data) lies between 20°00'S to 22(30'S and 116°00'E to 121°00'E. All datasets are projected in Lamberts Conformal Conic projection with a central meridian 118°30'E, 1st standard parallel 20°12'30"S, and 2nd standard parallel 22°02'30"S for comparative purposes. The Australian Surveying and Land Information Group (AUSLIG) 1:100 000 map sheet frames and coastline are presented on each map.

DATA AVAILABILITY

General information

Information on datasets, publications, and the work programme are available from the project internet websites www.agso.gov.au/minerals/pilbara and www.dme.wa.gov.au. AGSO text publications and maps are generally available from the AGSO Sales Centre (E-mail: sales@agso.gov.au; Telephone: 02 62499519; Facsimile 02 2499982), and digital information from the originating section. A teaching GIS package of geological and geophysical data for the Pilbara area 20°52'S to 21°52'S and 119°34'E to 120°24'E is available from AGSO (see website).

Geological mapping

Outcrop mapping has been published in a series of 1:250 000 geological maps by the GSWA and BMR/AGSO from 1964 to 1989. This information was summarised at 1:1 000 000 scale by Hickman (1983). Recent GSWA mapping in the North Pilbara

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Craton has resulted in the publication of several 1:100 000 scale geological maps, viz Braeside (1998), Cooragoora (1999), Dampier (1997), Isabella (1998), Mount Wohler (1998), Muccan (1998), North Shaw (1999), Pearana (1998), Sherlock (1997), Warrawagine (1998), and Yule (1999). Other 1:100 000 scale geological map sheets are in press or preparation.

The basement solid geology map has been prepared by AGSO. This map is based mainly on the available outcrop geology maps, and the short-wavelength magnetic anomalies. Where the basement is obscured by deep cover, the map is based on the longer wavelength magnetic anomalies and the residual gravity anomalies. Aspects of the interpretation of geophysical data in terms of geology are discussed by Wellman (1999).

Airborne geophysical data

Airborne geophysical surveys over the Pilbara Craton were flown during two main periods. Most of the area was flown by AGSO between 1985 and 1992 using 17 litres of detectors, about 1500 m flight-line spacing, and 150 m flying height (surveys P225-P562 of Figure 1). These surveys map the total intensity of the earth's magnetic field, and the distribution of K, Th, and U at the earth's surface using gamma-ray spectrometry. In the period 1995-96 most of the area of outcropping Early-Mid Archaean rocks was flown by AGSO, GSWA, and mineral companies, with more modern equipment, at 400 m flight-line spacing, and 80 m above ground level, and 33 litre detector volume (surveys P636-P656 of Figure 1). These surveys map the total intensity of the earth's magnetic field, and the distribution of K, Th, and U at the earth's surface using gamma-ray spectrometry, and the elevation of the land surface.

The airborne geophysical survey data are available in digital and hardcopy line maps format. The availability of 1:250 000 scale geophysical images of the Pilbara Craton can be found at www.agso.gov.au/minerals/pilbara. Pixel image maps of the whole area at 1:500 000 scale are available from AGSO (Mackey and Richardson, 1997; Milligan et al., 1999).

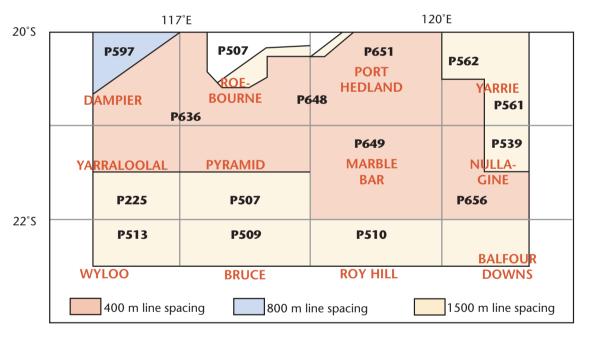


Figure 1 - Index to airborne geophysical surveys of the Pilbara craton

Gravity data

Gravity surveys of the Pilbara Craton have been compiled and integrated by the Gravity Section of AGSO. The gravity field is essentially defined by the following three surveys: AGSO survey 6824 which covered the marine area by a series of east-west ship-borne traverses at about 16 km line spacing, AGSO survey 6914 which covered the land area on a grid at 11 km line spacing, and survey 9063 of the southern part of the area by Hamersley Iron (CRA now RTZ) on a 5 km line-spaced grid. Using these surveys the southern part of the land area has a well defined gravity field, the northern part of the land area is adequately defined, the near-shore 30 km of the marine area is undefined by surveys, and the remainder of the marine area is relatively poorly defined because of poor ship-navigation. Gravity data can be obtained in either a principal facts form, or as a grid from the AGSO Sales Centre.



Landsat TM-5 thematic mapper data

The observed Landsat TM-5 thematic mapper data can be obtained from the Australian Centre for Remote Sensing (ACRES), GPO Box 28, Belconnen ACT 2616, Telephone: 02 6201 4107, Website: www.auslig.gov.au. The method of producing the directed principal component three-band data set is described by Glikson (1998), and the resultant grid can be obtained from AGSO. Images are available for the individual 1:100 000 sheet areas at 1:100 000 scale (Glikson, 1997), and the whole area at 1:500 000 scale (Macias, 1998).

Altitude data

The altitude data are from two sources. Altitudes are available over the whole atlas area from an Australia-wide 9-second grid based on spot heights, contours, stream segments, and the coastline (Carroll, 1996). This digital elevation model (DEM) can be purchased from AUSLIG and AGSO. Higher resolution altitude data are available where the area of the later geophysical surveys (P636-P656) altitudes have been calculated from the aircraft radar altimeter and GPS data. The results from the P636 survey were of poorer quality than the 9-second grid, so this data set was not used. The results from the P648, P649, and P656 surveys were used to replace the 9-second grid. The results from the P651 survey were combined with the 9-second data, and the combined data used.

Point data

AGSO has a comprehensive collection of geoscientific information in the following National Oracle-based relational databases: OZROX (field observations including magnetic susceptibility, structural readings); OZCHEM (whole-rock geochemistry); OZCHRON (geochronology); and OZMIN (mineral deposits).

1:500 000 scale maps

The image and map plates are also available from AGSO as print-on-demand maps. Contact AGSO Sales Centre for further information.

Acknowledgements

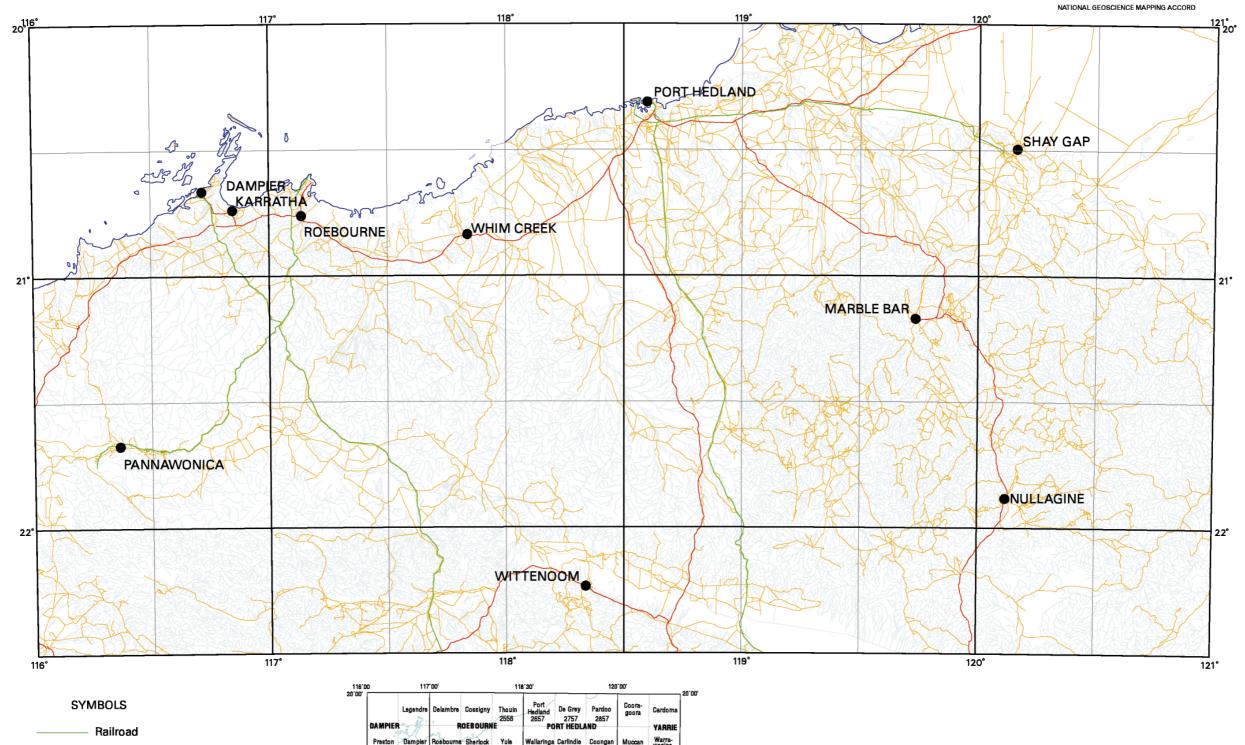
We would like to thank Dean Hoatson and Brian Minty from AGSO for their reviews on this atlas. Thanks to Tim Mackey for preparing the magnetic grids, Brian Minty for his work on the gamma-ray data, and Taro Macias for the Landsat image. The AGSO graphic design unit prepared the final print files.

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DRAINAGE, COAST, INFRASTRUCTURE, MAP GRID

NORTH PILBARA ATLAS NGMA



Sealed highway

Unsealed road

Drainage

116'00 0'00' r)	117'00'			116'30'			120`00'			- 20°00°
		Legendre		Cossigny	2556	Port Hedland 2657	De Grey 2757	Pardoo 2857	Coora- goora	Cardoma	
- 1	DAMPIER	7 19	R	OEBOUR	IE	PC	RT HEDLA	ND		YARRIE	ł
1.00,	Preston 2156	Dampier 2256	Roebourne 2356	Sherlock 2456	Yule 2556	Wallaringa 2656	Carlindie 2756	Coongan 2856	Muccan 2956	Warra- wagine 3056	21'00
	Fortescue 2155 YARRALO	Pinderi Hills 2255	Cooya Pooya 2355	Mount Wohler 2455	Satirist 2555	Wodgina 2655	North Shaw 2755	Marble Bar 2855	Mount Edgar 2955	Yilgalong 3055	2,00
- 1	YANNALU	ULA		PYRAMID		M	ARBLE BA	R	NULLA	GINE	ł
5.00,	Panna- wonica 2154	Elvire 2254	Millstream 2354	Mount Billroth 2454	Hooley 2554	White Springs 2654	Tambourah 2754	Split Rock 2854	Nullagine 2954	Eastern Creek 3054	22'00'
נט ג	Mount Stuart 2153	Farquhar 2253	Jeerinah 2353	McRae 2453	Wittencom 2553	2653	Mount Marsh 2753	Warrie 2853	Noreena Downs 2953 BALFOUR	Mount Cooke	
116'0	WYLOO	117	7'00'	IT BRUCE	110	,30,	ROY HILL	120		UUWN6	







SCALE 1:1 500 000

Lamberts Conformal Projection, WGS84 Datum lst Standard Parallel: 20°12'30S', 2nd Standard Parallel: 22°02'30S' Central Meridian: 118°30'00E'

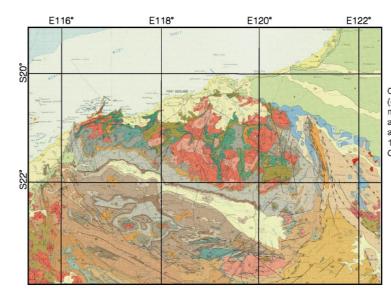
PILBARA CRATON'S EXTENT MARGINS AND REGIONAL ANOMALIES NORTH PILBARA ATLAS

NGMA

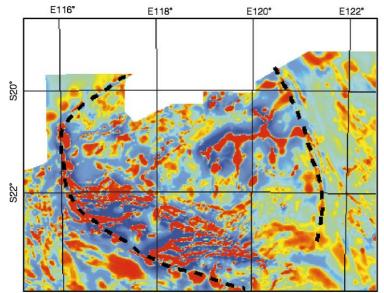
NATIONAL GEOSCIENCE MAPPING ACCORD

E116* E118* E120* E122*

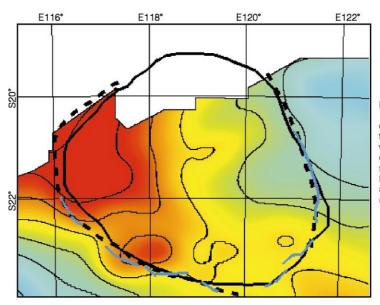
Gravity anomalies; contour interval 200 µm.s ². Terrain-corrected free air gravity anomalies — an approximation to isostatic anomalies. The line traces the dipole gravity anomaly at the margin of the Pilbara Craton, due to the abrupt change in crustal thickness and density at the margin of the craton. At this line, gravity anomalies due to the domal and synclinal structure of the Pilbara Craton are truncated by Proterozoic structures parallel to the craton margin. Note that the gravity anomalies within the craton are generally low, with the lowest anomalies near the centre of the craton, and relatively high anomalies along the northeast third of the craton.



Geological map. This shows that Early-Mid Archaean (granite/greenstone) rocks are generally not exposed at the margin of the Pilbara Craton. The margin is marked by faults and thrusts, and abrupt changes in extent of Late Archaean and Proterozoic rocks. (Myers J.S. & Hocking R.M. (compilers), 1988. Geological map of Western Australia 1:2 500 000. Geological Survey of Western Australia).



Magnetic anomaly map. The magnetic field has been reduced-to-the-pole, so that highs lie over the high magnetisation bodies. The dashed line shows the extent of magnetic anomalies characteristic of the Pilbara Craton. On the eastern margin of the craton the high-amplitude anomalies associated with the domal and synclinal structure of the Pilbara Craton are truncated by NNIW-trending Proterozoic structures. On the southwest margin the generally West-trending structures of the Late Archaean Mt Bruce Supergroup are truncated by Proterozoic NW-trending structures. The northwest margin of the craton is thought to be along a line of magnetic highs.



Magnetic anomalies upward continued to 50 km; contour interval 100 nT. Magnetic field reduced-to-the-pole, and upward continued to 50 km; contour interval is 100 nT. This plate shows that the regional magnetic field changes abruptly near the western margin of the Pilbara Craton, but shows a gradual change at other extents of the margin. The superimposed lines show the general agreement in the estimates of the extent of the Pilbara Craton: from gravity (thick continuous line), magnetic anomalies (dashed lines) and geology of post Early Archaean rocks (thin blue continuous lines).







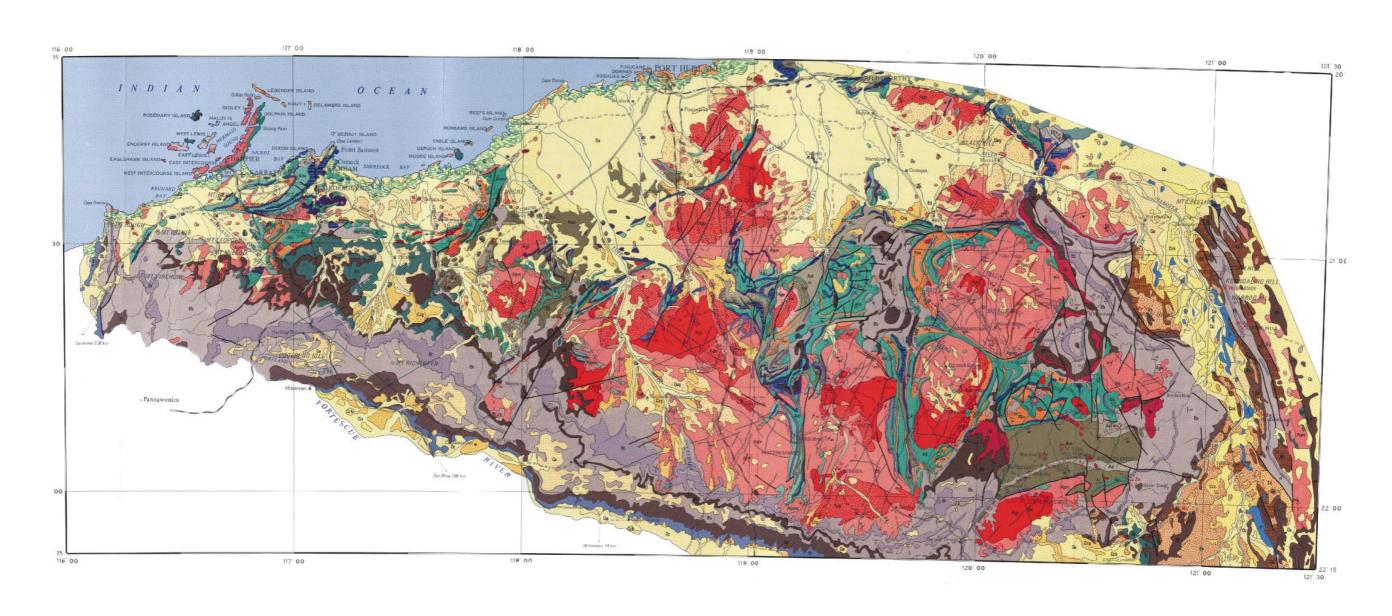


NORTH PILBARA GEOLOGY

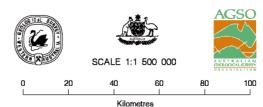
NORTH PILBARA ATLAS

NGMA

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This map (facsimile of the 1:1 Million scale Lithological Map of the Pilbara Block (Hickman, A.H. 1980. Lithological Map, Plate 1A, GSWA Bulletin 127 - 1983)) shows the simplified geology including the late Archaean and younger cover rocks. The map frame is 15' less latitude north and south and an additional 30' of longitude to the east compared to the solid geology map of Plate 4. Of note, are the large expanses of exposed granite/greenstone in the southeast compared to the west and north of the craton. The map projection differs from the others in this atlas; it is Albers equal area projection using the AGD66 datum with standard parallels 17°30'S and 31°30'S.



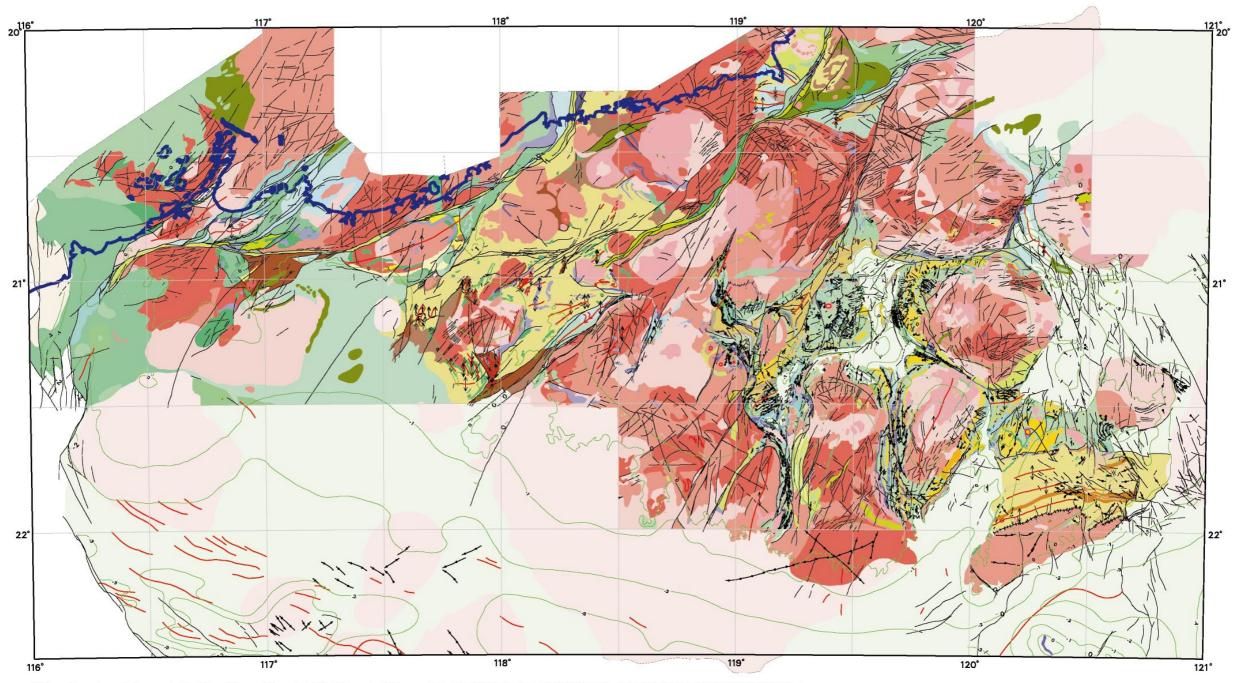
Albers Equal Area Projection lst Standard Parallel: 17*30'00", 2nd Standard Parallel: 31*30'00" Central Meridian: 118*45'00"

SOLID GEOLOGY

NORTH PILBARA ATLAS SERIES

NGMA

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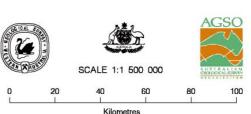


This solid geology plate was derived from interpretation at 1:100 000 scale of the aeromagnetic and gravity data by P. Wellman and R.S. Blewett. Up to four presentations of each 1:100 000 Sheet area of the 400 m flight line-spacing data supplemented by regional gravity images were used for interpretation. The coarser 1500 m flight line-spacing data were used in the south, southwest, and east which is largely concealed by younger rocks (<2780 Ma) and generally the only discrimination possible was between granitoid and non-granitoid (greenstone). The Mount Bruce Supergroup has been 'stripped' to reveal the outline of the granite/greenstone terrane underneath, and depth contours shown in green.

The plate is an attempt to consistently describe the granitoids in terms of their magnetic character (high, medium, low, flat) and the greenstones into their major rock types (lithology).

This process was aided by 1:250 000 scale geological maps by GSWA and AGSO, and more recent (post 1995) 1:100 000 scale geological maps by GSWA. Some simplification of the known geology was made in order to produce a map at 1:500 000 scale. The greenstone geology of the eastern Pilbara was clipped from the 1:250 000 geology.

Features to note on this map include: 1) 60% of the craton is granitoid, the largest (>100 km diameter) is the Yule Granitoid Complex (central south); 2) greenstones envelope ovoid granitoid complexes; 3) the magnetic character of granites 'conflicts' with traditional mapping approach (plate 3) and gamma-ray spectrometric boundaries (plates 25, 26, 33); 4) east-to-north-trending curvilinear shear zones transect the west and north Pilbara; 5) dyke swarms are more common in the granitoids.



Lamberts Conformal Projection, WGS84 Datum lst Standard Parallel: 20"12"305", 2nd Standard Parallel: 22"02"305" Central Meridian: 118"30"00E"

SOLID GEOLOGY LEGEND

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Late Archaean - Early Proterozoic

Mixed Rocktypes

Dolerite dyke
Hornblende-a

Hornblende-adamellite/quartz-monzonite

Gabbro dyke or sill

Quartz-plagioclase porphyry dyke

Hornblende porphyry dyke, related to -Pgh

Felsic rock containing granophyric and granitic xenoliths

Chert, tectonically controlled

Dolerite dyke
Pegmatite vein

Quartz

Porphyritic, fine to medium grained granophyre (Gidley Granophyre)

Gabbro (Gidley Granophyre)

Archaean

Undefined greenstone

AX AXF AXL AXM

Undefined greenstone
Undefined greenstone; flat magnetisation
Undefined greenstone; low magnetisation
Undefined greenstone; medium magnetisation
Undefined greenstone; high magnetisation

Mixed granitoid/greenstone rocks



Mixed rocktypes (granite, gneiss, & greenstone); low magnetisation
Mixed rocktypes (granite, gneiss, & greenstone); medium magnetisation
Mixed rocktypes (granite, gneiss, & greenstone); high magnetisation

Archaean

Mafic rocks

ABL
ABM
ABH
ABA
ABE
ABT

Basaltic andesite, and unsubdivided mafic volcanic rocks Basalt; low magnetisation Basalt; medium magnetisation Basalt; high magnetisation

Altered mafic rock rich in epidote Basaltic tuff

Amphibole-plagioclase schist

Agglomerate

Archaean

Sedimentary rocks

	(20)
AC	Chert
ACL	Sediment; low magnetisation
ACM	Sediment; medium magnetisation
ACH	Sediment; high magnetisation
ACF	Ferruginous chert
ACG	Green chert
ACI	Banded Iron Formation and jaspilite
ACIH	Banded Iron Formation; high magnetisation
ACJ	Red/white banded chert
ACG	Quartzite or meta-chert
ACW	Black-white and grey-white banded chert
AS	Sedimentary rocks, not divided
ASL	Siltstone
ASM	Sediment; medium magnetisation
ASH	Sediment; high magnetisation
ASF	Ferruginous sandstone, siltstone, shale and chert
ASL1	Psammitic schist, cleaved sandstone
ASL3	Pelitic schist and phyllite
ASL4	Chert
ASL5	Well sorted sandstone and conglomerate
ASC	Conglomerate
ASK	Carbonate rock (bedded, but origin not certain)

Felsic rocks

AA	Rhyolite to dacite lava
AFL	Felsic rock; low magnetisation
AFM	Felsic rock; medium magnetisation
AFH	Felsic rock; high magnetisation
AAL	Fine-grained lava with quartz and feldspar phenocryst
AAT	Tuff
AAV	Agglomerate, tuff and lava, chiefly dacitic
AR	Porphyritic felsic rock
APA	Felsic porphyry
APF	Dark feldspar-quartz-biotite porphyry

Granitoid rocks

AGVL	(
AGL	(
AGM	(
AGH	0
AGVH	(
AGF	(
AGX	(

Granite; very low magnetisation Granite; low magnetisation Granite; medium magnetisation Granite; high magnetisation Granite; very high magnetisation Granite; flat magnetisation Granite; undifferentiated, unexposed

Fault

Elevation of the Mount Bruce Supergroup base

Intrusive rocks

AO	Gabbro dyke or sill
AOL	Gabbro & dolerite; low magnetisation
AOM	Gabbro & dolerite; medium magnetisation
AOH	Gabbro & dolerite; high magnetisation
ALOL	Gabbro layered complex; low magnetisation
ALOM	Gabbro layered complex; medium magnetisation
ALUL	Ultramafic layered complex; low magnetisation
ADI	Diorite
AD	Dolerite dyke

Ultramafic rocks

AU	Ultramafic rock (not subdivided)
AUL	Pyroxene peridotite and phlogopite Iherzolite
AUM	Ultramafic rock; medium magnetisation
AUH	Ultramafic rock; high magnetisation
AUE	Carbonate - talc rock
AUA	Tremolite/actinolite +/- chlorite rock. Generally schistose
AUP	Peridotite
AUX	Pyroxenite
AUC	Serpentinite
AUT	Talc schist, mostly with chlorite, actinolite and carbonate









NORTH PILBARA ATLAS NGMA GREENSTONE GROUPS AND GRANITOID COMPLEXES NATIONAL GEOSCIENCE MAPPING ACCORD 21° 22° 120° 116° 121° Louden & Mt Negri Volcanics Portree Granite De Grey Group Pippingarra Granitoid Complex Satirist Granitoid Complex GENERALISED GRANITE-GREENSTONE MAP Cleaverville Formation Yule Granitoid Complex Whundo Group Dampier Granitoid Complex DG FB Sulphur Springs and Gorge Creek Groups Forrester Bay Granitoid Complex Roebourne Group Chirratta Granitoid Complex CH Wyman Formation Caines Well Granitoid Complet CW Strelley Granite Warrawoona Group ST Coonterunnah Group Karratha Granodiorite KR Muccan Granitoid Complex Unassigned greenstone Corunna Downs Granitoid Complex Mount Edgar Granitoid Complex Kurrana Granitoid Complex Layered mafic/ultramafic intrusions Yilgalong Granitoid Complex Quartz Carlindi Granitoid Complex Tectonic chert Shaw Granitoid Complex

North Pole Monzogranite

Warrawagine Granitoid Complex

Unassigned unexposed granitoid complex

Lamberts Conformal Projection, WGS84 Datum

Ist Standard Parallel: 20°12'30S', 2nd Standard Parallel: 22°02'30S'

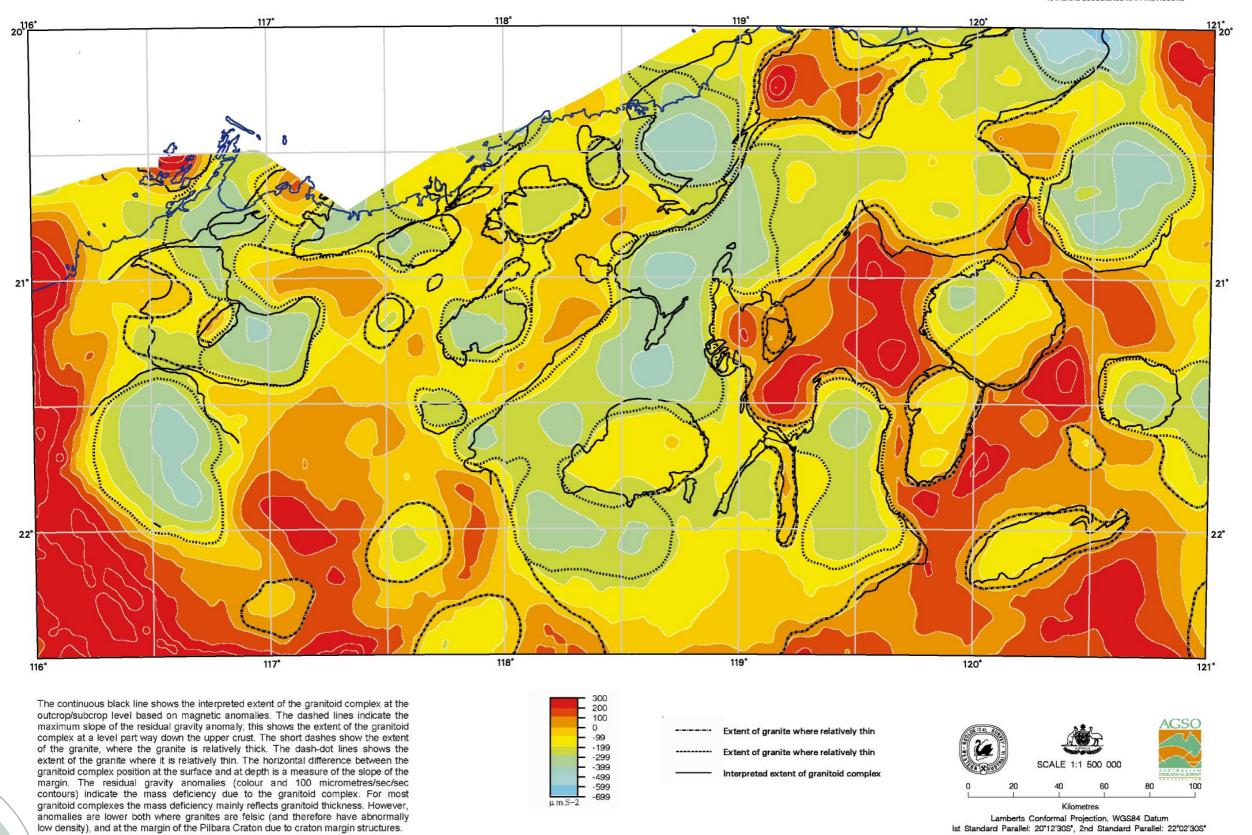
Central Meridian: 118°30'00E°

3D SHAPE OF GRANITOID COMPLEXES

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NGMA

NATIONAL GEOSCIENCE MAPPING ACCORD

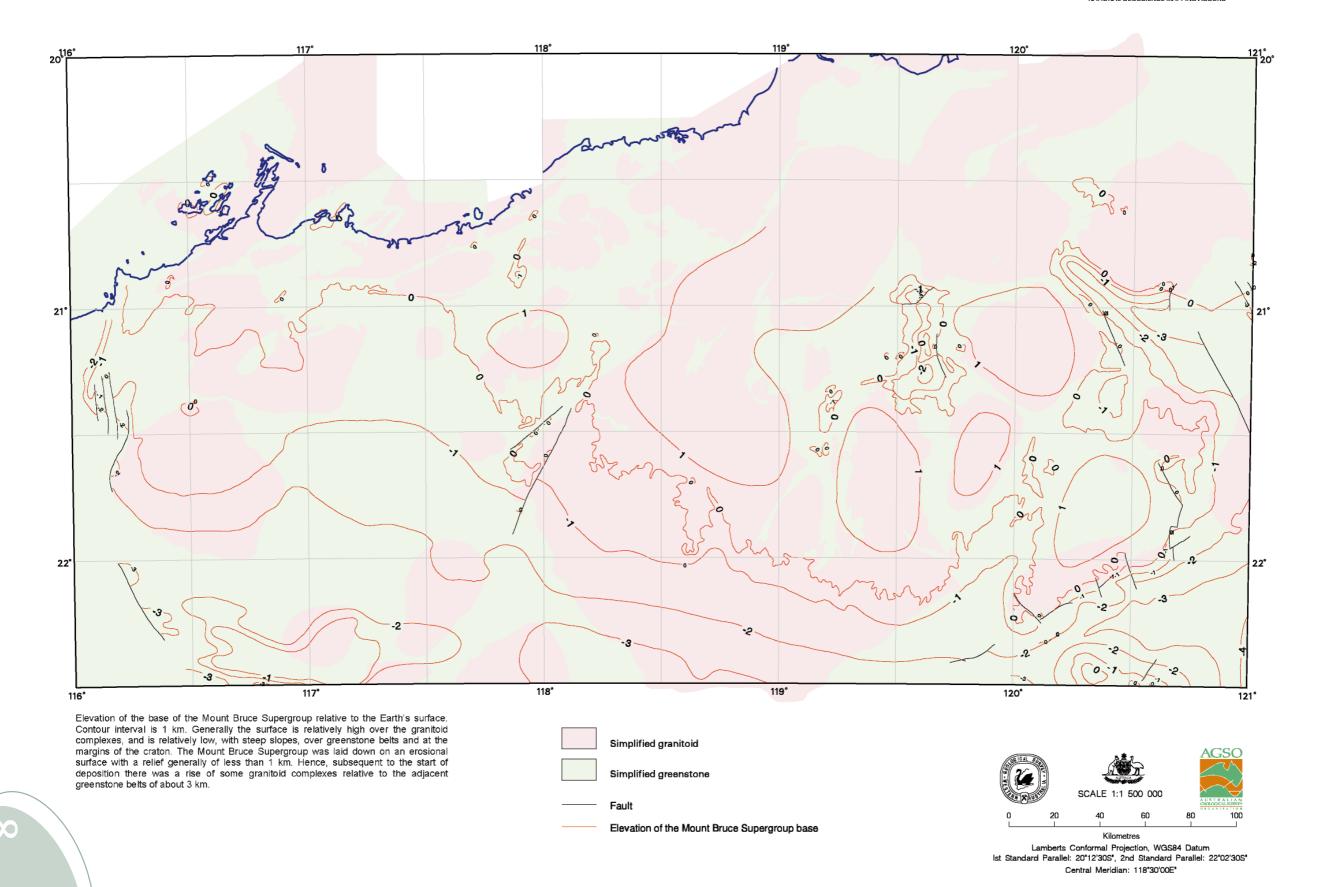


Lamberts Conformal Projection, WGS84 Datum Ist Standard Parallel: 20°12'30S', 2nd Standard Parallel: 22°02'30S' Central Meridian: 118°30'00E°

HAMERSLEY BASE ON SIMPLIFIED GRANITES

NORTH PILBARA ATLAS NGMA

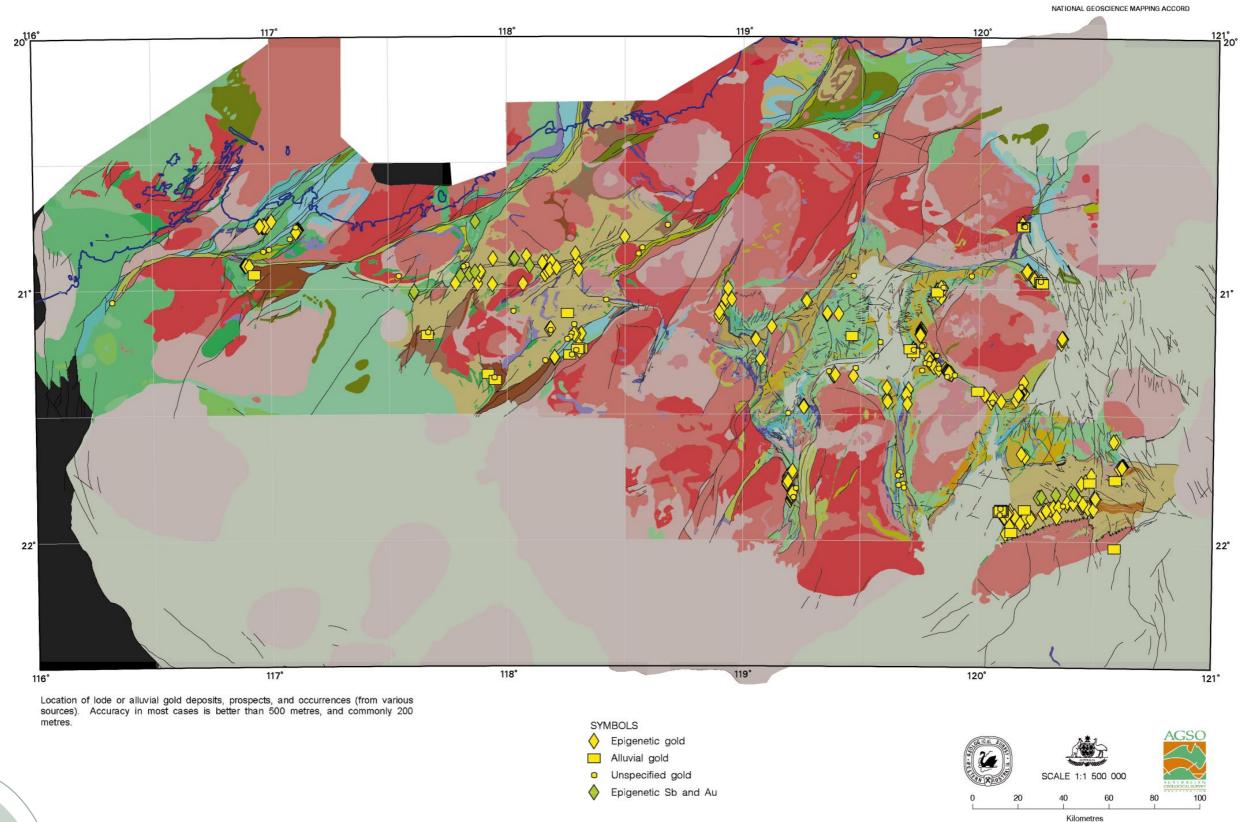
NATIONAL GEOSCIENCE MAPPING ACCORD

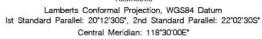


MINERAL DEPOSITS - GOLD

NORTH PILBARA ATLAS

NGMA

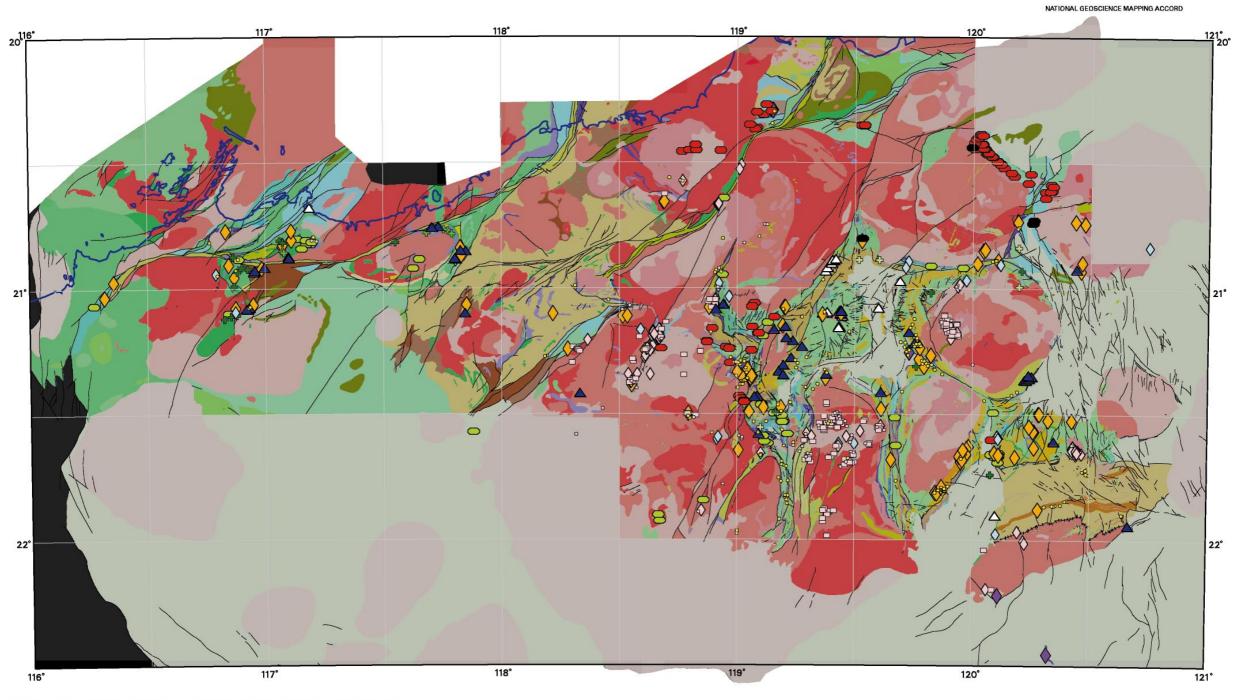




MINERAL DEPOSITS OTHER METALS AND MINERALS

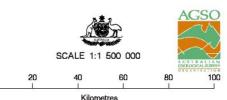
NORTH PILBARA ATLAS

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Location, (from various sources), of non-gold mineral deposits, prospects and occurrences. Accuracy in most cases is better than 500 metres, and commonly 200 metres. Gemstones include chrysoprase, corundum, diamond, pyrophyllite, and tiger eye.





Lamberts Conformal Projection, WGS84 Datum lst Standard Parallel: 20"12'30S", 2nd Standard Parallel: 22"02'30S" Central Meridian: 118"30'00E"

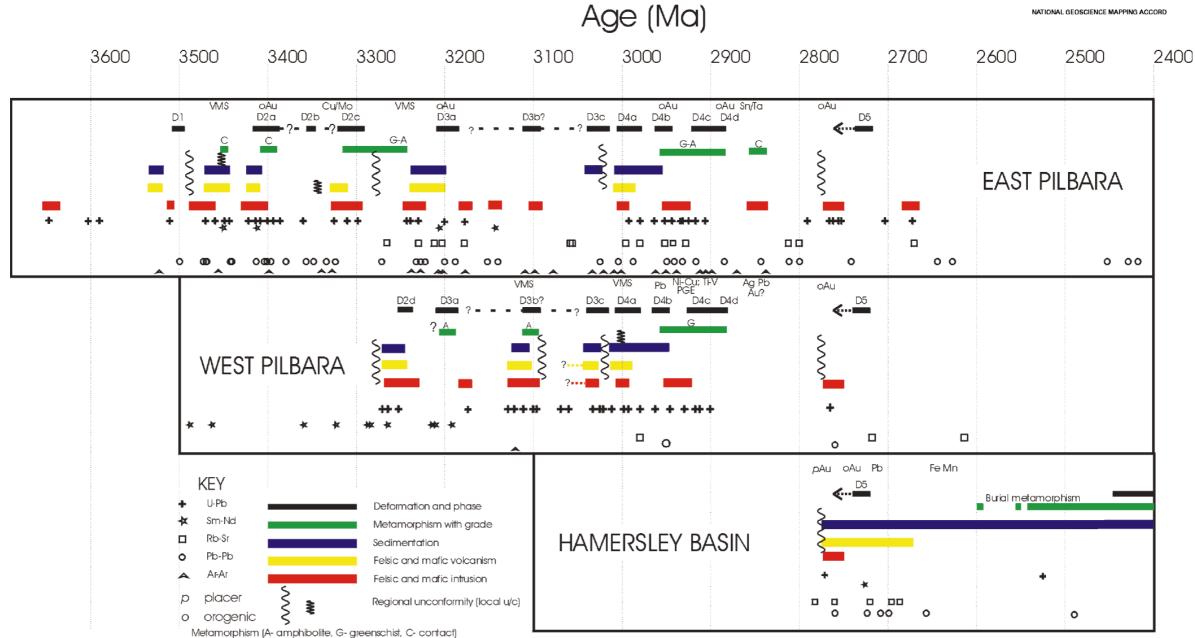


EVENTS CORRELATION DIAGRAM

NORTH PILBARA ATLAS

NGMA

NATIONAL GEOSCIENCE MAPPING ACCORD



Compiled by Richard Blewett (AGSO) 11/2/00

This diagram was compiled from various sources in the literature to show the possible links between deformational metamorphic, volcano-magmatic, basin-forming, and mineralisation events between the east and west Pilbara, and the Hamersley Basin. The available geochronology is also included (error bars excluded).

Of particular note are:1) 13 phases of penetrative deformation have been identified; 2) Some phases of deformation coincide with orogenic gold mineralisation, 3) Mineralisation is punctuated and spread across the time domain 4) The spatial complexity of the granitoid complexes (see solid geology maps) is further complicated (temporally) by up to 12 pulses of magma; 5) Deformation events commonly separate greenstone packages (blue and yellow lines).





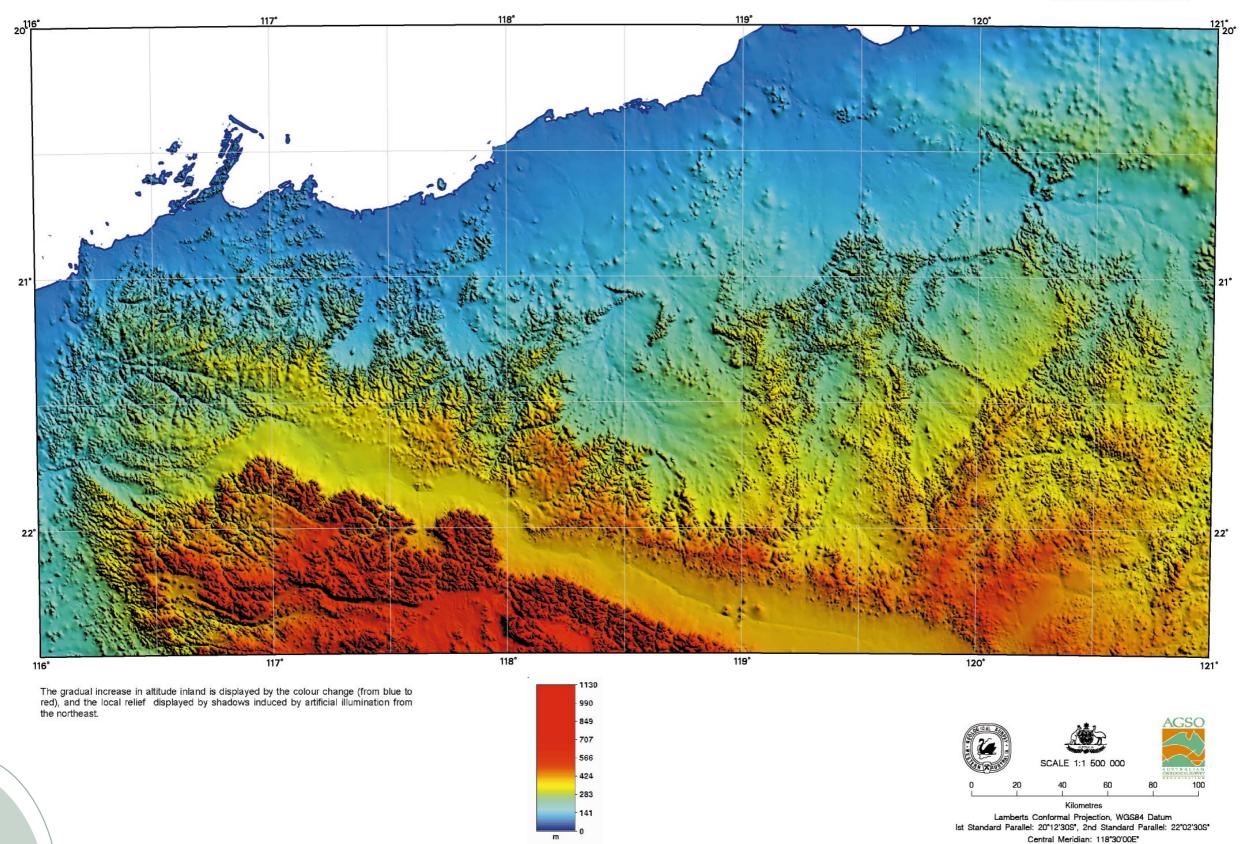


TOPOGRAPHY GRADIENT-ENHANCED PSEUDOCOLOUR IMAGE

NORTH PILBARA ATLAS

NGMA

NATIONAL GEOSCIENCE MAPPING ACCORD



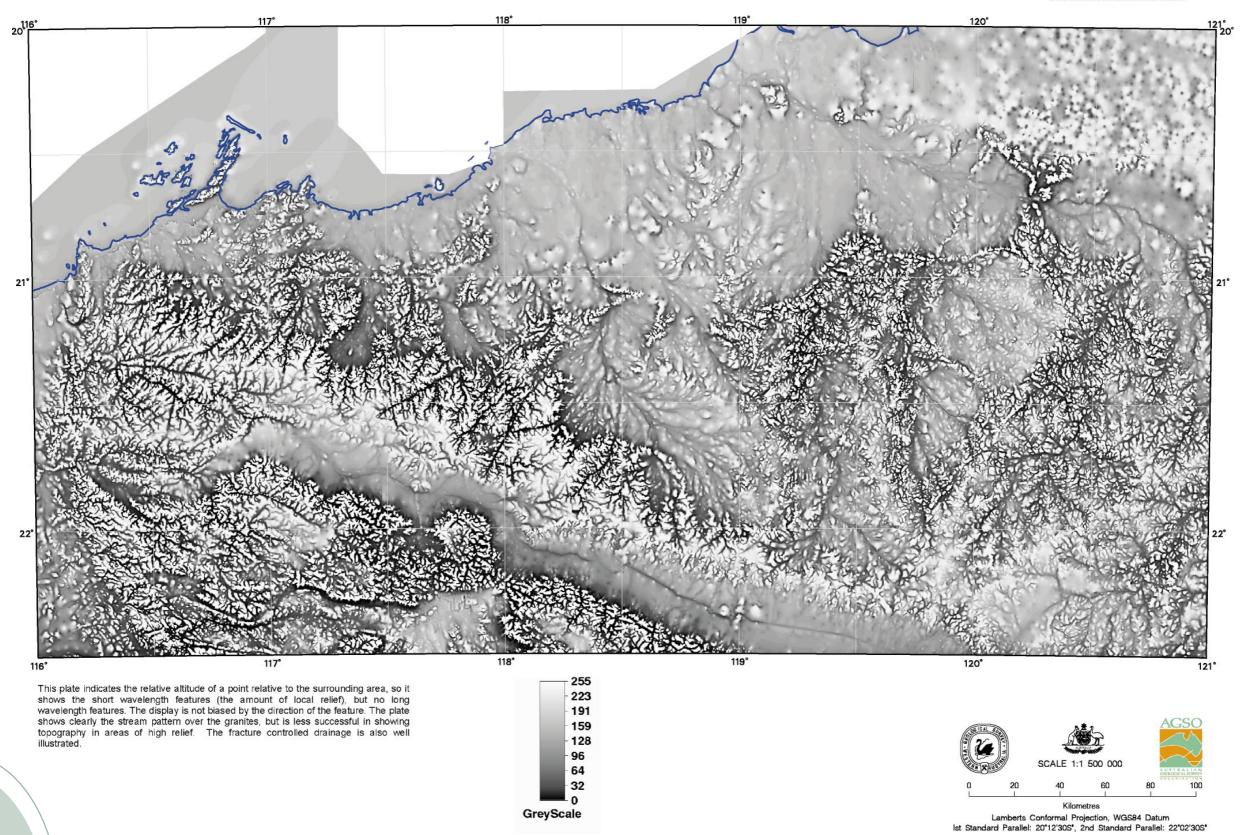
TOPOGRAPHY FIRST VERTICAL DERIVATIVE

NORTH PILBARA ATLAS

NGMA

NATIONAL GEOSCIENCE MAPPING ACCORD

Central Meridian: 118"30'00E"

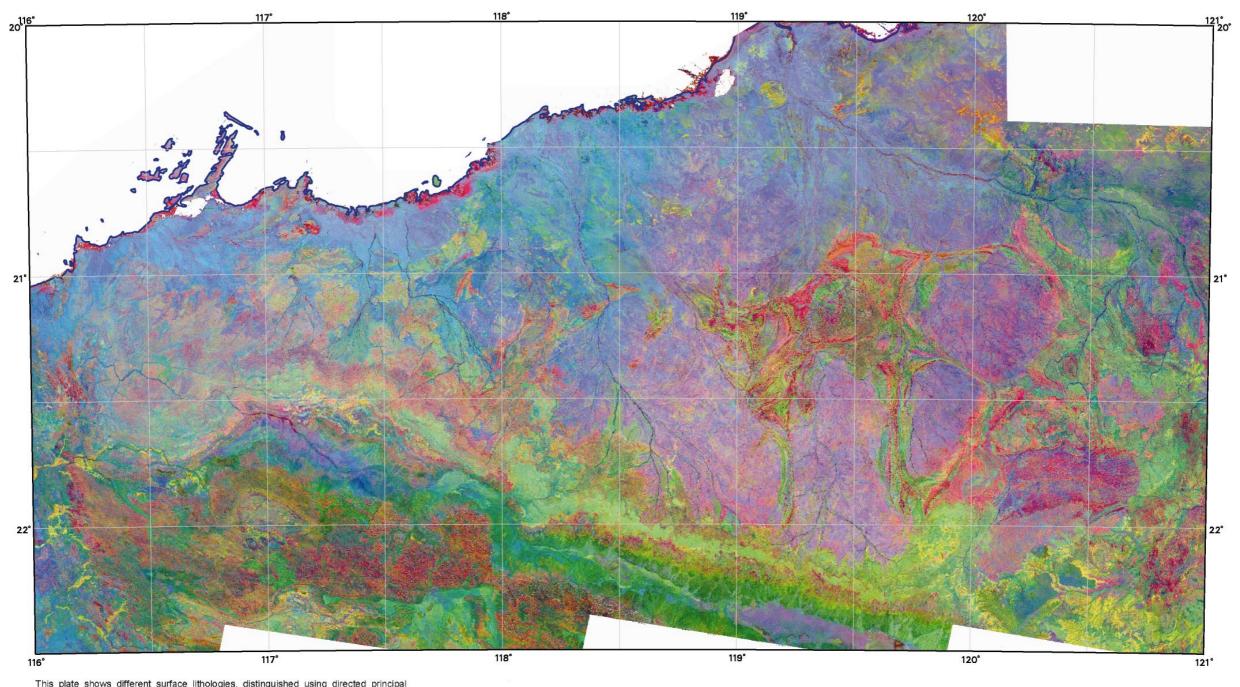


LANDSAT DATA - TM IMAGE

NORTH PILBARA ATLAS

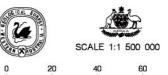
NGMA

NATIONAL GEOSCIENCE MAPPING ACCORD



This plate shows different surface lithologies, distinguished using directed principal components of ratios of the observed Landsat bands. The display is a composite red, green, and blue image. Red displays clay, hydrosilicates and carbonates using the second principal component of the combined band ratio (5/4; 5/7). Green displays iron oxides using the 5/4 band ratio. Blue displays silica using the 1+7 bands. The mixture of the primary colours indicates the relative proportion of the materials (e.g. yellow indicates equal amounts of clays and iron oxides).







Kilometres

Lamberts Conformal Projection, WGS84 Datum Ist Standard Parallel: 20°12'30S', 2nd Standard Parallel: 22°02'30S' Central Meridian: 118°30'00E'

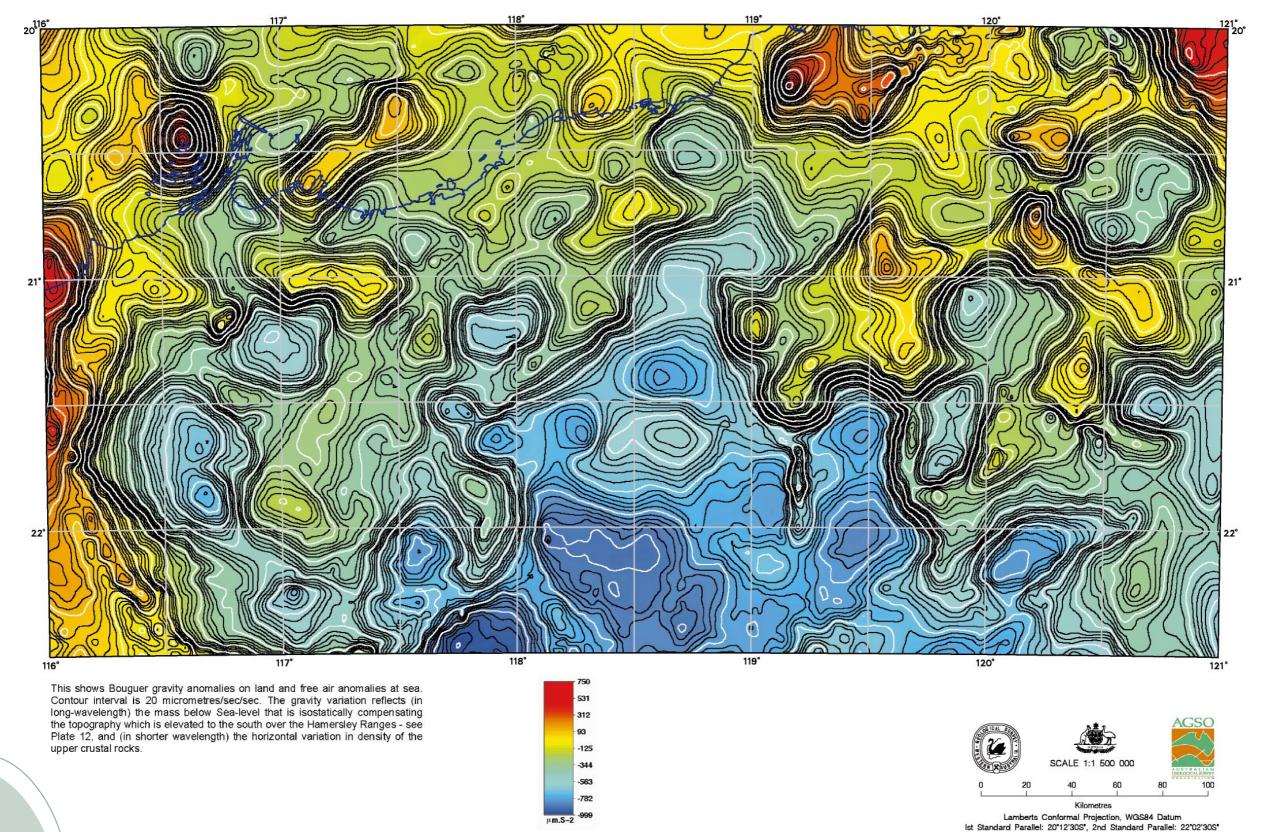
GRAVITY BOUGUER ANOMALY

NORTH PILBARA ATLAS

NGMA

NATIONAL GEOSCIENCE MAPPING ACCORD

Central Meridian: 118°30'00E°

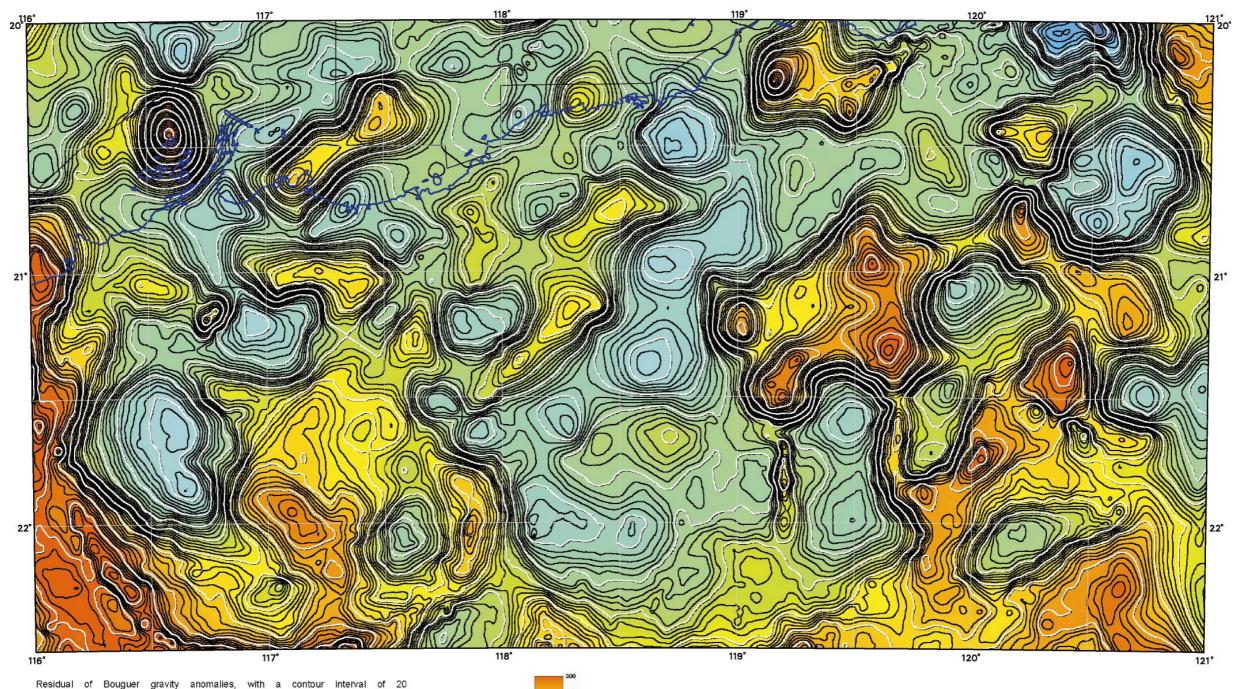


GRAVITY RESIDUAL GRAVITY ANOMALY

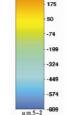
NORTH PILBARA ATLAS

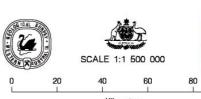
NGMA

NATIONAL GEOSCIENCE MAPPING ACCORD



Residual of Bouguer gravity anomalies, with a contour interval of 20 micrometres/sec/sec. The image shows the gravity variation that reflects the horizontal variation of the density in the upper crustal rocks. The anomaly has been calculated by taking the Bouguer anomaly on land and the free air anomaly at sea, on land subtracting the smoothed Bouguer correction (to get a Faye anomaly; a type of isostatic anomaly), then subtracting a second-order polynomial, such that the resultant residual anomaly will have a similar value near the middle of most of the larger granites. These residual anomalies show the mass deficiency associated with each granite, and the total mass associated with each greenstone belt. Blue and green colours reflect granitoid complexes (batholiths), red and yellow colours reflect greenstone belts.





Lamberts Conformal Projection, WGS84 Datum

Ist Standard Parallel: 20"12"30S", 2nd Standard Parallel: 22"02"30S"

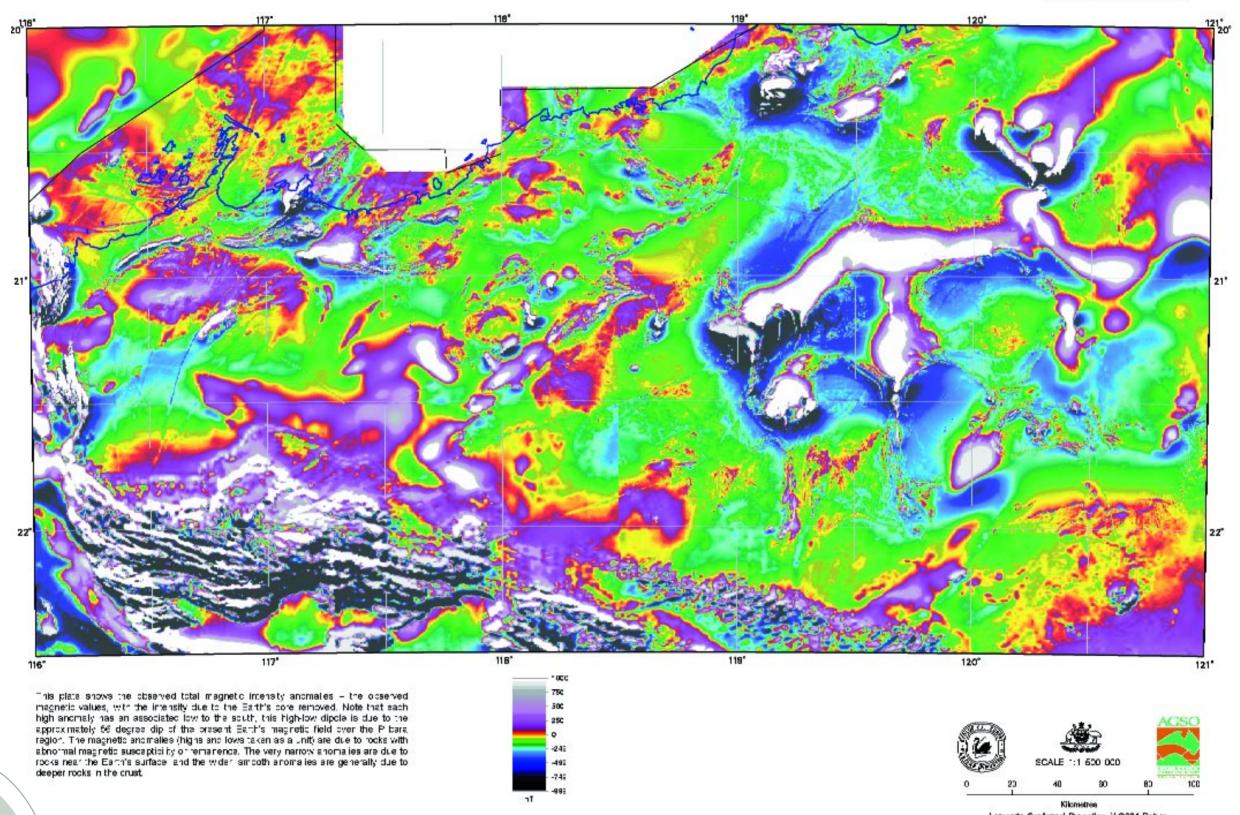
Central Meridian: 118"30"00E"

TOTAL MAGNETIC INTENSITY PSEUDOCOLOUR IMAGE OF RESIDUAL ANOMALIES

NORTH PILBARA ATLAS

NGMA

NATIONAL BEOBCIEVES WARPING ACCORD

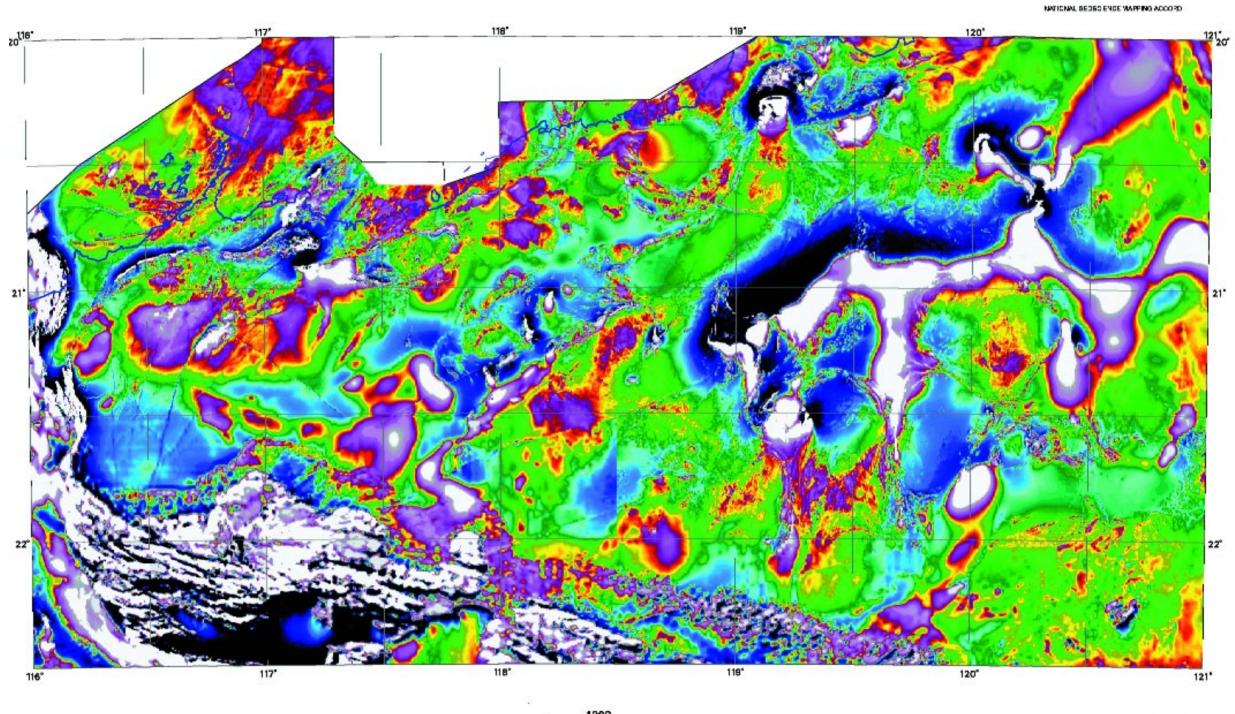


Lamperts Conformal Projection WGS84 Debum st Standaro Parallel: 2012/2005* 2nd Standard Parallel: 22102/303* Central Mendion: "187301006*

TOTAL MAGNETIC INTENSITY REDUCED TO POLE (RTP)

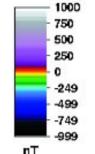
NORTH PILBARA ATLAS

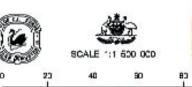
NGMA



This plate shows the reduced-to-pole total magnetic intensity anomalies – the observed magnetic values, with removal of the intensity due to the Earth's core, and the effect of the 56 degree dip of the Earth's magnetic field. The effect of reducing the anomaly to the pole claces the anomalies symmetrically over the causative codies. All the magnetic anomalies are due to rocks with abnormal magnetic susceptibility or remanence. The very narrow anomalies are due to abnormal rocks near the Earth's surface, and the wide and smooth anomalies are due to deeper abnormal rocks. Generally the warmer colours (tending to white) on this map overly crustal rocks with relatively higher magnetite contents (e.g. canded-iron -formation)

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Lamperta Conformal Projection WG884 Datum s: Standaro Parallel: 2012/305° 2nd Standard Parallel: 22102/303° Central Mendian: "8"30"00E"

TOTAL MAGNETIC INTENSITY - FIRST VERTICAL DERIVATIVE OF RESIDUAL ANOMALIES REDUCED TO POLE

NORTH PILBARA ATLAS

NGMA
NATIONAL BEDBC EVICE WARPING ACCORD

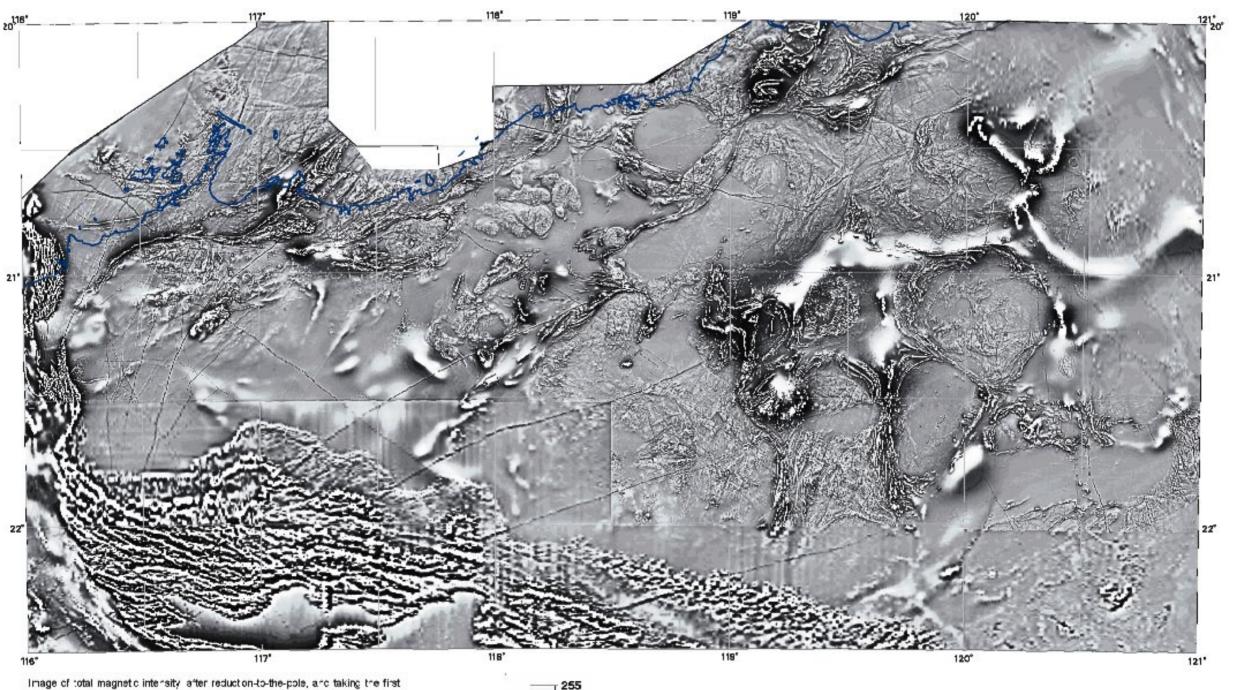
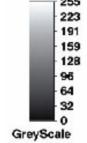
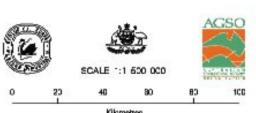


Image of total magnetic intensity after reduction-to-the-pole, and taking the first vertical derivative. The effect of reducing the data to the pole places the anomalies symmetrically over the causative bodies. The effect of taking the first vertical derivative of the data is to increase the amoltude of the short-wavelength anomalies relative to the long-wavelength anomalies. This plate shows the shorter magnetic anomalies but a without directional poles. In particular, it shows the variation in the texture and amplitude of the anomalies; this is used to map the extent of rock podies and map deformation features. Within the area of good magnetic data, note: 1) the difference in texture between the granifold complexes; and greenstone pelts 2) the detailed internal structure of the granifold complexes; 3) the pattern of cross-cuting fractures and dykes; and 4) the width and continuity of the major northeast-trending shear zones.



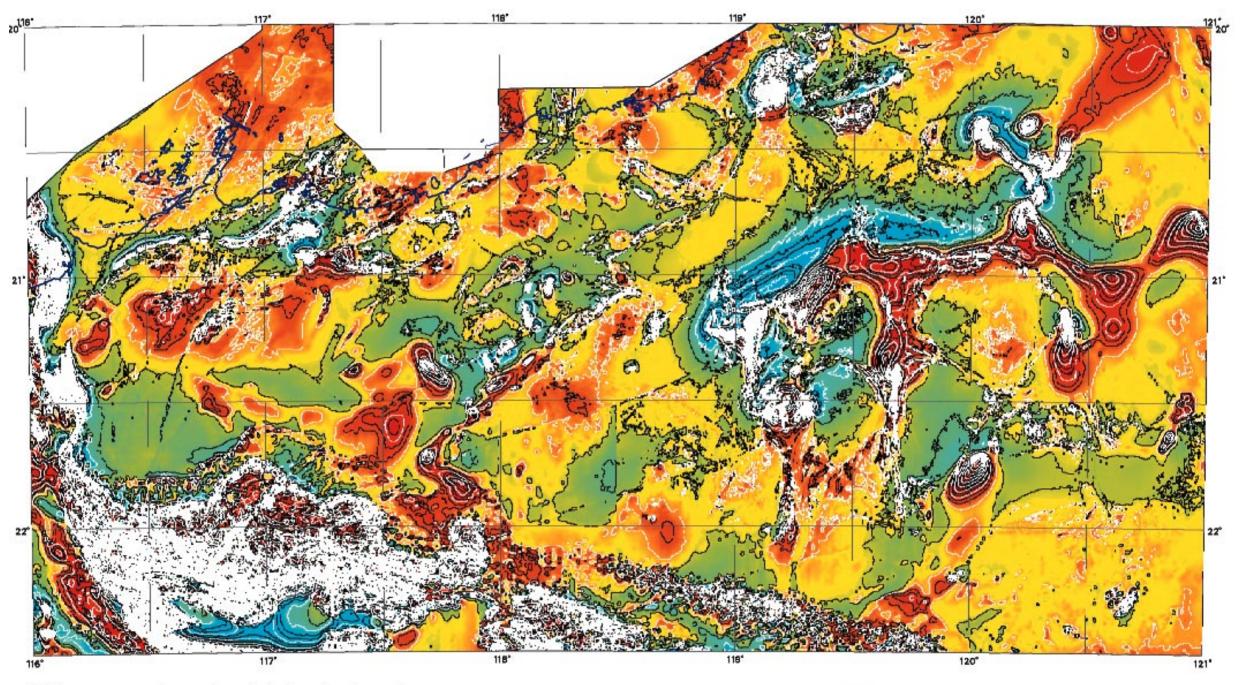


Lamperts Conformal Projection WGS84 Debum et Stundero Penal et: 2012/3061 2nd Stenderd Panallet: 22102/3061 Central Mendian: "187300061

TOTAL MAGNETIC INTENSITY REDUCED TO POLE, COLOUR CONTOURS

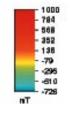
NORTH PILBARA ATLAS NGMA

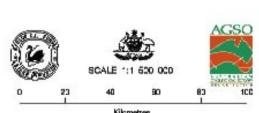
NATIONAL SECRET EYES WAPPING ACCORD.



This place shows the reduced-to-pole total magnatic intensity anomalias – the anomaly values after removal of the intensity due to the Earth's core, and the effect of the 66 degree dip of the Earth's magnetic field. The effect of reducing the anomaly to the pole places the anomalies symmetrically over the causative codes. All the magnetic aromalies are due to tooks with abnormal magnetic susceptibility or remarence. The very narrow anomalies are due to abnormal rocks near the Earth's surface and the wide and smooth anomalies are due to deeper abnormal rocks. Generally the warmer colours (red prange, yellow), on this map overly crustal rocks with relatively higher magnetite contents.

This plate gives comburs at 200 nT in black and at 600 nT in white in the southwest of the plate short-wave eight enomalies are largely due to banded-iron-formations in the Mourt Bruce Supergroup Over the remainder of the map, the narrower of the anomalies shown as a mass of white contours, are due to outdropping other, banded for-formation, and ultramatic rocks. Over the remainder of the plate, the broader anomalies shown as redictionable are due to bodies with a top at 1.6-2.0 km depth, a width commonly of 8 km, and a depth of their base at about 14 km. The magnetic material is thought to be canded-iron-formation.



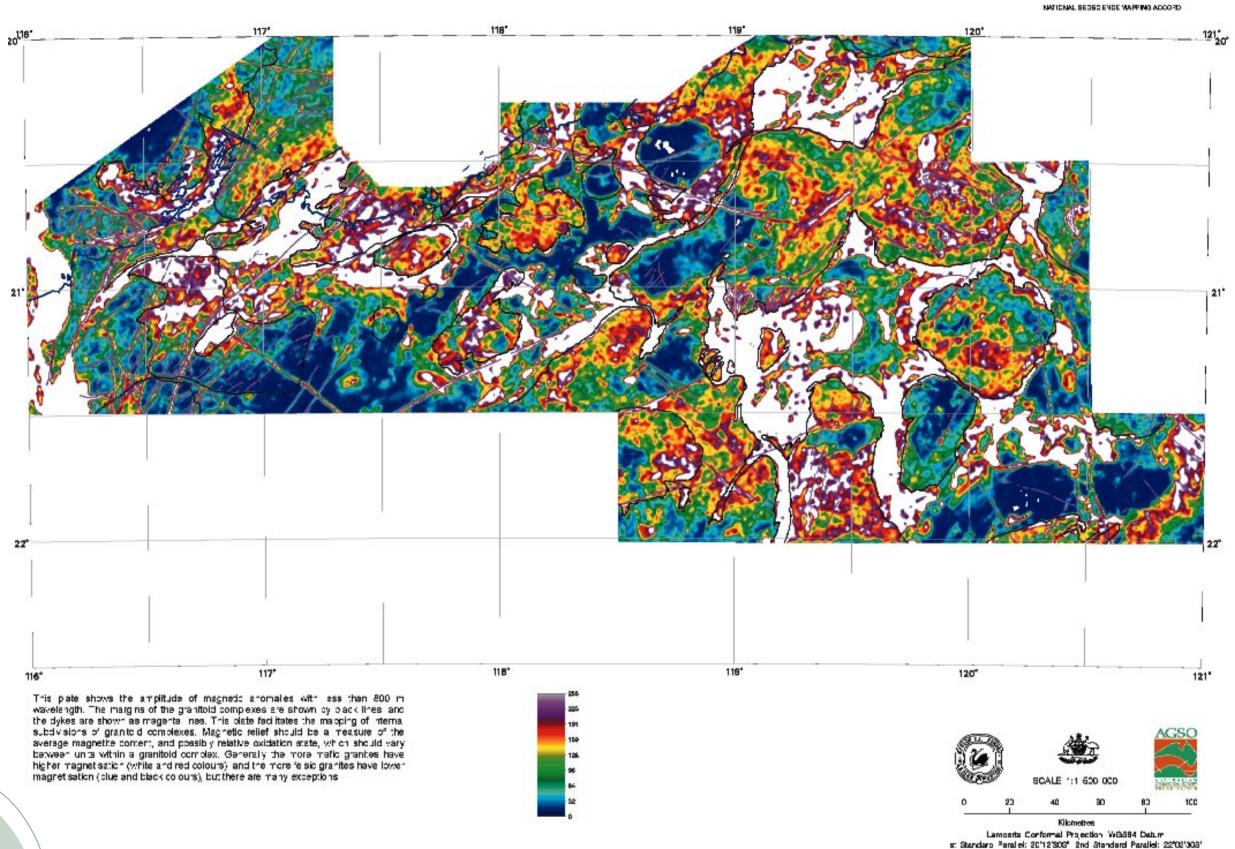


Lamoetta Conformal Projection WG884 Datum s: Standaro Parallel: 2012/2021 2nd Standard Parallel: 2210213031 Central Mendian: 1187300061

TOTAL MAGNETIC INTENSITY SHORT-WAVELENGTH MAGNETIC RELIEF

NORTH PILBARA ATLAS NGMA

Certral Meridian: "8'30'00E"



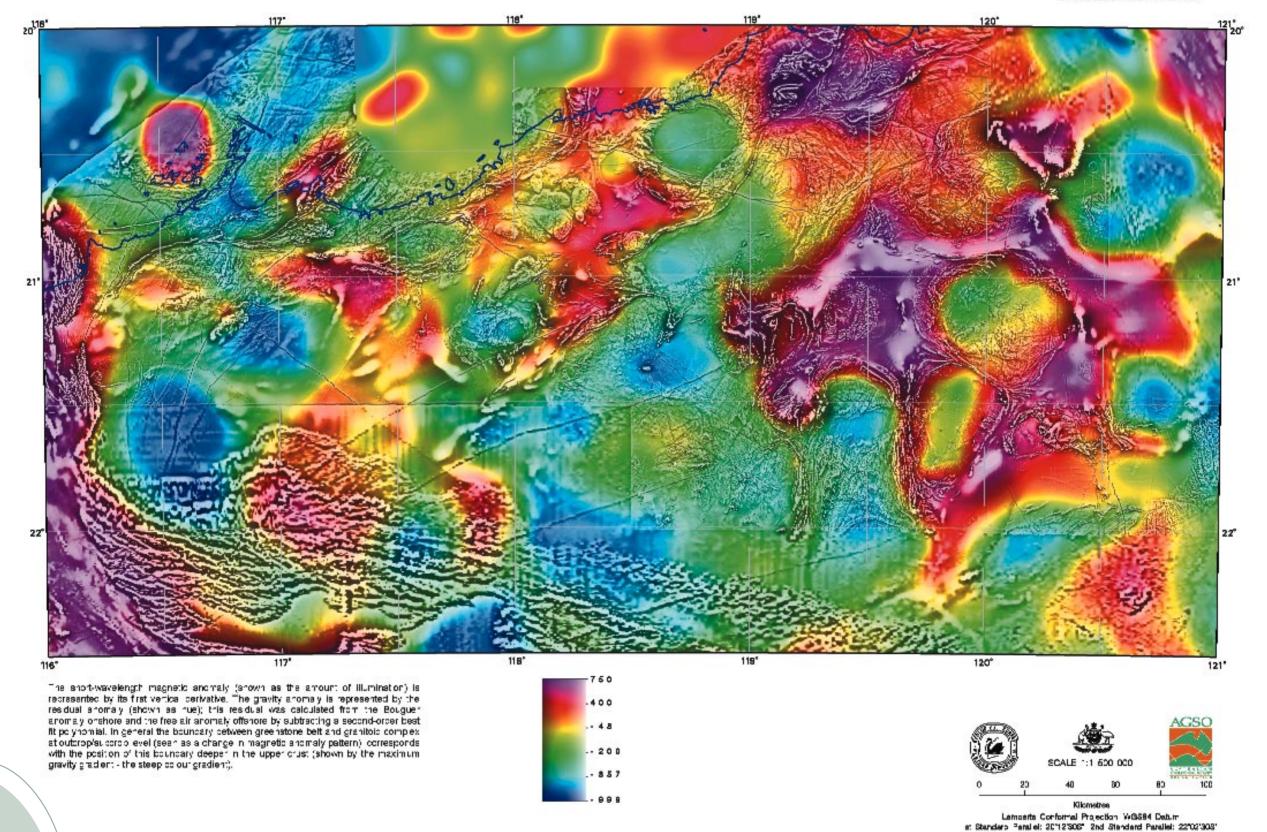
TOTAL MAGNETIC INTENSITY FIRST VERICAL DERIVATIVE WITH GRAVITY COLOUR

NORTH PILBARA ATLAS

NGMA

MATICINAL BEOBC EYES WARPING ACCORD

Central Mendian: "8"30"00E"

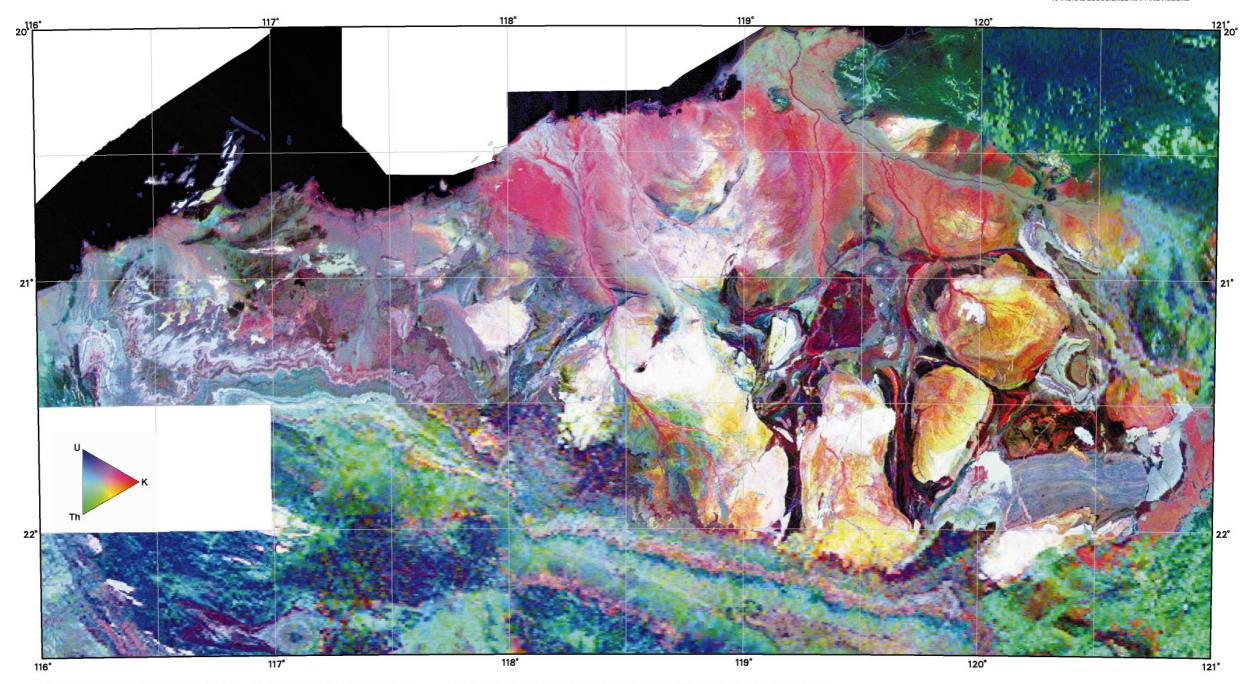


GAMMA-RAY SPECTROMETRIC DATA POTASSIUM (RED), THORIUM (GREEN) AND URANIUM (BLUE) IMAGE

NORTH PILBARA ATLAS

NGMA

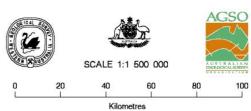
NATIONAL GEOSCIENCE MAPPING ACCORD



Red-Green-Blue composite image that was histogram equalised for an area of basement outcrop. This image gives the best overall display of the K:Th:U data. The spectrometric images correlate more closely with traditional geological maps than magnetic images, as they display both outcropping solid rock and cover material (regolith). Lateral down-slope movement of material may shift the boundary relative to its true position in the solid rock or displayed in magnetic images.

Spectrometric data gives the absolute concentration of K, Th, and U in the upper 0.3 m of the Earth. In this composite image the relative concentration of K is shown as the amount of red, concentration of Th as the amount of green, and concentration of U as the amount of blue. Areas of black have a low concentration of all three elements, white have a high concentration of K and Th. In areas of outcrop the extent of single colours shows the extent of rocks with that relative proportion of elements, e.g. white and light yellow colours give the extent of granites.

In areas of young transported regolith the colours show the composition of material in the riverbed (often alluvium derived from granite). The K, Th, and U concentrations correlate with one another, so their images have a similar pattern. In this image the lightness shows the average concentration of elements, and the hue shows the ratio of the elements. The concentrations have been transformed non-linearly to colour intensity, and the transformation of each element is different, so the hue does not give information as to the absolute ratio between concentrations. Due to the large dynamic range of the data, information is 'lost' by over-saturating areas of high K, Th, and U (late-stage granites) into near white colours, and undersaturating areas of low K, Th, and U (mafic and ultramafic rocks) into near black colours. The result is therefore a compromise and illustrates the need for access to alternative presentations to display the full information contained in the digital, absolute values of K, Th, and U.

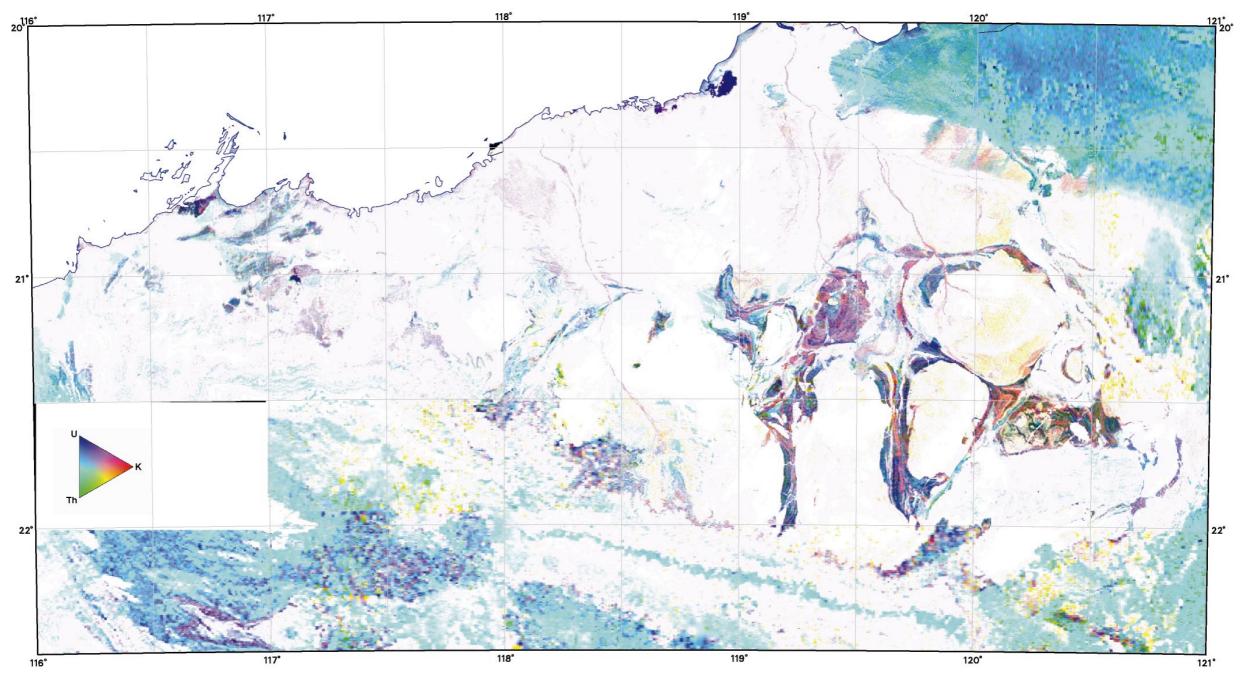


Lamberts Conformal Projection, WGS84 Datum lst Standard Parallel: 20°12'30S*, 2nd Standard Parallel: 22°02'30S* Central Meridian: 118°30'00E*

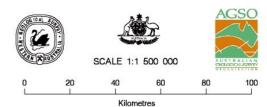
GAMMA-RAY SPECTROMETRIC DATA - RED-GREEN-BLUE IMAGE LOW CONCENTRATIONS OF K (RED), Th (GREEN), AND U(BLUE)

NORTH PILBARA ATLAS NGMA

NATIONAL GEOSCIENCE MAPPING ACCORD



This Red-Green-Blue standard composite image has been optimised to show the relative K, Th, and U compositions in mafic and ultramafic rocks, by histogram equalisation in an area of low K, Th and U concentration. This presentation has 'lost' all information on the granites; but it allows the interpreter to map the different lithologies of the greenstone packages. Spectrometric data gives the absolute concentration of K, Th, and U in the upper 0.3 m of the Earth. In this composite image the relative concentration of K is shown as the amount of red in the colour, concentration of Th as the amount of green, and concentration of U as the amount of blue.



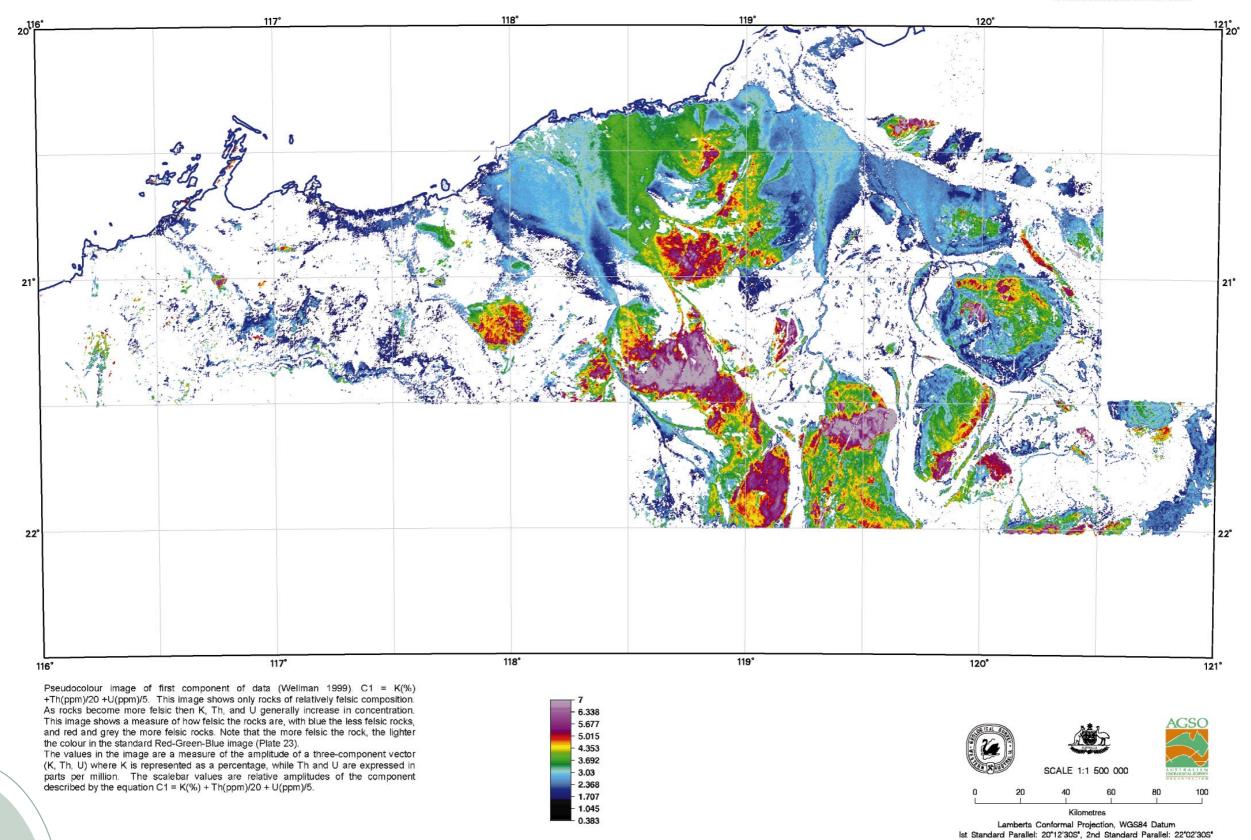
Lamberts Conformal Projection, WGS84 Datum lst Standard Parallel: 20*12'30S*, 2nd Standard Parallel: 22*02'30S* Central Meridian: 118*30'00E*

GAMMA-RAY SPECTROMETRIC DATA FELSIC IGNEOUS ROCKS - C1

NORTH PILBARA ATLAS

NGMA
NATIONAL GEOSCIENCE MAPPING ACCORD

Central Meridian: 118°30'00E"

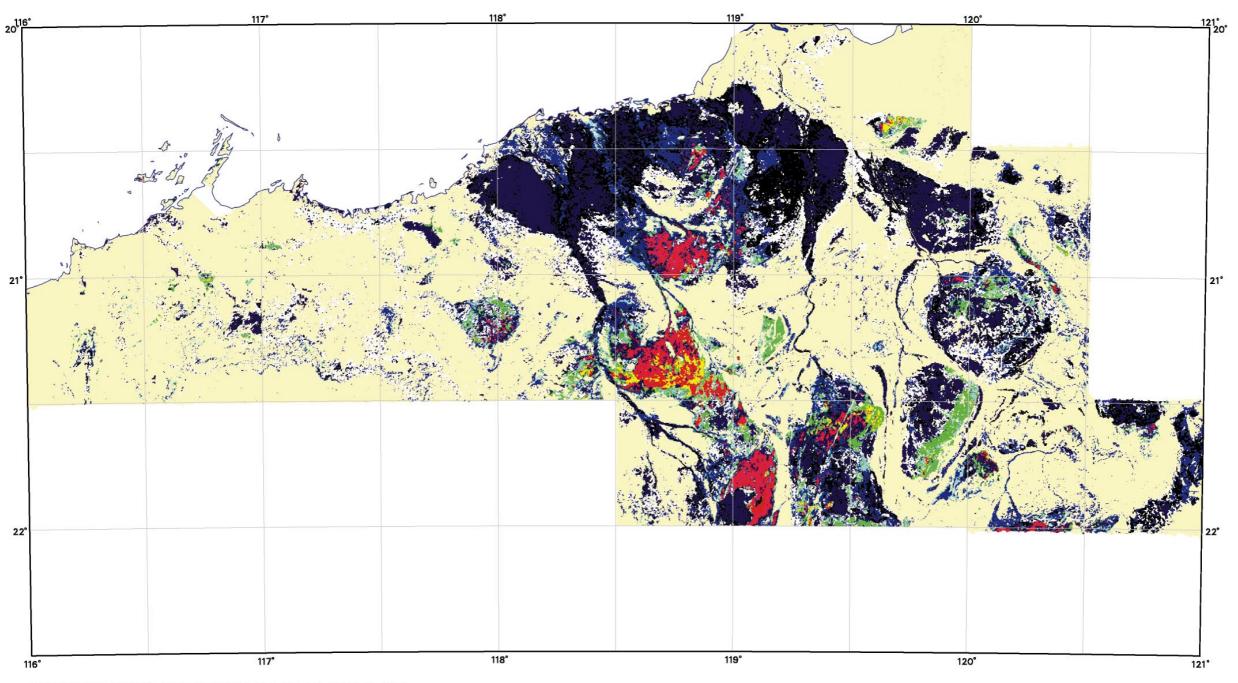


SPECTROMETRIC DATA FELSIC IGNEOUS ROCKS - C2

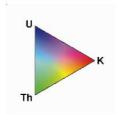
NORTH PILBARA ATLAS

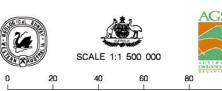
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Red-Green-Blue composite image of residuals of K, Th, and U from the first component-C1 (Wellman 1999). C2 (Residual K) = (K - (K + Th/20 + U/5) * 0.115 - 2.8). This image shows only rocks of relatively felsic composition. As rocks become more felsic then K, Th, and U generally increase in concentration. This image shows the deviation of K, Th, and U from their average increase in concentration. The image is a composite image with deviations of K shown in red, Th shown in green, and U shown in blue. Deviations less than one standard deviation are shown in half strength colours, deviations between minus one standard deviation and plus one standard deviation are not coloured, and deviations of greater than one standard deviation are shown in full strength colours. Hence bright yellow has K and Th more positive than one standard deviation from expected, and U within one standard deviation of that expected.





Kilometres

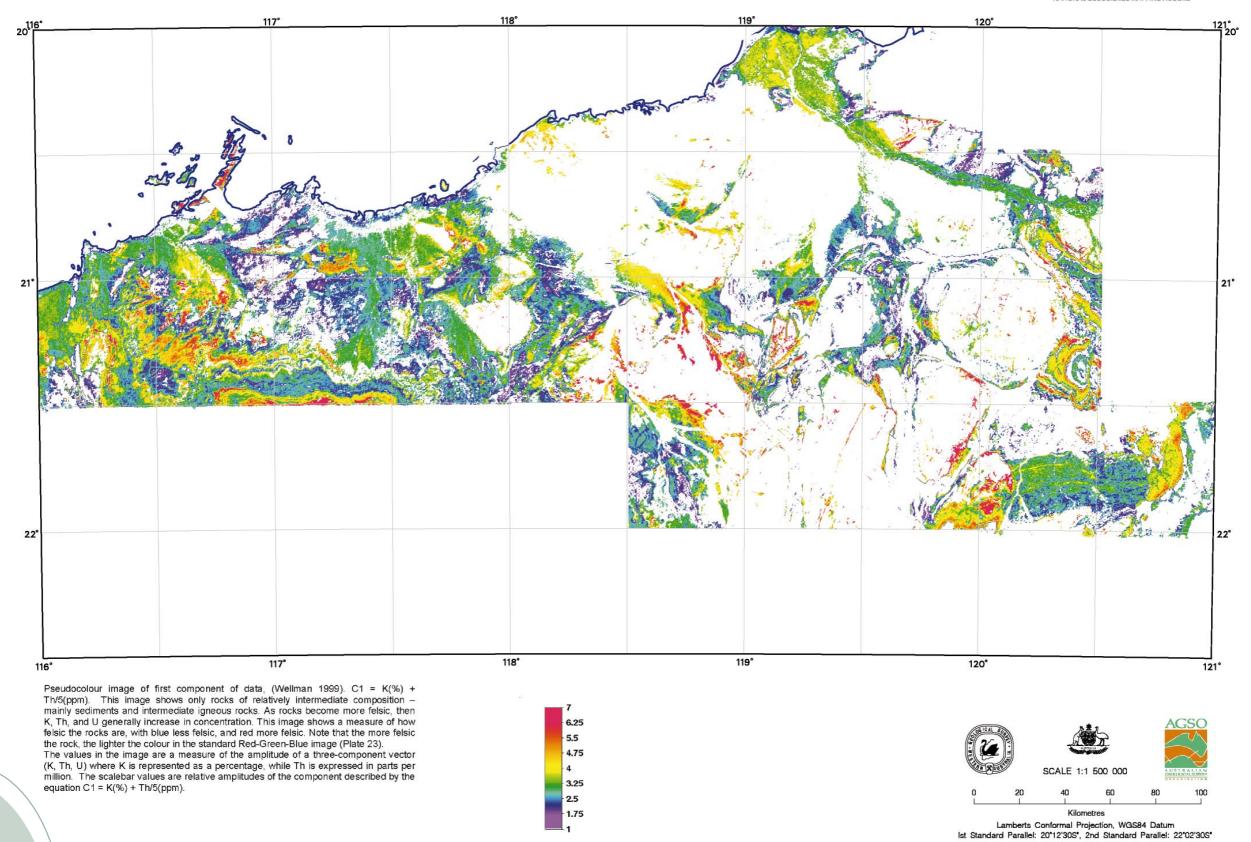
Lamberts Conformal Projection, WGS84 Datum lst Standard Parallel: 20"12'30S", 2nd Standard Parallel: 22"02'30S" Central Meridian: 118"30'00E"

GAMMA - RAY SPECTROMETRIC DATA INTERMEDIATE IGNEOUS ROCKS AND SEDIMENTS - C1

NORTH PILBARA ATLAS NGMA

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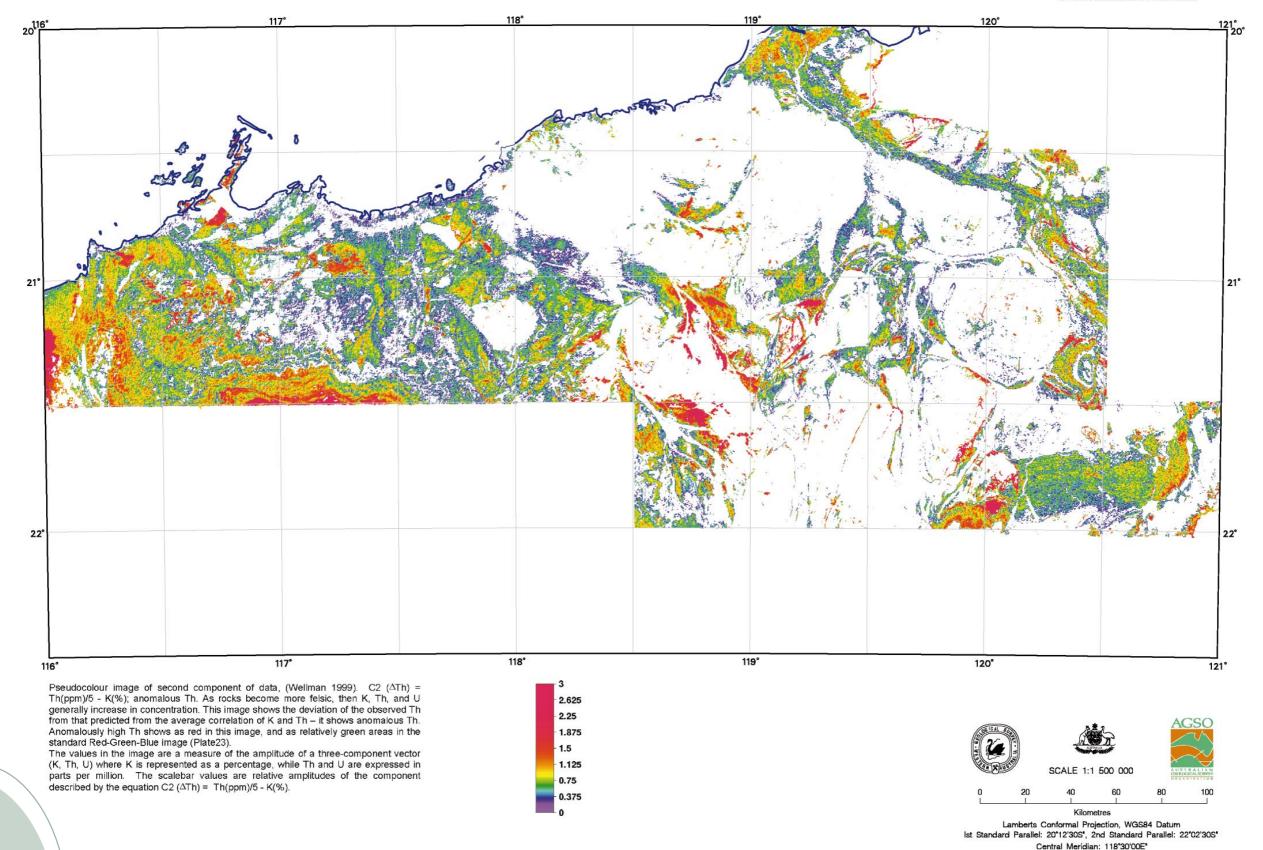
Central Meridian: 118°30'00E°



GAMMA-RAYSPECTROMETRIC DATA INTERMEDIATE IGNEOUS ROCKS AND SEDIMENTS - C2

NORTH PILBARA ATLAS

NGMA
NATIONAL GEOSCIENCE MAPPING ACCORD

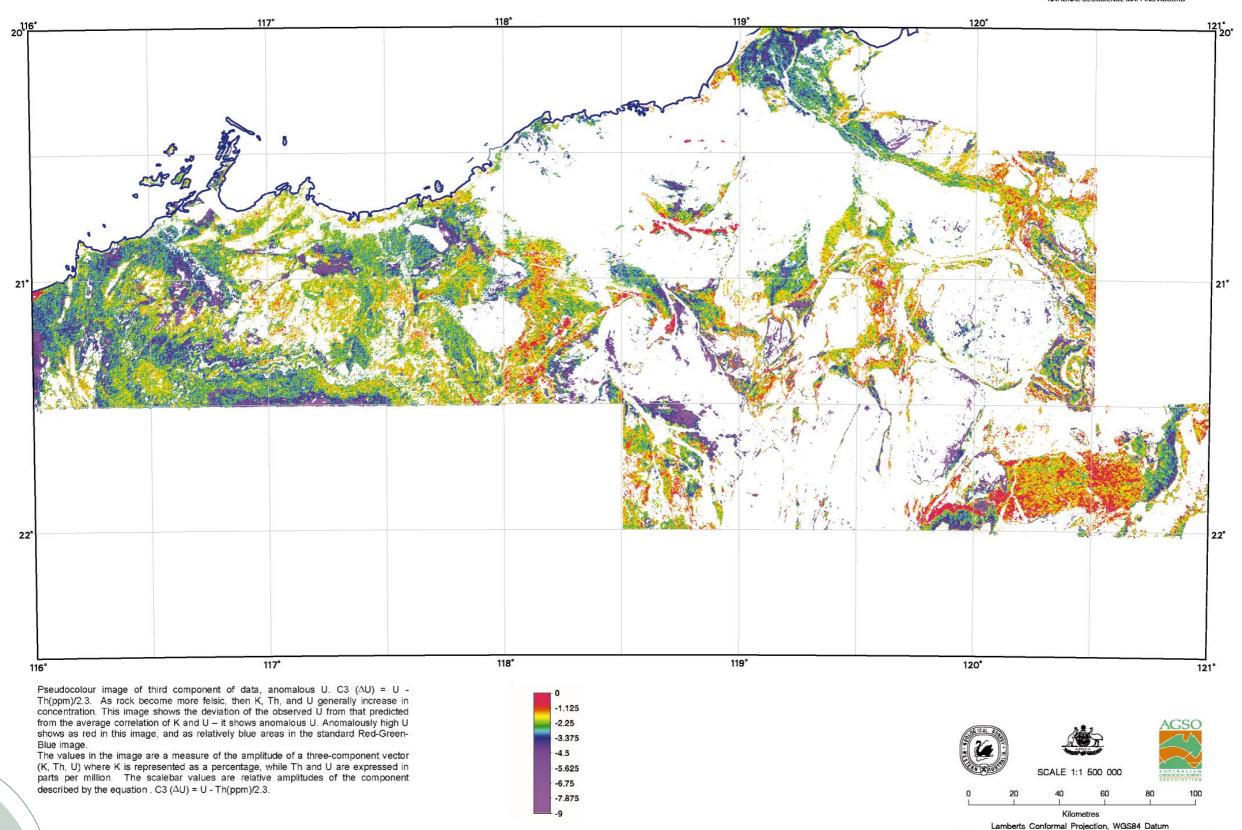


GAMMA - RAY SPECTROMETRIC DATA INTERMEDIATE IGNEOUS ROCKS AND SEDIMENTS - C3

NORTH PILBARA ATLAS NGMA

NATIONAL GEOSCIENCE MAPPING ACCORD

lst Standard Parallel: 20*12'30S', 2nd Standard Parallel: 22*02'30S' Central Meridian: 118*30'00E'



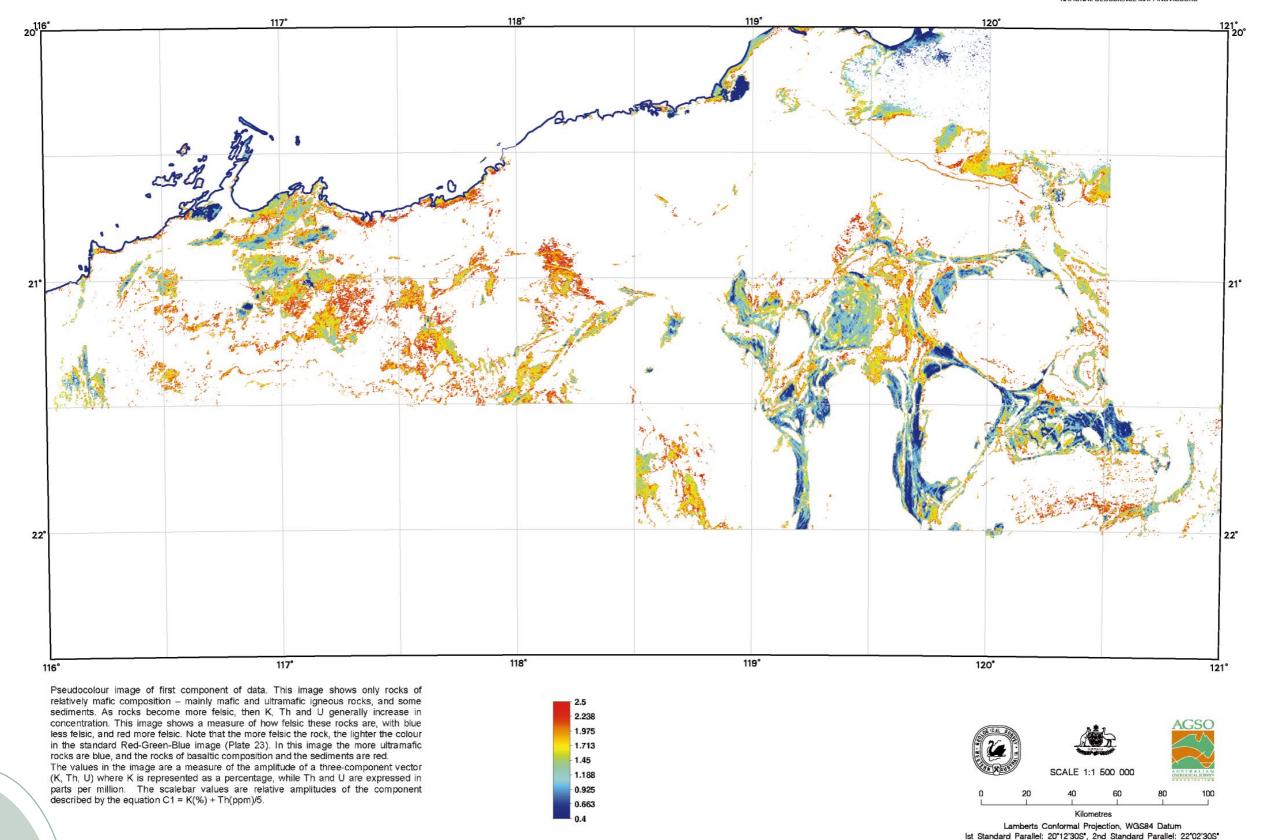
79

SPECTROMETRIC DATA MAFIC IGNEOUS ROCKS - C1

NORTH PILBARA ATLAS NGMA

NATIONAL GEOSCIENCE MAPPING ACCORD

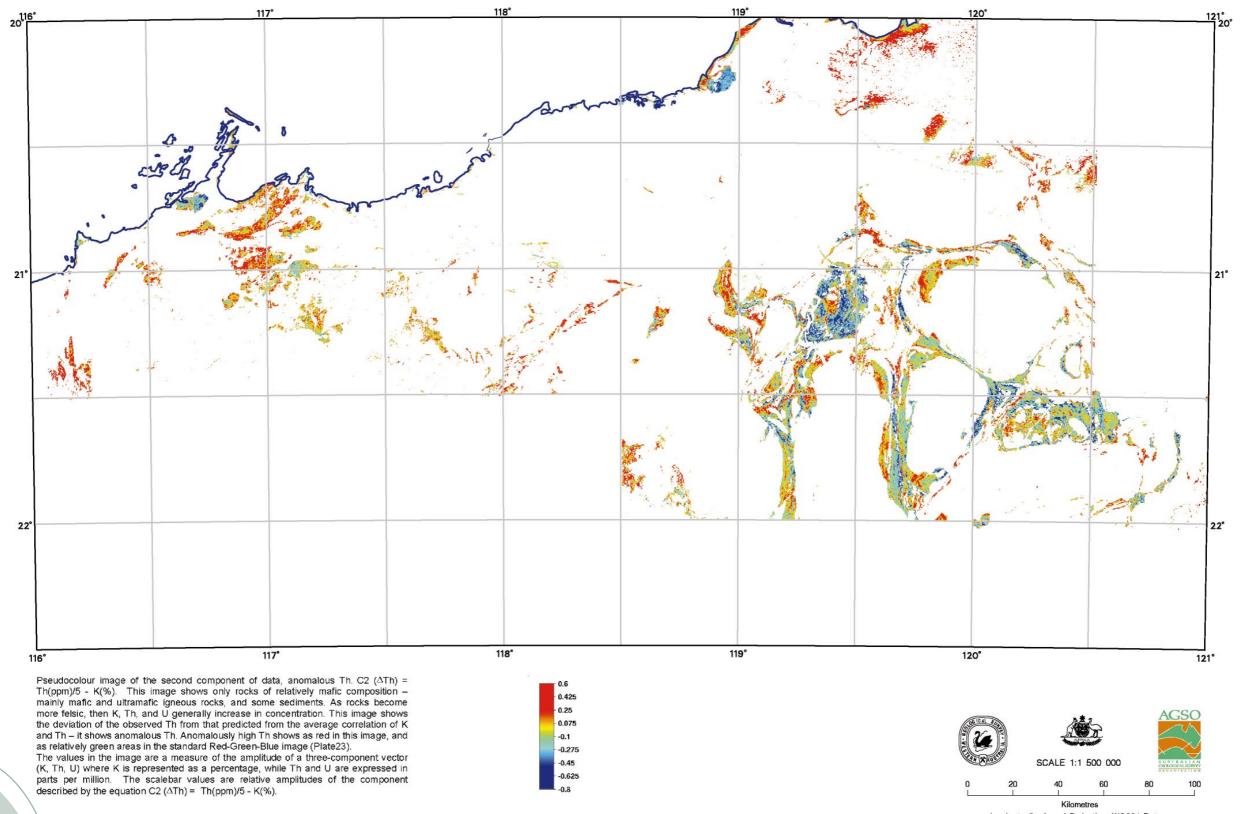
Central Meridian: 118°30'00E*



GAMMA - RAY SPECTROMETRIC DATA MAFIC IGNEOUS ROCKS - C2

NORTH PILBARA ATLAS NGMA

NATIONAL GEOSCIENCE MAPPING ACCORD



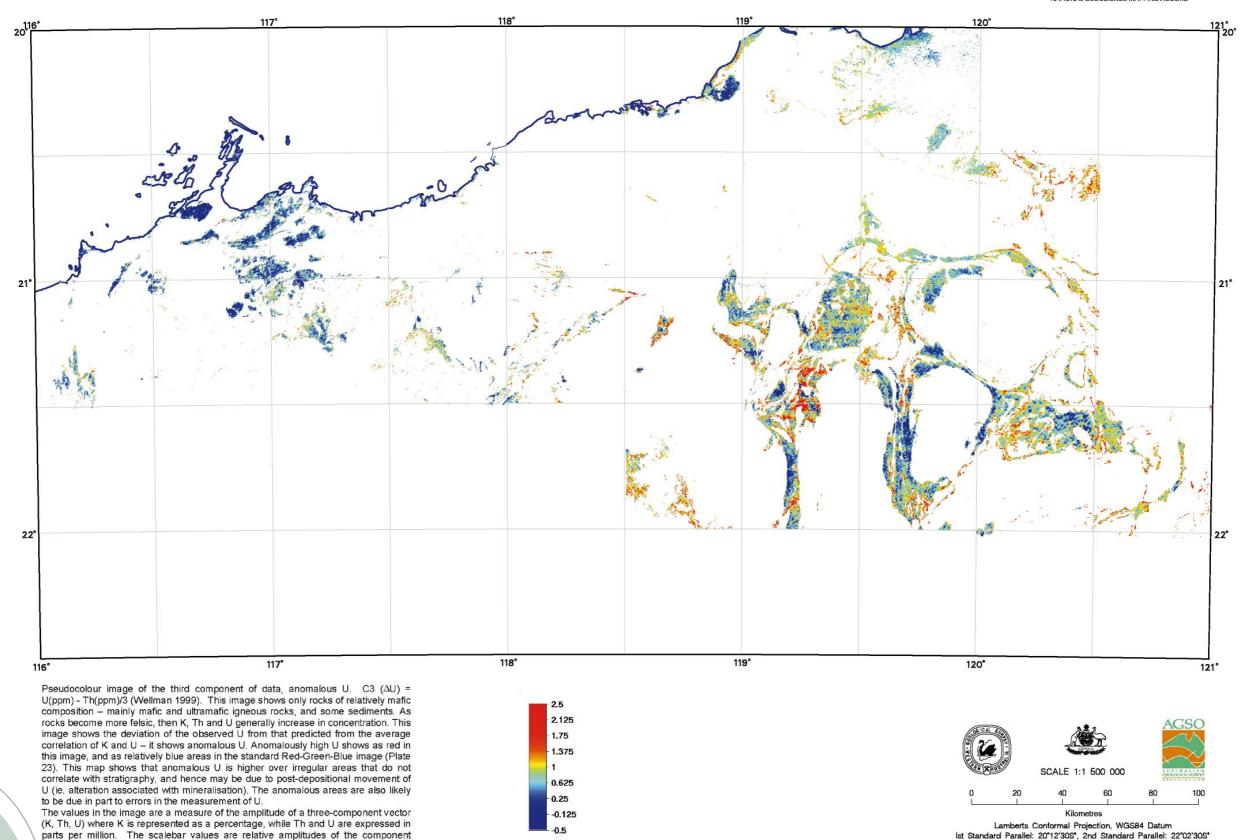
Lamberts Conformal Projection, WGS84 Datum Ist Standard Parallel: 20*12'30S*, 2nd Standard Parallel: 22*02'30S* Central Meridian: 118*30'00E*

GAMMMA - RAY SPECTROMETRIC DATA MAFIC IGNEOUS ROCKS - C3

NORTH PILBARA ATLAS NGMA

NATIONAL GEOSCIENCE MAPPING ACCORD

Central Meridian: 118°30'00E"



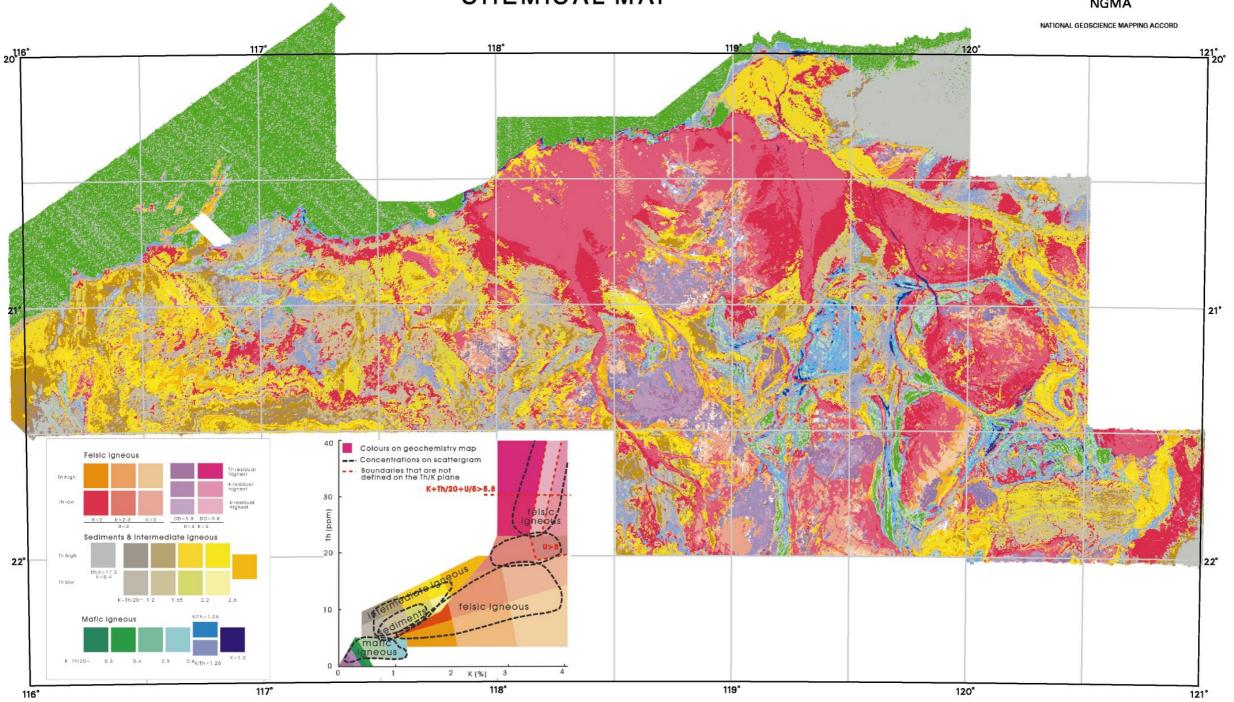
32

described by the equation C3 (ΔU) = U(ppm) - Th(ppm)/3.

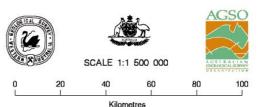


NORTH PILBARA ATLAS

NGMA



This is a simple example of image classification, in this case identifying rocks whose composition forms clumps in K-Th space. Classification uses the absolute values of K and Th in each pixel area to subdivide the rocks into classification types, where each classification type has a finite range of K and Th values – see legend. If this method of image analysis was perfect, then an area of colour on this map should correspond to the polygons in the outcrop geological map. Differences are due to many factors, including the concentrations of K and Th not separating rock types, to transported material in streams and plains, and to smoothing during data preparation.



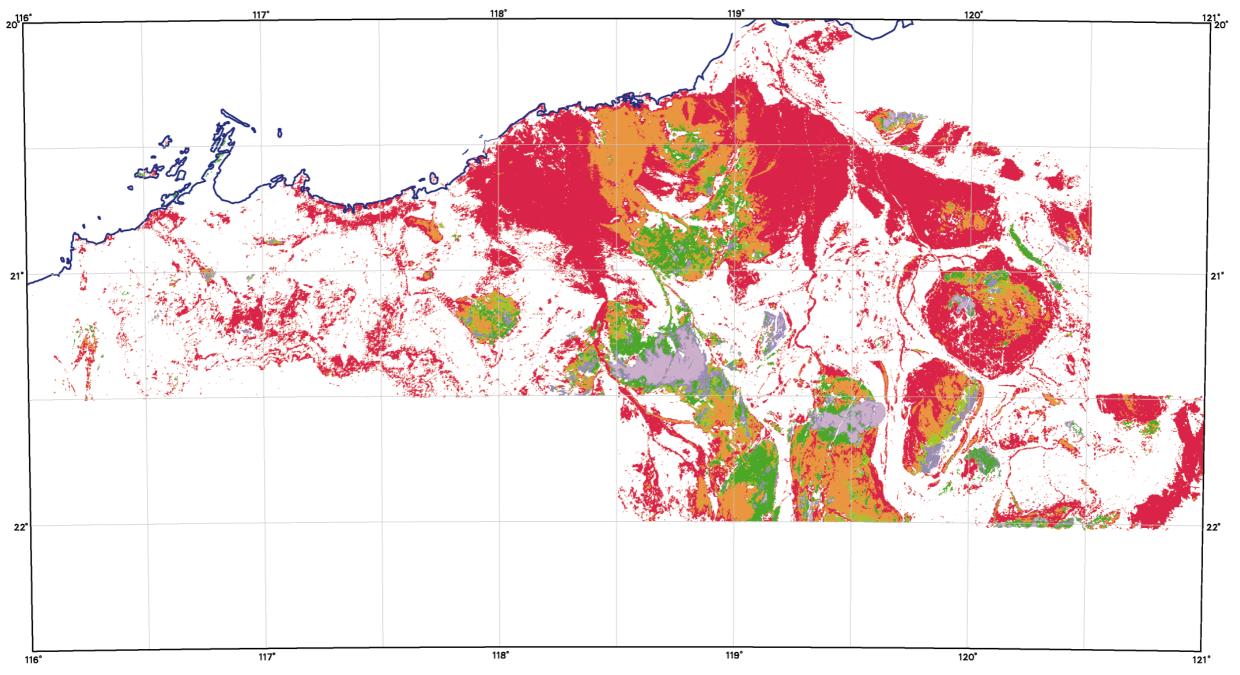
Lamberts Conformal Projection, WGS84 Datum Ist Standard Parallel: 20°12'30S', 2nd Standard Parallel: 22°02'30S' Central Meridian: 118°30'00E*

GAMMA - RAY SPECTROMETRIC DATA FELSIC IGNEOUS ROCKS - TYPES

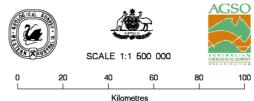
NORTH PILBARA ATLAS

NGMA

NATIONAL GEOSCIENCE MAPPING ACCORD



Spectrometric data classified to try to separate felsic igneous rocks into the three types of Hickman (1983). The more mafic types, Agm of Hickman, with Th < 15 ppm, and U < 3 ppm, are shown in red. The porphyritic types, Agp of Hickman, with Th <23 ppm, are shown in green. The more felsic types, Agc of Hickman, with Th > 23 ppm, are shown in magenta. Within each type, the darker colours give subdivisions with lesser distance along the average differentiation path.



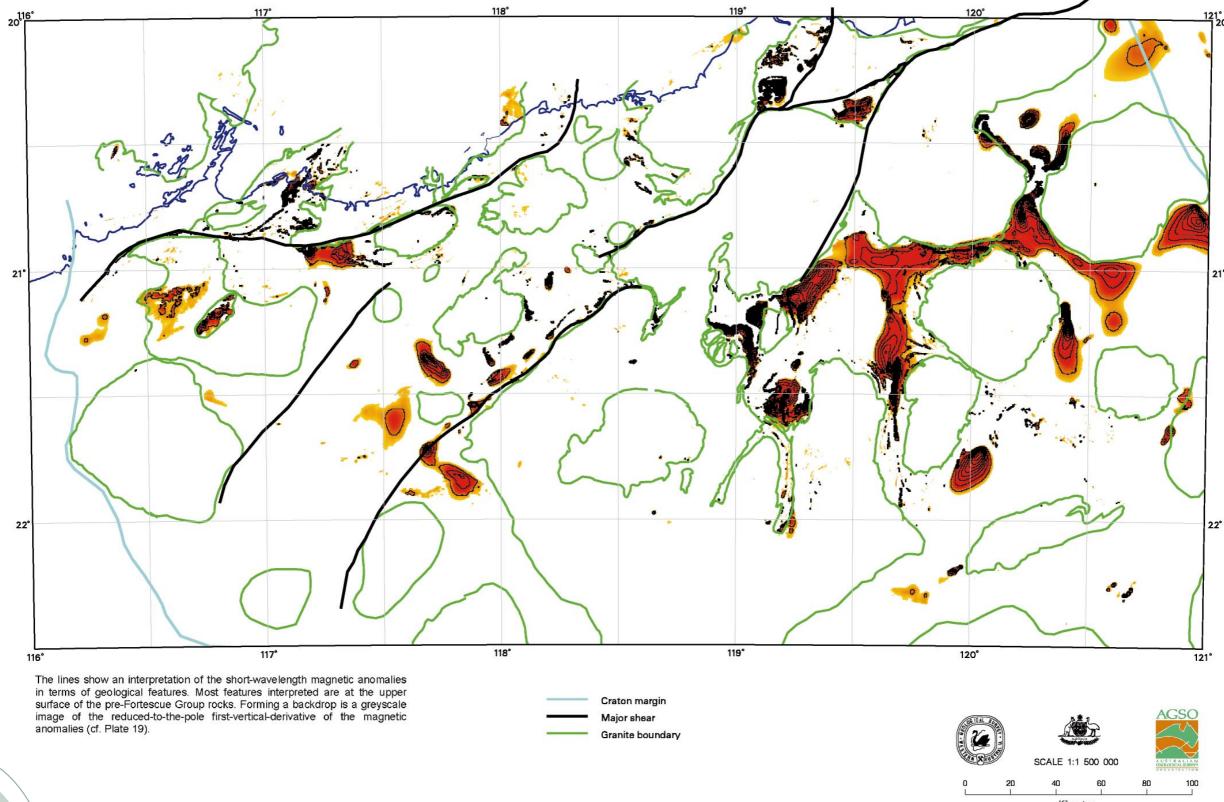
Lamberts Conformal Projection, WGS84 Datum lst Standard Parallel: 20°12'30S', 2nd Standard Parallel: 22°02'30S' Central Meridian: 118°30'00E'

INTERPRETED DEEP MAGNETIC SOURCES

NORTH PILBARA ATLAS

NGMA NATIONAL GEOSCIENCE MAPPING ACCORD

Lamberts Conformal Projection, WGS84 Datum Ist Standard Parallel: 20°12'30S', 2nd Standard Parallel: 22°02'30S' Central Meridian: 118°30'00E'

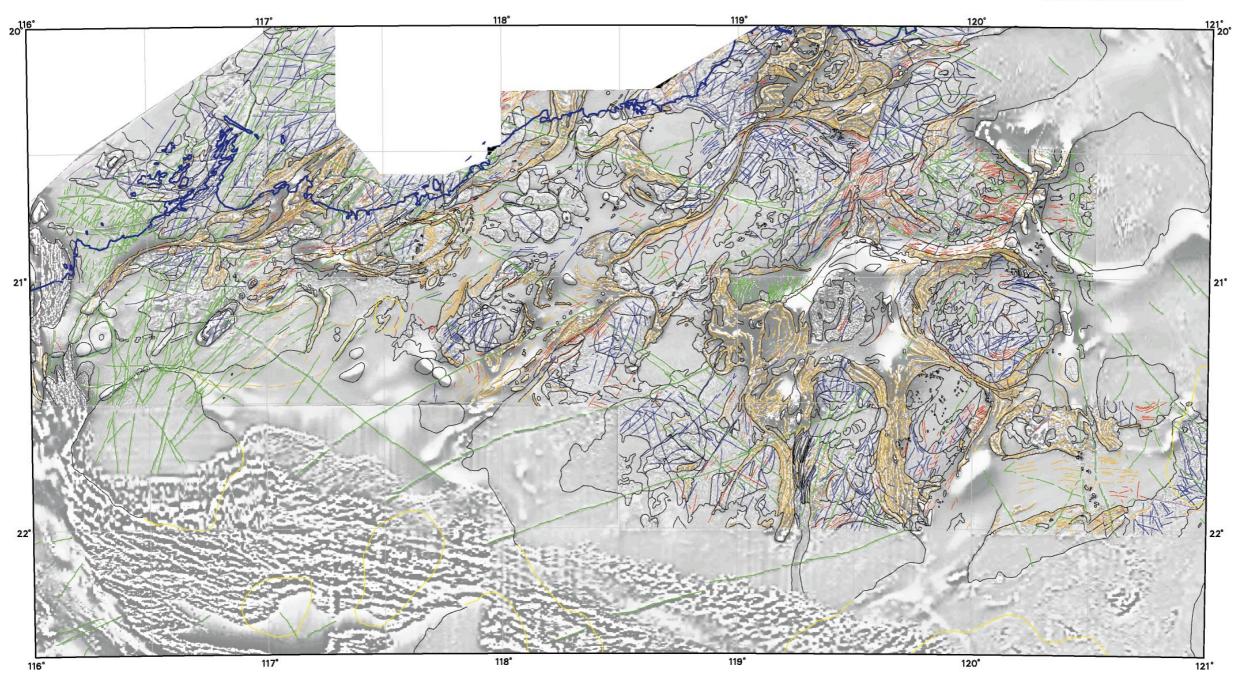


GEOPHYSICAL INTERPRETATION NEAR-SURFACE FEATURES

NORTH PILBARA ATLAS

NGMA

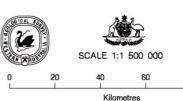
NATIONAL GEOSCIENCE MAPPING ACCORD



The lines show an interpretation of the short-wavelength magnetic anomalies in terms of geological features. Most features interpreted are at the upper surface of the pre-Fortescue Group rocks. Forming a backdrop is a greyscale image of the reduced-to-the-pole first-vertical-derivative of the magnetic anomalies.

Negative fracture
Positive fracture
Fault
Boundary determined from gravity and magnetics
Geophysical trends
Gravity boundary
Dyke

Graticule





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