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MARYBOROUGH, A NEW H5 METEORITE FIND FROM VICTORIA, AUSTRALIA

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ABSTRACT: The Maryborough meteorite is a new H5 ordinary chondrite discovered about 2 km south of Maryborough, Victoria, in May 2015. It is a single stone measuring approximately 39 x 14 x 14 cm and with a mass of 17 kg. Plentiful indistinct chondrules are up to 1 mm across in a strongly recrystallised plagioclase-bearing matrix. Olivine and orthopyroxene in both the matrix and chondrules are uniform in composition ($Fo_{80.1}Fa_{19.3}Te_{0.5}Ca\text{-}ol_{0.04}$ and $En_{81.5}Fs_{17.1}Wo_{1.5}$ respectively).The main metallic phases present are kamacite, taenite and tetrataenite, often forming composite grains with troilite. There is no evidence for any shock-inducing event and the meteorite shows incipient weathering in the form of thin iron-oxide mantles around the Fe–Ni grains. A terrestrial age of less than 1000 years is estimated from C14 dating. While there are a number of historic reported meteor sightings in the Maryborough district, none can be tied to the meteorite's find site. To date, Maryborough is the third H5 ordinary chondrite and the second largest single chondritic mass, after Kulnine (55 kg), found in Victoria.

Keywords: Maryborough, meteorite, find, H5 ordinary chondrite

INTRODUCTION

In May 2015, Mr David Hole discovered a 17 kg single mass of a stony meteorite while fossicking for gold, using a metal detector, in Maryborough Regional Park, Victoria. The meteorite was found on the surface, resting on a yellowish brown clay, in open box–ironbark forest. The recovery site (latitude 37º 05' 21" S and longitude 143º 44' 32" E) is adjacent to Wells Track, approximately 2 km south of the town of Maryborough, which gives its name to the meteorite (Figures 1 and 2). In 2018, Mr Hole brought the specimen to Museums Victoria for identification. After weighing, photography and moulding, a portion of the meteorite was sliced from one end, providing material for thin-sectioning and density determination. After investigation confirmed the meteorite to be an H5 ordinary chondrite, it was purchased from Mr Hole and is now in the Museums Victoria collection. The main mass is now 15.9 kg and is registered as E19297; a slab of 680 g is registered as E19296. The name and data for classification were approved by the Nomenclature Committee of the Meteoritical Society in December 2018.

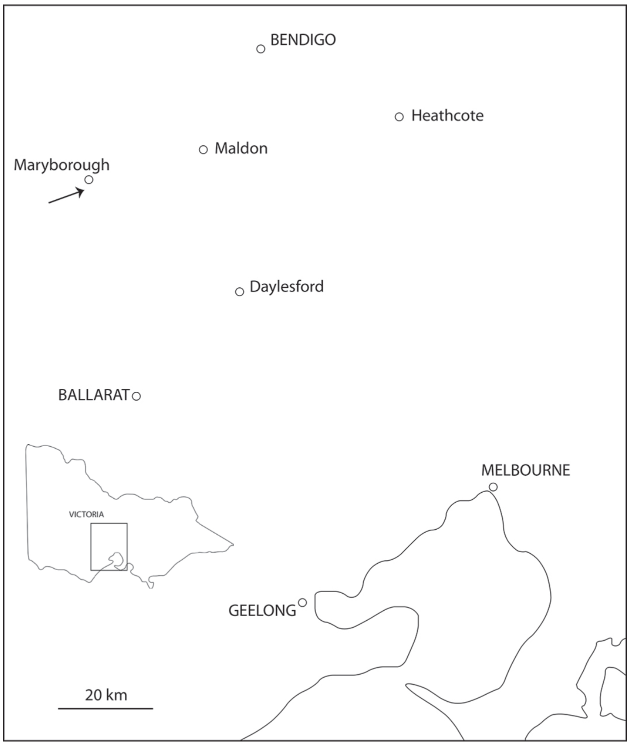

Figure 1: Locality map (map of Victoria inset).

Figure 2: The finder, David Hole, at the approximate site of the discovery of the Maryborough meteorite.

GEOLOGY OF THE SITE

The bedrock in the region consists of weathered and folded Ordovician sedimentary rocks that host gold-bearing quartz reefs, exploited mainly during the nineteenth century. Bedrock is generally not exposed in the vicinity of the discovery site, but pieces of white reef quartz occur in the soil, which is pale yellowish and clayey. There was no evidence for the meteorite leaving an impact, and no further pieces had been found in the vicinity at the time of writing.

APPEARANCE

The specimen is elongated and has a distorted five-sided cross-section, with overall dimensions of 38.5 x 14.5 x 14.5 cm (Figure 3). Two of the longer surfaces are relatively flat, and only one surface, which is slightly concave, appears to show broad shallow regmaglypts. Most of the other surfaces have been scarred by shallow holes drilled with a titanium bit and by grooves cut with an angle grinder by the finder. All surfaces are coloured reddish brown by a patina of iron oxides but there is no clear evidence for a fusion crust. The finder reported he had soaked the meteorite in acid for some time, but it is not clear what effect this has had on the original surface features of the meteorite.

Figure 3: The Maryborough meteorite prior to cutting. Museums Victoria specimen E19297.

The 680 g slab was used to determine the meteorite's density of 3.32 gcm^{-3} and to inspect the general texture. The cut surface shows evidence of internal rusting, but with a high content of preserved bright metal grains up to 1 mm across and uniformly distributed (Figure 4). No larger inclusions are evident and chondrules are only vaguely distinguishable.

PETROGRAPHY AND MINERALOGY

In thin section, the Maryborough meteorite shows plentiful chondrules up to 1 mm across. Chondrule edges are indistinct, matrix and chondrule mesostases are strongly recrystallised, and plagioclase grains are up to 50 µm across but mostly less than 20 µm. Discernible chondrule varieties include RP, BO, PO, PP and POP (Figure 5). Olivine has sharp optical extinction, and there are irregular fractures and no melt pockets. About 20% of the metal has been destroyed by rusting, mostly by replacement of the rims of individual grains, whereas most troilite has been preserved (Figure 6).

Figure 4: The slab cut from the main mass showing the general texture of the meteorite, in particular the distribution of metallic minerals. Slab is 15 cm long. Museums Victoria specimen E19296.

Microprobe analyses of the main minerals were obtained on a Cameca SX50 instrument, with beam conditions of 15 kV and 25 nA, and with appropriate standards. The results (Table 1) show uniform olivine compositions in the matrix and the chondrules, with an average of 24 analyses giving a formula of $Fo_{80.1}Fa_{19.3}Te_{0.5}Ca\text{-}ol_{0.04}$. Orthopyroxene is similarly uniform, and an average of 27 analyses gave $En_{81.5}Fs_{17.1}Wo_{1.5}$. Grains of chromite are relatively common but were not analysed (Figure 7). No clinopyroxene was detected and plagioclase in the groundmass was not analysed.

The main metallic minerals in the meteorite are kamacite, taenite, tetrataenite and troilite, together constituting around 30% of the stone. All occur as irregular

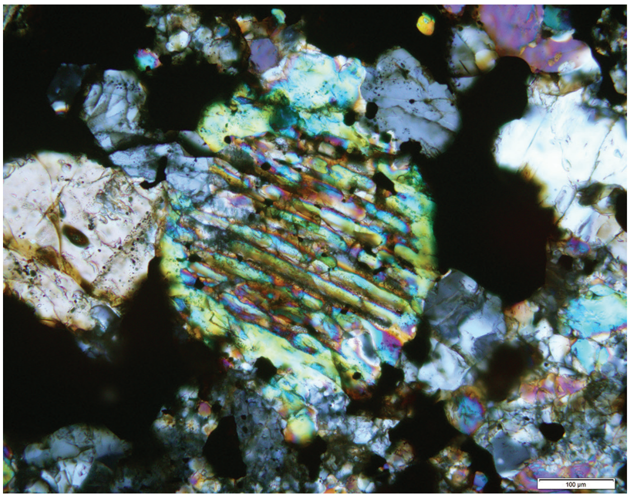

Figure 5a: Barred olivine (BO) chondrule 1 mm across (thin-section image with cross-polarised light).

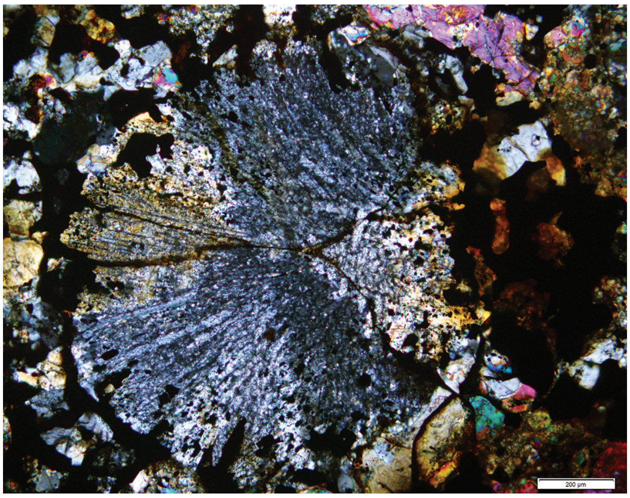

Figure 5b: Radial pyroxene (RP) chondrule 0.4 mm across (thin-section image with cross-polarised light).

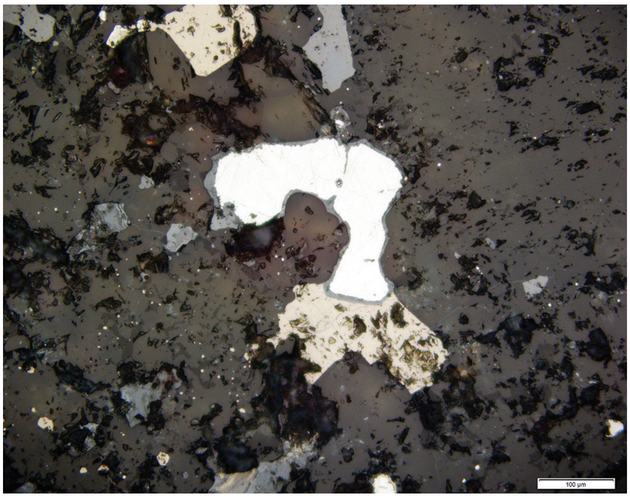

Figure 6: Reflected light image showing composite grain of taenite (bright white) and troilite (pale buff). Note the thin oxidation rim (grey) around the taenite, which is 0.25 mm across.

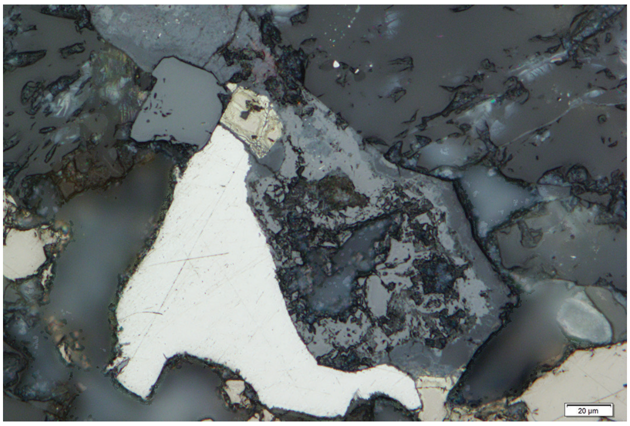

Figure 7: Squarish equant chromite grain (mid-grey) to the left of, and in contact with, a junction between white FeNi metal and pale buff troilite. Chromite grain is 0.04 mm across.

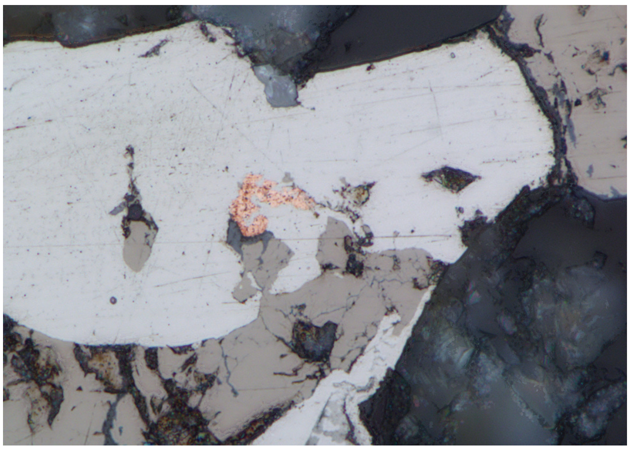

Figure 8:Grains of copper (bright yellow–orange) enclosed in FeNi metal (bright white), adjacent to troilite (pale buff). Copper is 20 microns across.

grains up to about 1 mm across. Composite kamacite–taenite–tetrataenite grains are usually mantled by iron oxide. Microprobe analyses show quite uniform kamacite compositions averaging 93.0% Fe, 6.5% Ni and 0.6% Co. Taenite is more variable, grading into tetrataenite with a composition ranging between $Fe_{66.4}Ni_{34.2}$ and $Fe_{50.1}Ni_{48.9}$. A few grains of native copper were also detected (Figure 8).

CLASSIFICATION AND AGE

A number of criteria clearly define Maryborough as an ordinary chondrite, Type H. The fayalite (Fa) content of olivine and the ferrosilite (Fs) content of orthopyroxene fall within those expected for the field of H chondrites (Mason 1963; Brearley & Jones 1998). The somewhat indistinct nature of the chondrules is typical of Type 5, as are the CaO contents of orthopyroxene (Scott et al. 1986). The absence of features attributable to shock, such as undulose extinction and planar fractures in olivine, indicate that the meteorite was not affected by any significant shock-inducing event, so its rating on the scale of shock metamorphism is S1 (Stöffler et al. 1991). The presence of veinlets and mantles of iron oxides around metal grains suggest a rating of W1 on the weathering scale of Wlotzka (1993).

Table 1: Microprobe analyses of minerals in the Maryborough meteorite.

Wt%	1	2	Wt%	3	4	5	6
SiO_2	38.13	54.83	Fe	94.10	66.36	50.13	63.73
TiO_2	0.01	0.18	Ni	6.55	34.17	48.94	0.35
Al_2O_3	0.02	0.17	Co	0.59	0.20	0.24	0.06
Cr_2O_3	0.02	0.15	Cr	0.00	0.02	0.01	0.01
Fe_2O_3	2.32	2.66	S	0.00	0.00	0.03	35.91
FeO	16.17	9.13	Total	101.24	100.8	99.35	100.1
MnO	0.48	0.51					
MgO	42.4	30.84					
CaO	0.03	0.77					
Na_2O	_	0.02					
K_2O	_	_					
Total	99.58	99.26					
			Formulae*				
Si	0.977	1.955	Fe	93.0	65.9	50.5	1.02
Ti	0.000	0.005	Ni	6.5	33.9	49.3	0.005
Al	0.001	0.007	Co	0.6	0.2	0.2	0.00
Cr	0.000	0.004	Cr	0.0	0.0	0.0	0.00
Fe^{3+}	0.045	0.071	S	0	0	0	1.00
Fe^{2+}	0.346	0.272					
Mn	0.010	0.015					
Mg	1.620	1.639					
Ca	0.001	0.029					
Na	_	0.002					
Total	3.000	4.000					
	Te=0.52	Wo=1.46					
	Fo=80.10	En=81.47					
	Fa=19.34	Fs=17.07					
	Ca-ol=0.04						

1 Average olivine (n=24) (Fe^{3+} calculated from charge balance)
2 Average orthopyroxene (n=27) (Fe^{3+} calculated from charge balance)
3 Average kamacite
4 Representative taenite analysis
5 Tetrataenite analysis
6 Average troilite (n-11)
* Formulae for olivine and orthopyroxene based on 3.000 and 4.000 total cations respectively.
Formulae for metals normalised to 100% Fe+Ni+Co+Cr.
Troilite formula based on S=1.00

Table 2: Historical newspaper reports of meteor sightings in the Maryborough district.

***The Herald* (Tuesday 20 August 1889)**
Strange Aerial Phenomenon (By wire – from our own correspondent, Maryborough, Tuesday)
A strange aerial phenomenon was witnessed a few evenings since by a number of local residents, who observed a meteor of exceptional magnitude and brilliance shooting over the town in a westerly direction. When it reached the Ball Hill, near Carisbrook, it was seen to come in contact with a smaller body passing in an opposite direction, and an explosion and loud reports immediately followed. The report was heard for miles around and, by many, was thought to be indicative of a mild shock of earthquake.

***The Avoca Mail* (Tuesday 27 November 1894)**
A beautiful meteor was seen by local residents to traverse the heavens in a south-westerly direction, shortly before midnight on Sunday. The light caused was most brilliant and made a very pretty sight.

***The Age* (Wednesday 27 July 1898)**
A Brilliant Meteor (Maryborough, Tuesday)
An intensely bright meteor fell here this morning shortly after 2 o'clock. It filled the sky with a most dazzling light for fully a couple of seconds.

***The Age* (Monday 13 May 1901)**
The Comet (Maryborough, Sunday)
An excellent view of the comet was obtainable last night. The two tails visible seemed considerably longer than usual.
A meteor of great brilliance was seen last night, after 9 o'clock, in the northern sky.

***The Ballarat Courier* (Thursday 23 August 1917)**
The Meteor
The meteor which burst across the heavens on Monday night was plainly visible in Maryborough, where it was seen by a number of people. After the intense, vivid light, which lit up the surroundings with great brilliance, had disappeared, the two phosphorescent clouds remained for some minutes then gradually faded.

***The Argus* (Saturday 9 June 1923)**
A Brilliant Meteor
To the Editor of *The Argus*
Sir — While travelling towards Harcourt (i.e. north) last night (Tuesday) at between 25 minutes and 20 minutes to 8 o'clock, I witnessed a meteor coming towards the earth. It first appeared as a falling star in the NN-east sky, and going towards the WS-west. When it seemed to be over a place about a quarter to half a mile away, it suddenly burst into flames, and lit up the whole countryside, at the same time swerving more towards the west. So bright was it that, not having any light, it almost dazzled me, and horses out in the paddocks neighed such a neigh of fear that I will never forget it. It was a brilliant display of colours and was visible for fully half a minute. Perhaps somebody else has seen this meteor and knows where it has fallen. — Yours etc.
Harry E. Hallett
Barkers Creek, June 6

***The Argus* (Wednesday 20 June 1923)**
A Brilliant Meteor
To the Editor of *The Argus*
Sir — Referring to the letter of Mr Harry E Hallett, Barkers Creek, dated June 6, I wish to say that we saw the meteorite on Tuesday evening, June 5, about 23 minutes to 8 o'clock at Carisbrook; it was also seen at Maryborough.
Yours etc.
Cecille F Bucknall, Louise Robson
Hampstead, Carisbrook, June 15

***The Age* (Wednesday 6 June 1951)**
Meteor Lights Central Town
Maryborough, Tuesday.
A brilliant meteor lit the countryside here shortly after 11 o'clock tonight. It flashed over the town in a north-easterly direction and then seemed to burst into several parts.
Some late home-goers were badly frightened.

The approximate terrestrial age of the meteorite was determined by C14 radiometric methods (Jull 2006) at the University of Arizona's Accelerator Mass Spectrometer laboratory. A calculated 14C saturation activity of about 83+-1.5 dpm/kg gave rise to an estimation of a fall sometime in the last 1000 years. The general unweathered appearance of the meteorite suggests a fall at the lower end of that range, making it possible that it was observed historically. There are a number of historic sightings of meteor phenomena reported in newspapers between the late nineteenth and mid-twentieth centuries (Table 2), but none provides any clear observations that can be linked to the find site. The area around the find site has been prospected for gold on and off since the late nineteenth century, so if the meteorite was on the surface during those times, it did not attract sufficient curiosity from the miners for them to bring it to scientific attention. Nor is there any evidence for indigenous people interacting with the meteorite prior to European settlement.

CONCLUSIONS

Maryborough is only the seventeenth recorded meteorite from Victoria and the ninth chondrite. Along with Dimboola (Mason 1963) and Pigick (Birch et al. 2001), Maryborough is the third H5 ordinary chondrite and the second largest single chondritic mass, after Kulnine (55 kg), recovered from Victoria (Henry 2003). It is perhaps surprising that more meteorites have not been discovered in central Victoria since the hobby of metal detecting for gold boomed in the 1970s. Museums Victoria encourages all prospectors to bring in unusual rocks for identification.

Acknowledgements

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Conflict of interest

The authors declare no conflicts of interest.

References

Birch, W.D., Samuels, L.E. & Grossman, J.N., 2001. Willow Grove, Rainbow and Pigick: three new meteorite finds in Victoria, Australia. Proceedings of the Royal Society of Victoria 113(2): 247–257.

Brearley, A.J. & Jones, R.H., 1998. Chondritic meteorites. In *Planetary Materials*, J.J. Papike, ed., Reviews in Mineralogy, Vol. 36, Mineralogical Society of America, 3-1-3-398.

Henry, D.A., 2003. Meteorites and tektites. In *Geology of Victoria*, W.D. Birch, ed., pp. 663–670. Geological Society of Australia Special Publication 23. Geological Society of Australia (Victoria Division).

Jull, A.J.T., 2006. Terrestrial ages of meteorites. *In* Laurett, D.S & McSween, H.Y.Jr (Eds). *Meteorites and the Early Solar System II* (Space Science Series). University of Arizona Press. 889–905.

Mason, B., 1963. Olivine compositions in chondrites. *Geochimica et Cosmochimica Acta* 27: 169–188.

Scott, E.R.D., Taylor, G.J. & Keil, K., 1986. Accretion, metamorphism and brecciation of ordinary chondrites: evidence from petrologic studies of meteorites from Roosevelt County, New Mexico. Proceedings of the 17th Lunar and Planetary Science Conference, part 1. *Journal of Geophysical Research*, 91, B13: E115–123.

Stöffler, D., Keil, K. & Scott, E.R.D., 1991. Shock metamorphism of ordinary chondrites. *Geochimica et Cosmochimica Acta*, 55, 3845–3867.

Wlotzka, F., 1993. A weathering scale for the ordinary chondrites (abstract). *Meteoritics & Planetary Science,* 28: 460.