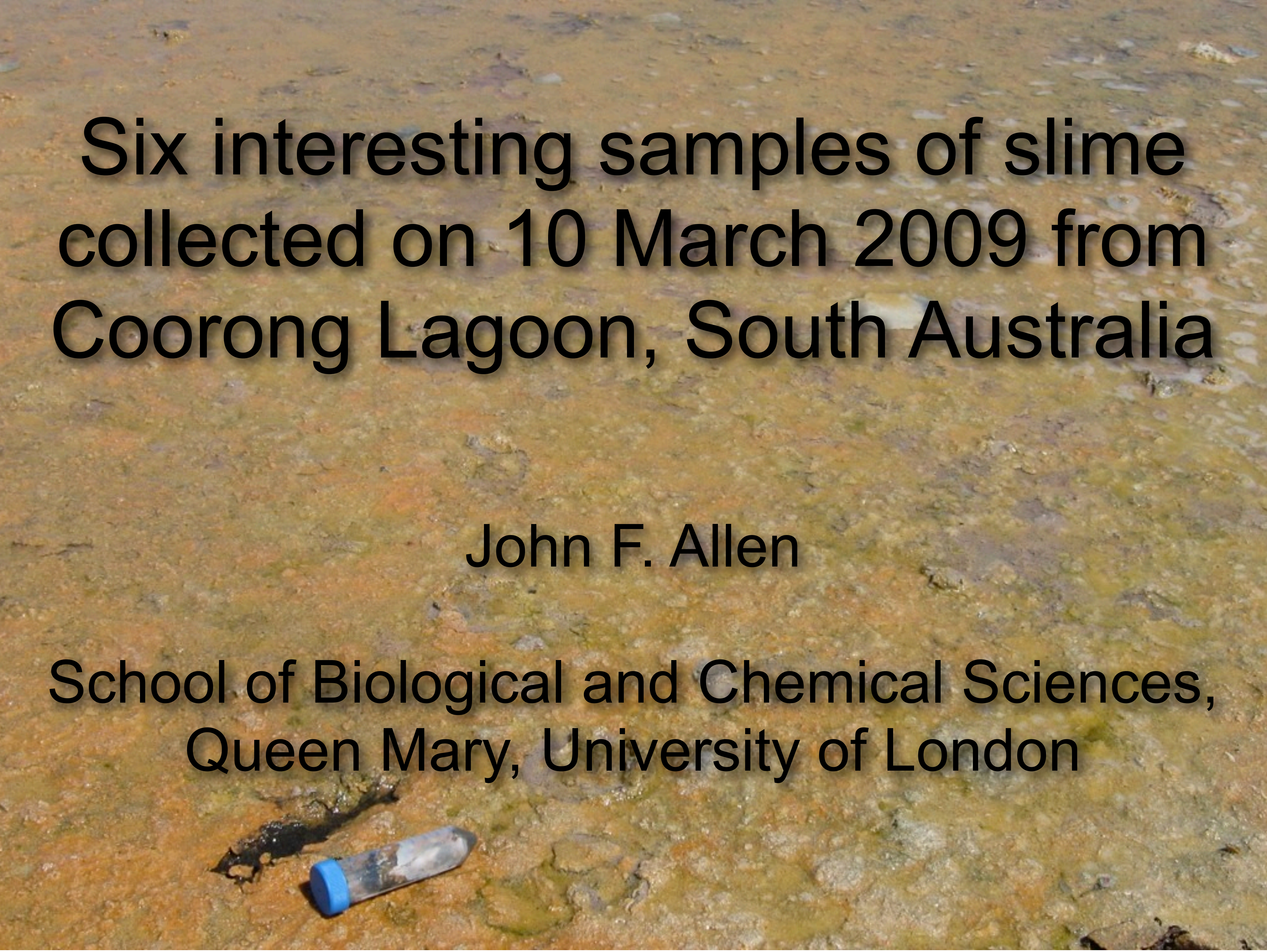

Six interesting samples of slime collected on 10 March 2009 from Coorong Lagoon, South Australia

John F. Allen

School of Biological and Chemical Sciences,
Queen Mary, University of London

On the Origin of

Photosynthesis

6 MARCH 2009 VOL 323 **SCIENCE** www.sciencemag.org

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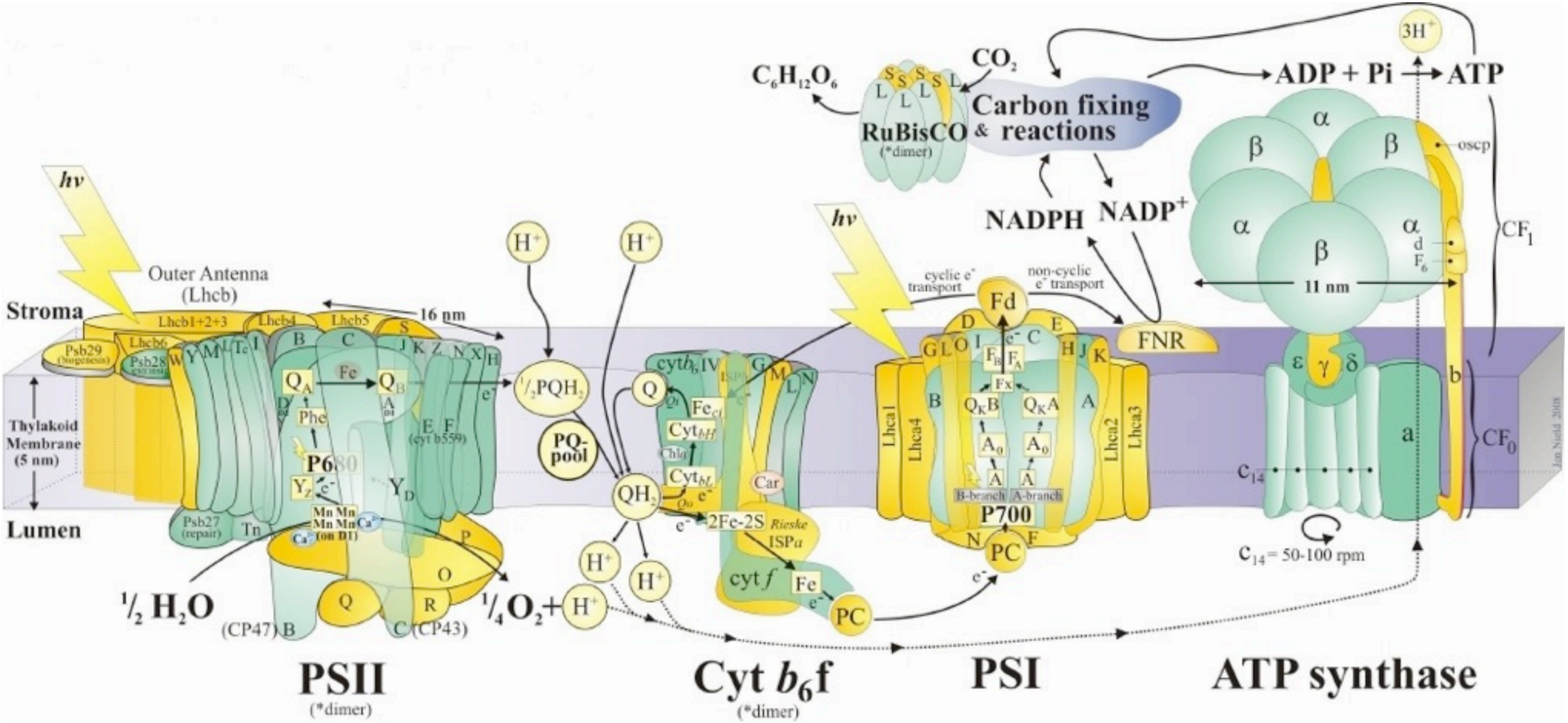
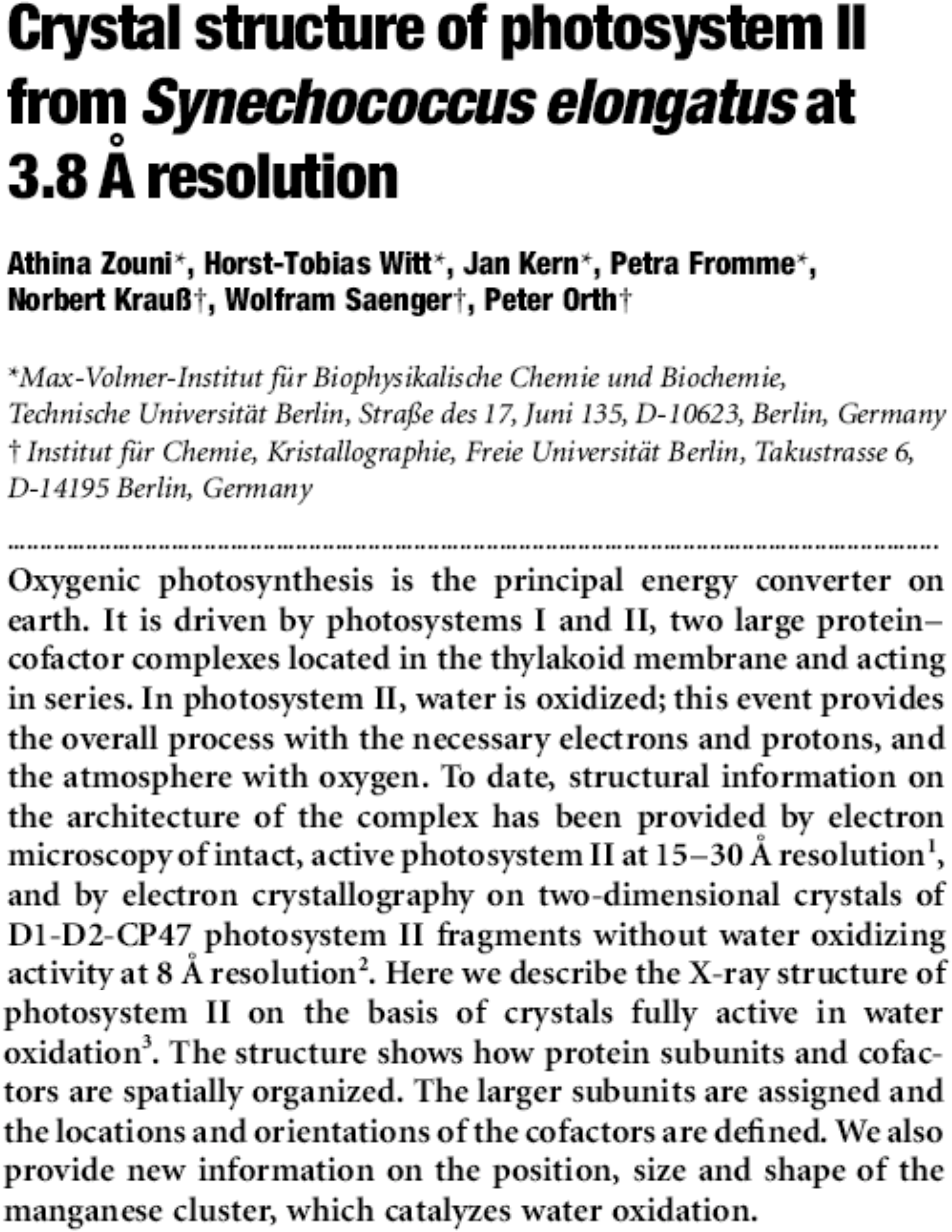
Oxygenic photosynthesis "was the last of the great inventions of microbial metabolism, and it changed the planetary environment forever."

—Paul Falkowski, Rutgers University



A molecular phylogenetic map of the photosynthetic membrane

Diagram by Jon Nield, Queen Mary, University of London



Crystal structure of photosystem II from *Synechococcus elongatus* at 3.8 Å resolution

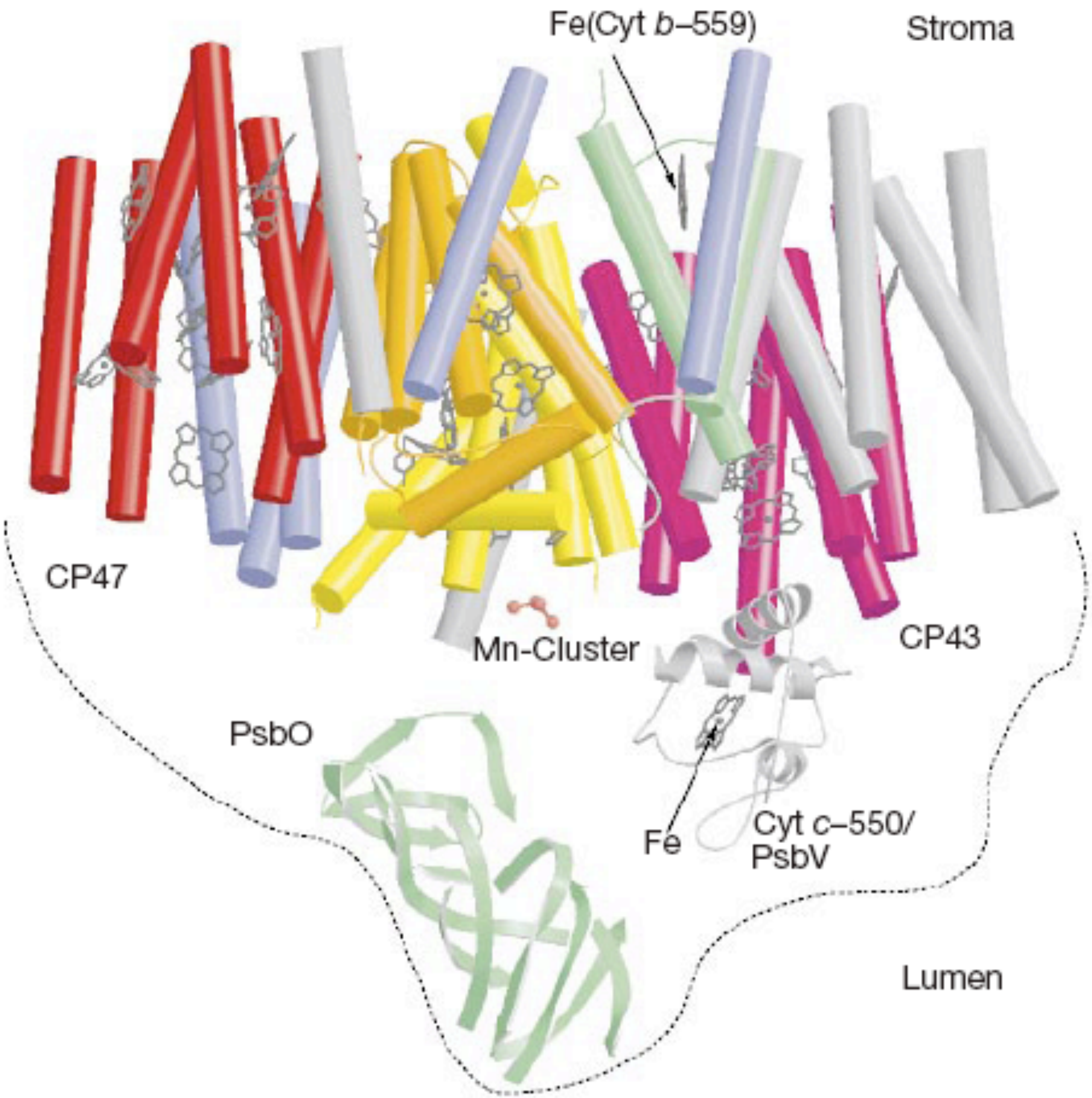
Athina Zouni[*], **Horst-Tobias Witt**[*], **Jan Kern**[*], **Petra Fromme**[*],
Norbert Krauß[†], **Wolfram Saenger**[†], **Peter Orth**[†]

[*] *Max-Volmer-Institut für Biophysikalische Chemie und Biochemie, Technische Universität Berlin, Straße des 17, Juni 135, D-10623, Berlin, Germany*
[†] *Institut für Chemie, Kristallographie, Freie Universität Berlin, Takustrasse 6, D-14195 Berlin, Germany*

……

Oxygenic photosynthesis is the principal energy converter on earth. It is driven by photosystems I and II, two large protein–cofactor complexes located in the thylakoid membrane and acting in series. In photosystem II, water is oxidized; this event provides the overall process with the necessary electrons and protons, and the atmosphere with oxygen. To date, structural information on the architecture of the complex has been provided by electron microscopy of intact, active photosystem II at 15–30 Å resolution[1], and by electron crystallography on two-dimensional crystals of D1-D2-CP47 photosystem II fragments without water oxidizing activity at 8 Å resolution[2]. Here we describe the X-ray structure of photosystem II on the basis of crystals fully active in water oxidation[3]. The structure shows how protein subunits and cofactors are spatially organized. The larger subunits are assigned and the locations and orientations of the cofactors are defined. We also provide new information on the position, size and shape of the manganese cluster, which catalyzes water oxidation.

Nature 409,
739-743
(2001)


Fe(Cyt *b*–559)
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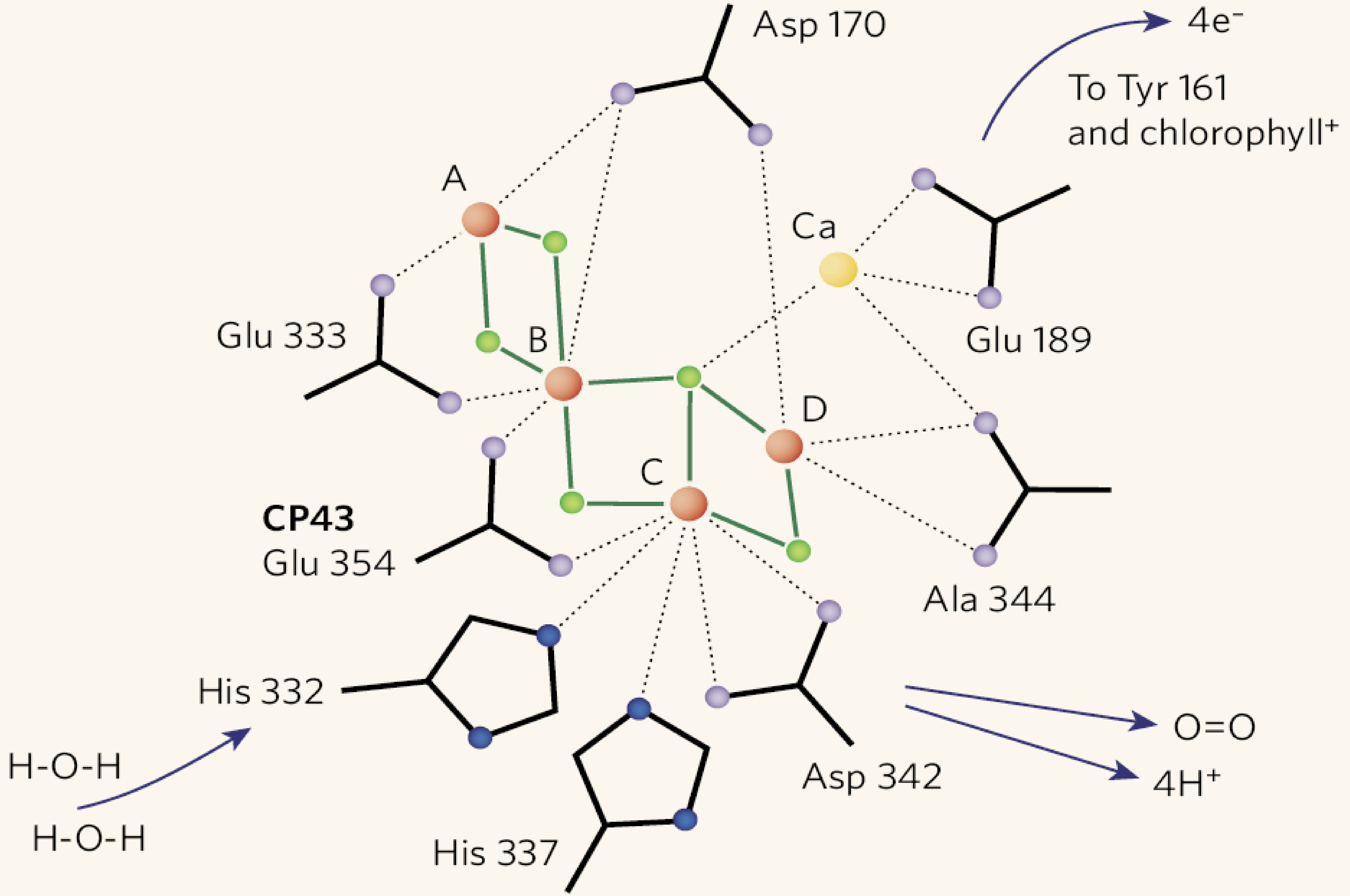
CP47
Mn-Cluster
CP43
PsbO
Fe
Cyt *c*–550/
PsbV
Lumen



The water-splitting complex of photosystem II.

Redrawn (Allen & Martin, Nature **445,** 610–612 (2007)) from Yano, J. *et al. Science* **314,** 821–825 (2006).

Inorganic Complexes Enabled the Onset of Life and Oxygenic Photosynthesis

Michael J. Russell[1], John F. Allen[2], and E. James Milner-White[3]

Abstract Mackinawite ([Fe>>Ni)S]), greigite ($NiS_2[Fe_4S_4]S_2Fe$) and a tunnel manganite ($CaMn_4O_8$) similar in structure to hollandite were minerals that enabled the onset of chemosynthesis and, later, of oxygenic photosynthesis – the two events to make the greatest impact at the surface of our planet. The inorganic complexes contributing to the growth of such minerals – ($[FeS_2Fe]4H_2O$; $[Fe_4S_4]^{2+/1+}$; $[Fe_3S_4]^{+1/0}$; $NiFe_5S_8$, $CaMn_4O_8$ as well as $HP_2O_7^{3-}$) – were later sequestered by small organic molecules (initially polypeptides or carboxylate groups) to become active centres of the enzyme precursors that initially catalyzed the primary reactions of energy conversion and nutrient cycling. Examples of such adventitious cooptions were to produce (i) pyrophosphate 'eggs' in successive main chain NH peptide nests; (ii) protoferredoxins as thiolated metal sulfide eggs in peptide nests; (iii) precursors to carbon monoxide dehydrogenase (CODH)/acetyl CoA synthetase (ACS) as a Ni-peptide and a thiolated egg in a peptide nest and (iv) the precursor to the active centre of the OEC by periplasmic carboxylates and hydroxyls adjacent to RC II in a protocyanobacterium.

Keywords Greigite, hollandite, mackinawite, origin of life, oxygen evolving complex

Introduction

Autogenic life emerged as the most effective way to discharge geochemical energy on the early Earth. The steepest chemical and electrochemical gradients obtained where alkaline hydrothermal spring waters at ≤120°C, issued into a cool Hadean ocean. This is where CO_2 in the acidulous ocean reacted with hydrothermal hydrogen and ammonia in reactions catalysed by pyrophosphate and trace metal sulfides. The strong chemical and physical gradients focussed at the surfaces of the hydrothermal mound thereby drove the acetyl-CoA pathway into existence. Acetate (joined later by methane) was the effluent produced during biosynthesis. These first microbes were to evolve into the acetogenic

---

[1] Jet Propulsion Laboratory, California Institute of Technology, CA91109, USA
[2] Biological & Chemical Sciences, Queen Mary, University of London, E1 4NS, London
[3] Institute of Biomedical and Life Sciences, University of Glasgow, G12 8QQ, Scotland, UK

J.F. Allen, E. Gantt, J.H. Golbeck, and B. Osmond (eds.),
Photosynthesis. Energy from the Sun:
14th International Congress on Photosynthesis,
1187–1192. © 2008 *Springer.*

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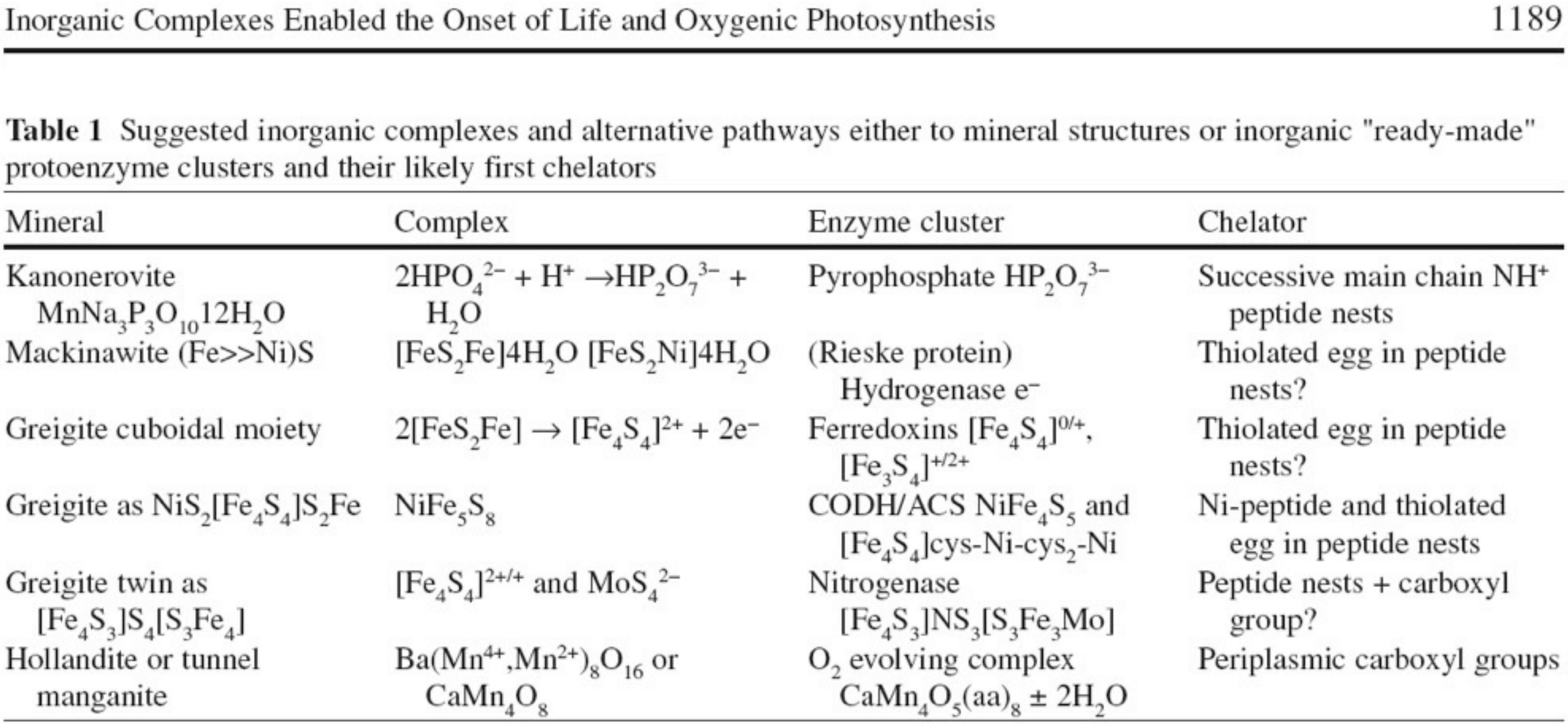


Table 1 Suggested inorganic complexes and alternative pathways either to mineral structures or inorganic "ready-made" protoenzyme clusters and their likely first chelators

Mineral	Complex	Enzyme cluster	Chelator
Kanonerovite $MnNa_3P_3O_{10}12H_2O$	$2HPO_4^{2-} + H^+ \rightarrow HP_2O_7^{3-} + H_2O$	Pyrophosphate $HP_2O_7^{3-}$	Successive main chain NH^+ peptide nests
Mackinawite (Fe>>Ni)S	$[FeS_2Fe]4H_2O$ $[FeS_2Ni]4H_2O$	(Rieske protein) Hydrogenase e^-	Thiolated egg in peptide nests?
Greigite cuboidal moiety	$2[FeS_2Fe] \rightarrow [Fe_4S_4]^{2+} + 2e^-$	Ferredoxins $[Fe_4S_4]^{0/+}$, $[Fe_3S_4]^{+/2+}$	Thiolated egg in peptide nests?
Greigite as $NiS_2[Fe_4S_4]S_2Fe$	$NiFe_5S_8$	CODH/ACS $NiFe_4S_5$ and $[Fe_4S_4]$cys-Ni-cys$_2$-Ni	Ni-peptide and thiolated egg in peptide nests
Greigite twin as $[Fe_4S_3]S_4[S_3Fe_4]$	$[Fe_4S_4]^{2+/+}$ and MoS_4^{2-}	Nitrogenase $[Fe_4S_3]NS_3[S_3Fe_3Mo]$	Peptide nests + carboxyl group?
Hollandite or tunnel manganite	$Ba(Mn^{4+},Mn^{2+})_8O_{16}$ or $CaMn_4O_8$	O_2 evolving complex $CaMn_4O_5(aa)_8 \pm 2H_2O$	Periplasmic carboxyl groups

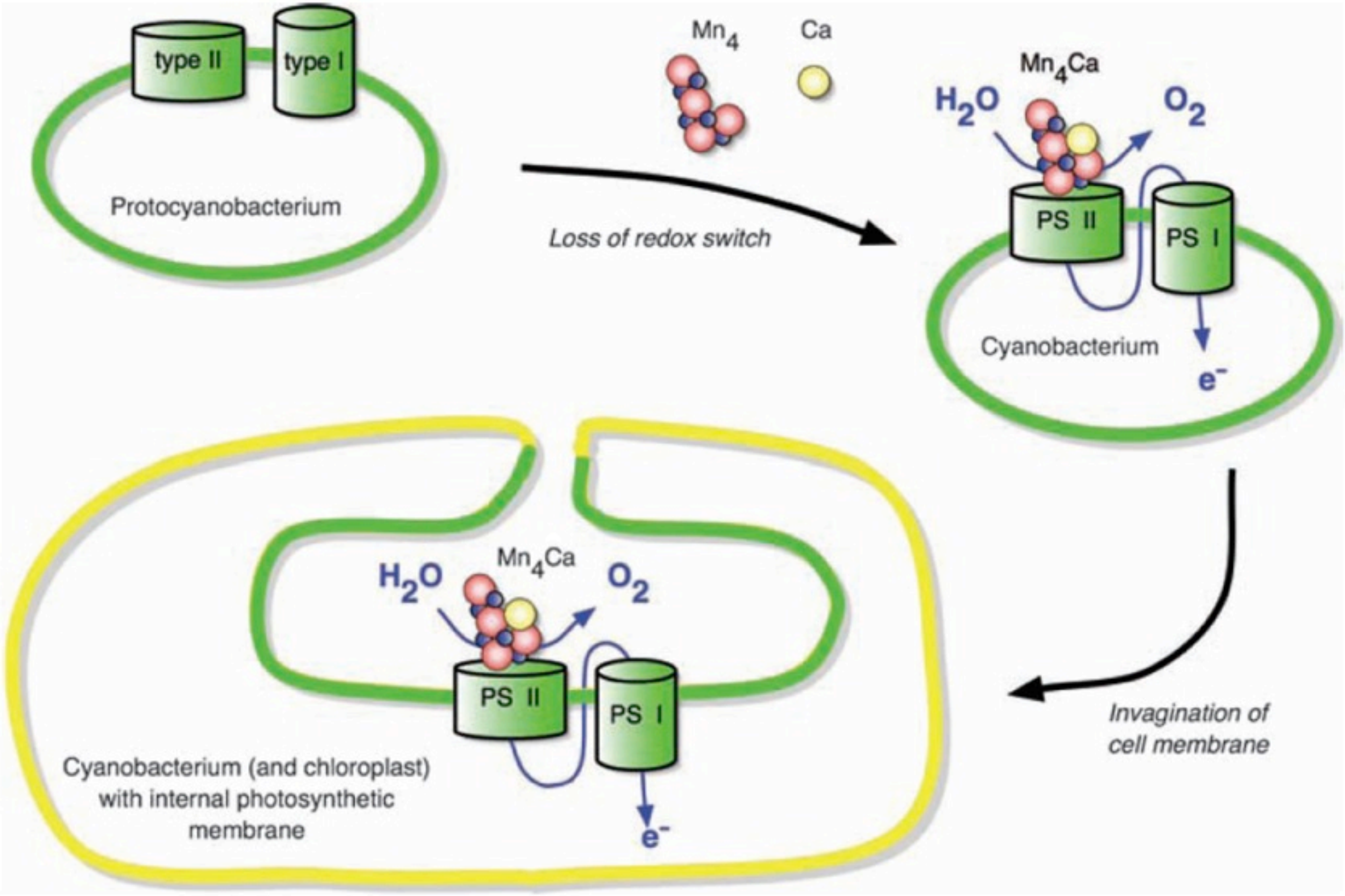
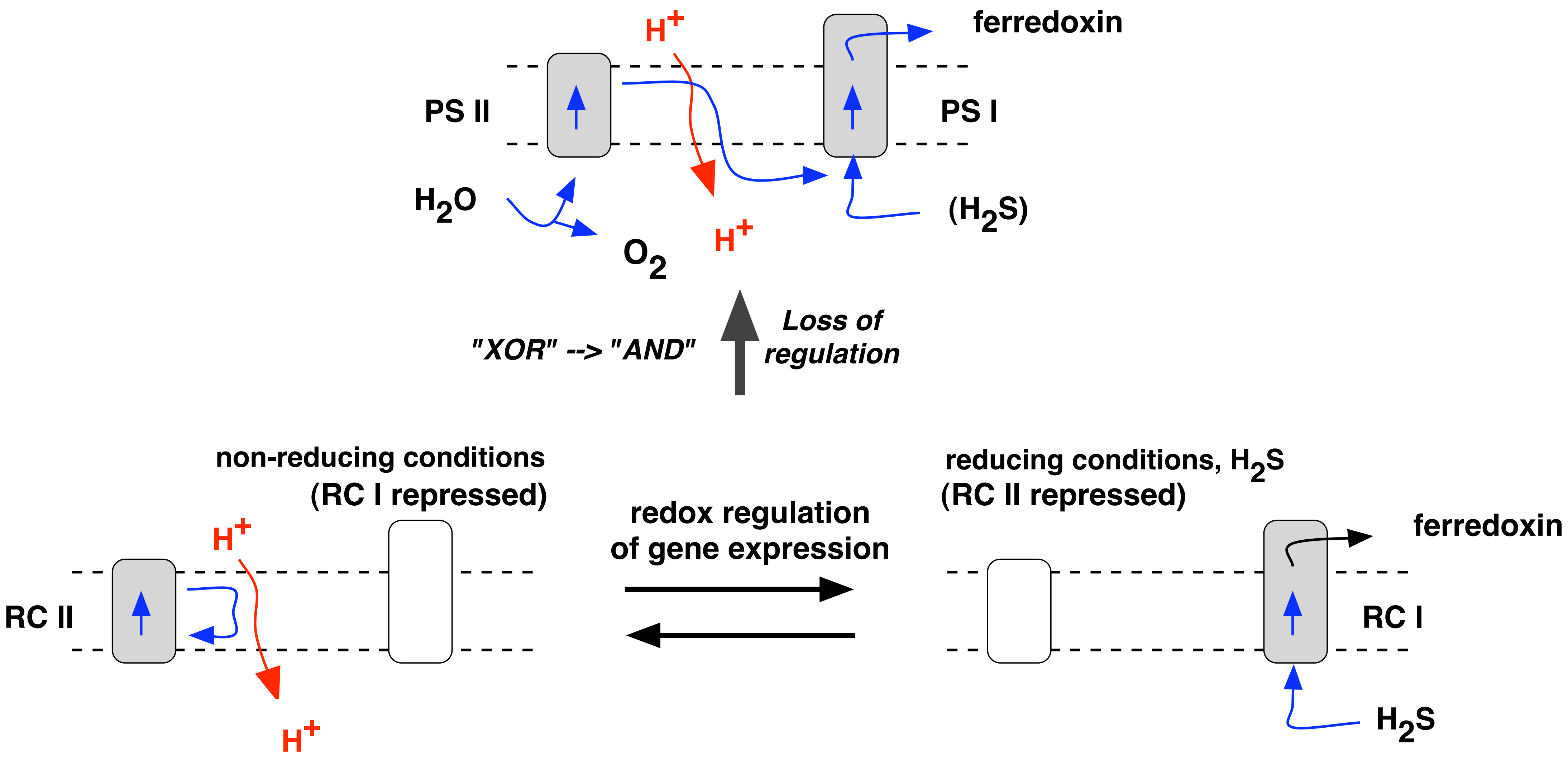


Fig. 2 Adventitious acquisition of a mineral, water-oxidising, Mn_4Ca catalyst at the external, donor side of a membrane-intrinsic Type II photosynthetic reaction centre; connection of type I and type II centres in oxygenic photosynthesis; and internalisation of the water-oxidising catalyst with the evolving topology of photosynthetic membranes



PS II

PS I

H^+

ferredoxin

H_2O

O_2

H^+

(H_2S)

"XOR" --> "AND"

Loss of regulation

non-reducing conditions
(RC I repressed)

redox regulation
of gene expression

reducing conditions, H_2S
(RC II repressed)

RC II

H^+

H^+

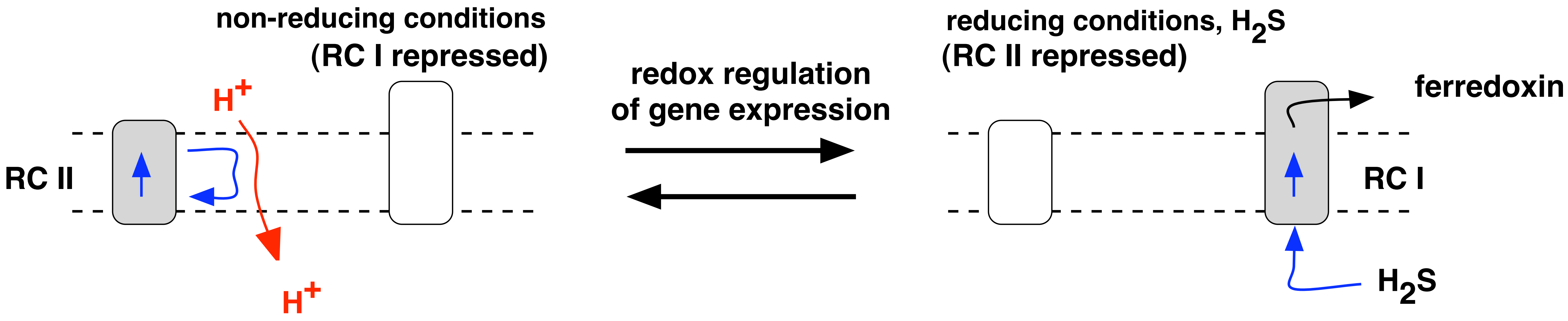
ferredoxin

RC I

H_2S

Allen, J.F. A redox switch hypothesis for the origin of two light reactions in photosynthesis. FEBS Letters 579 (2005) 963–968

Heteronuclear, Anoxygenic Phototroph



Where is **HAP**?

FACIES	41	1-14	Pl. 1-4	3 Figs.	--	ERLANGEN 1999

Microbial Mats Associated with Bryozoans (Coorong Lagoon, South Australia)

Katarzyna A. **Palinska**, Paris, Joachim **Scholz***, Hamburg, Katja **Sterflinger**, Oldenburg,
Gisela **Gerdes**, Wilhelmshaven and Yvonne **Bone**, Adelaide

KEYWORDS: BRYOZOANS – STROMATOLITES – BRYOSTROMATOLITES – CYANOBACTERIA – MARINE FUNGI – MICROBIAL MATS – AUSTRALIA – RECENT

SUMMARY

Bryostromatolites are laminated carbonate rocks composed of bryozoan zoarial laminae. The laminated texture is frequently caused by patterns of bryozoan self overgrowth as a regular defensive tactic against microbial fouling. In the Coorong Lagoon (South Australia), another type of bryostromatolite is present where the laminated growth of the weakly calcifying bryozoan species *Conopeum aciculata* is postmortally stabilized by cyanobacterial mats at the surface, and fungal mats settling in the zooecial cavities.

A tough extracellular slime network produced by benthic cyanobacteria is a trap for sediment particles, provides a method of adhesion to the bryozoan substrate, and produces a biological lamination by the vertical stratification of dead bryozoan skeletons. These slimes are also important for the preservation of cell structures and for their fossilization.

Seasonal fluctuations in salinity and water level are the most important regional control factors, causing a phase displacement in the growth optima of microbial mats and bryozoans, thereby resulting in a rigid bryostromatolitic fabric.

1 INTRODUCTION

1.1 Geological and hydrological setting

Holocene linear lagoons are common along the southern and south-western Australian margin. These coast-parallel lagoons are relicts of marine environments from the maximum sea-level high some 6 Ka ago. They have been trapped by the accumulation of sea-ward facing aeolian barrier dunes as sea-level adjusted to its 2 m lower present level. These interdunal corridors are the latest in a series that have formed throughout the Quaternary as a response to a frequently fluctuating sea-level.

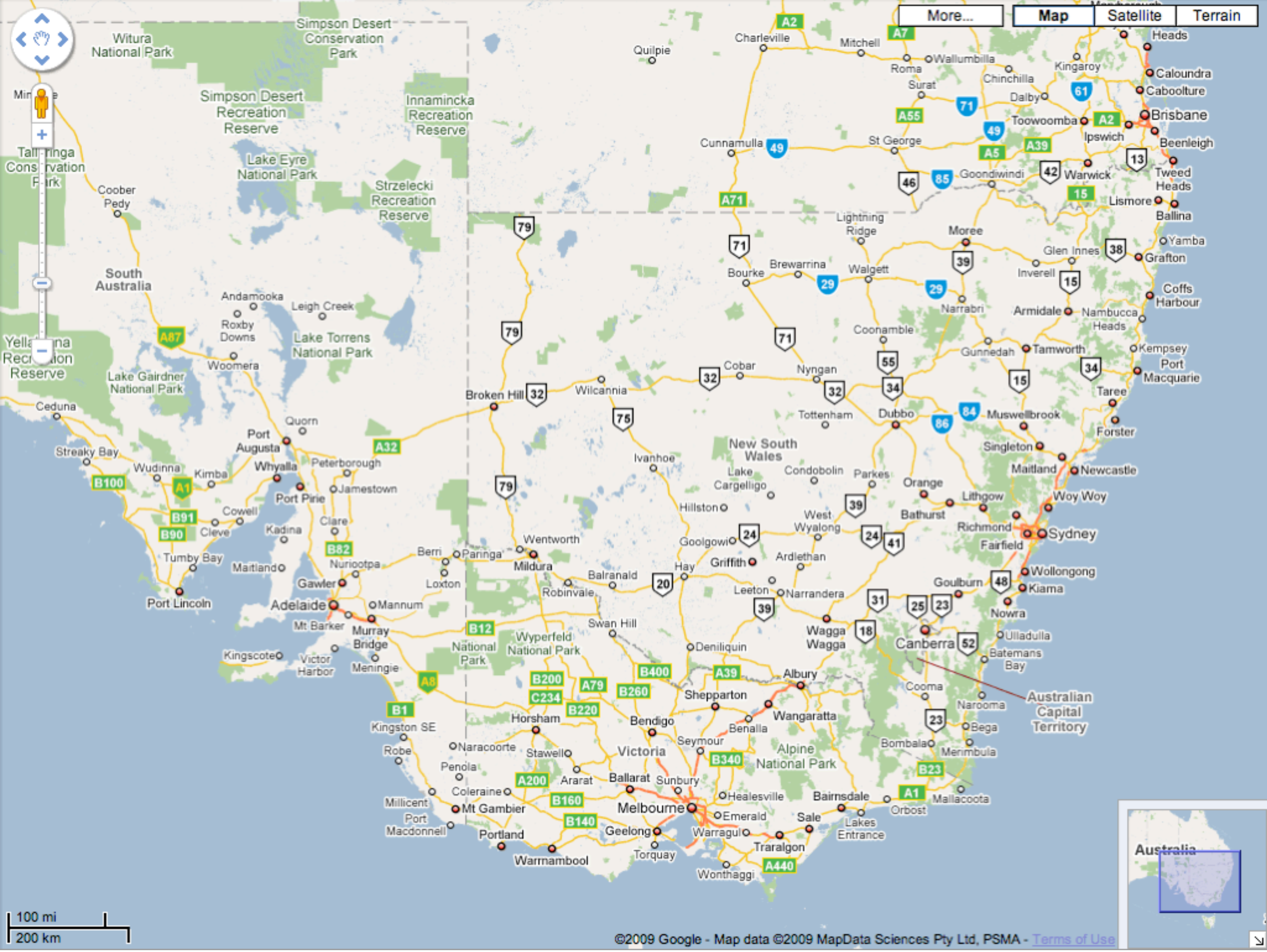
The arid environment is one of hot, dry summers and cool, wet winters, with evaporation >> infiltration. There is also little surface run-off, so that few of the lagoons receive any riverine input. Subsequently, the lagoons become either hypersaline or dry by the end of the summer. Consequently, they are hostile environments, with only limited opportunistic and salt-tolerant biota able to thrive.

The Coorong Lagoon is an example of such an environment. This well documented area is better known for the current deposition of carbonate minerals such as dolomite, magnesite and monohydrocalcite in the adjacent ephemeral evaporate lakes. This is also a common feature of many of the coastal lakes, e.g. the lakes south of the Coorong Lagoon such as Old Man Lake and Lake Amy. Details of the geological setting of the Coorong have been described by SPRIGG & BONE (1993, with references).

On the other hand, the marine environment of the modern Coorong estuary supports reefs constructed by bryozoans of the species *Conopeum aciculata* (MACGILLIVRAY 1891). They are found intergrown with the serpulid worm species *Ficopomatus enigmaticus* (FAUVEL) along the eastern margin of the Coorong from the Murray River to 2km north of Policeman's Point, and extending southward to Salt Creek (BONE & WASS 1990; BONE 1991).

The lagoon is characterized by significant salinity differences manifested along its length, and these fluctuate according to seasonal water influxes. Access to the open sea is restricted by the unconsolidated shoe-string sand barrier of the Younghusband Peninsula, which separates the Coorong Lagoon from the high energy environment of the Southern Ocean on its western flank, and by the changing pattern of the River

Addresses: Dr. K. A. Palinska, Institut Pasteur, Unité de Physiologie Microbienne, 25-28, Rue du Docteur Roux, F-75724 Paris Cedex 15, Tel.: +33 1 406 137 47, Fax: +33 1 406 130 42; Dr. K. Sterflinger, Carl von Ossietzky Universität Oldenburg, Institut für Chemie und Biologie des Meeres, P.O. Box 2503, D-26111 Oldenburg. Tel.: + 49 (0) 441 798-3382. Fax + 49 (0) 441 798-3384; Dr. habil. J. Scholz, Universität Hamburg, Geologisch-Paläontologisches Institut/Bryozoenzentrum, Bundesstraße 55, D-20146 Hamburg; Tel.: + 49 (0) 40 4123 5040. Fax + 49 (0) 40 4123 5007; Dr. G. Gerdes, Institut für Chemie und Biologie des Meeres, Meeresstation, Schleusenstr. 16, D-26382 Wilhelmshaven, Tel.:+49 (0) 4421 944 200, Fax: .:+49 (0) 4421 944 299, Dr. Y. Bone, University of Adelaide, Dept. of Geology and Geophysics, GPO Box 498, Adelaide, SA 5001, Australia. — * correspondent author



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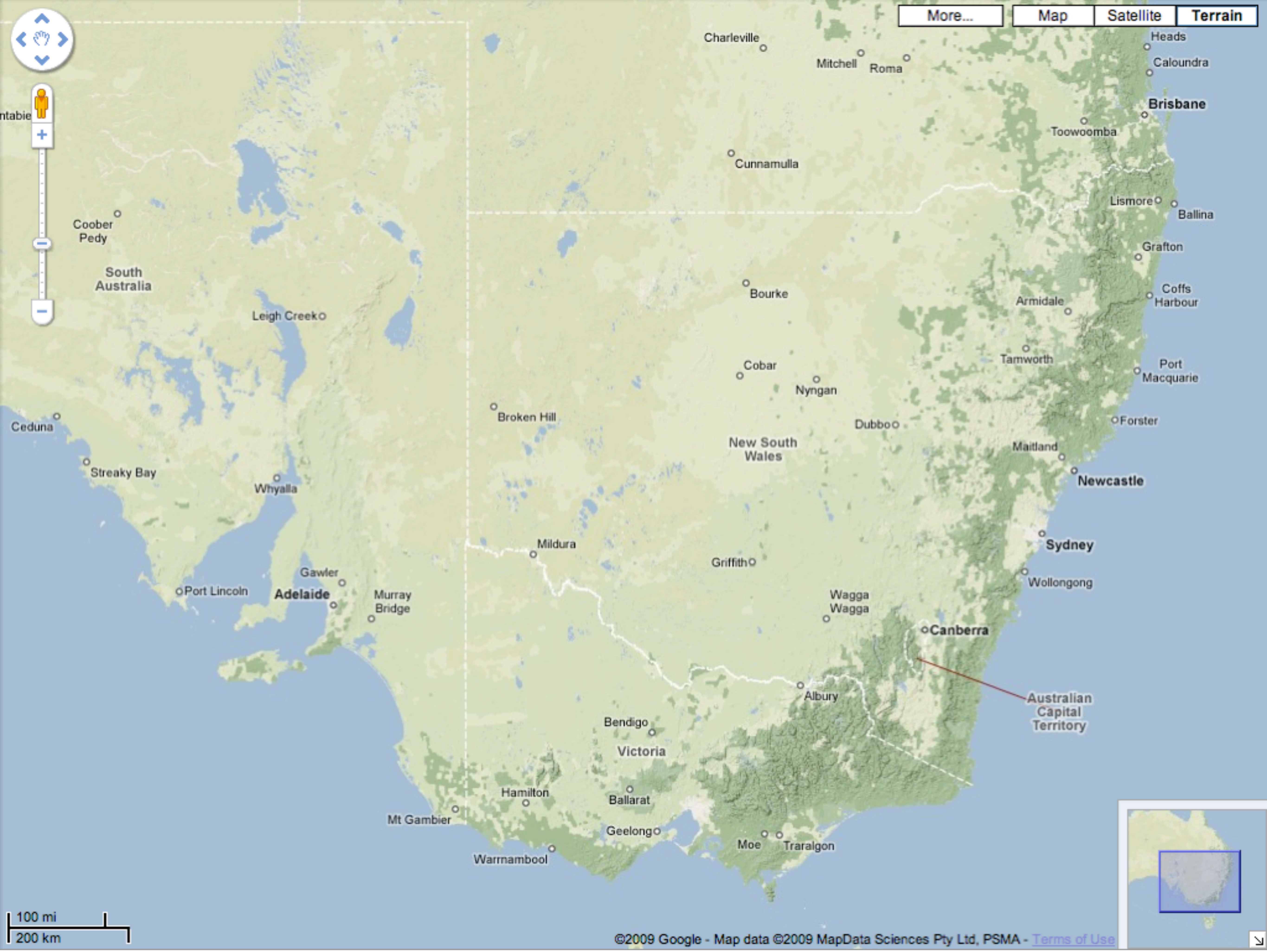

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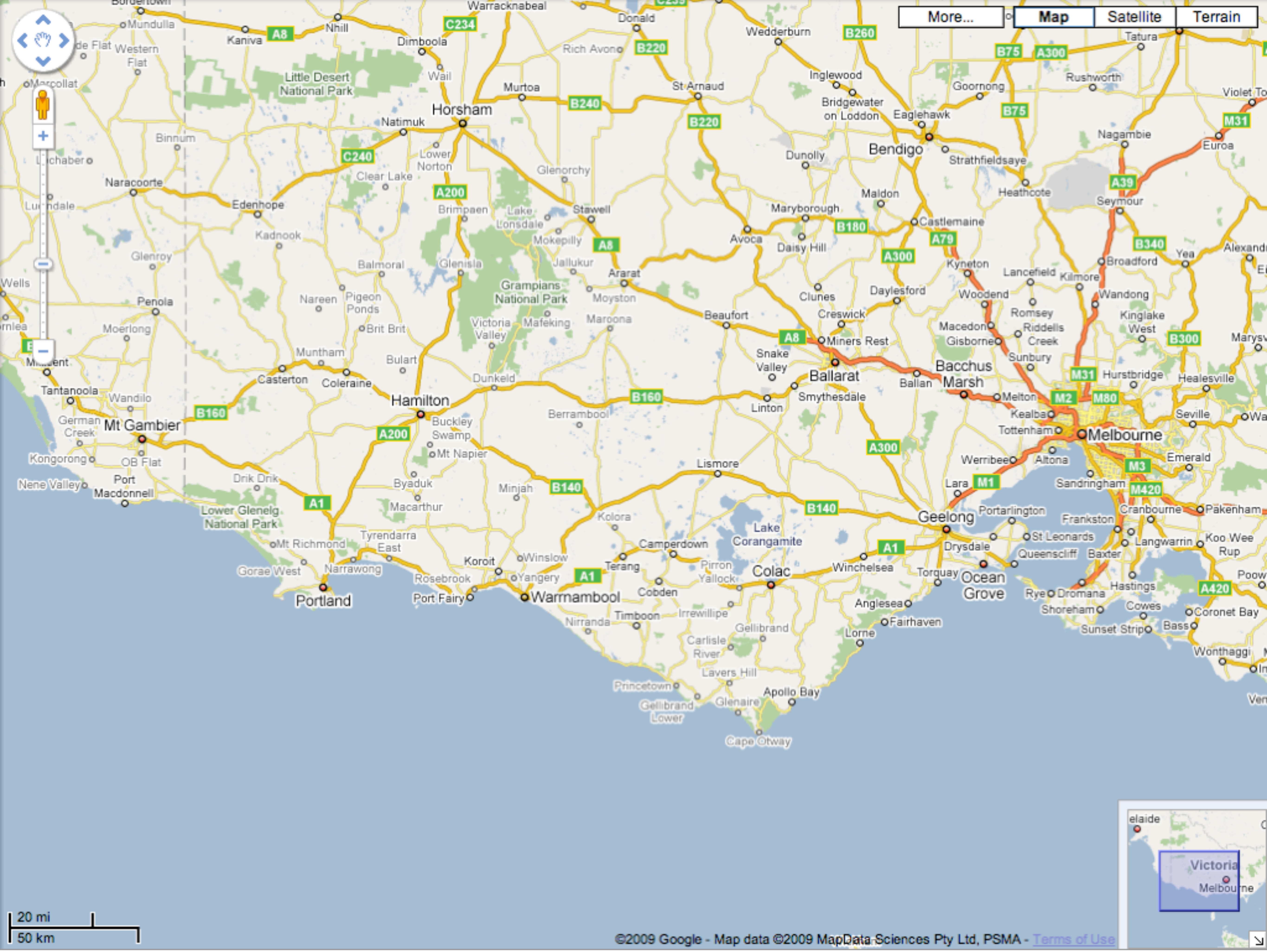

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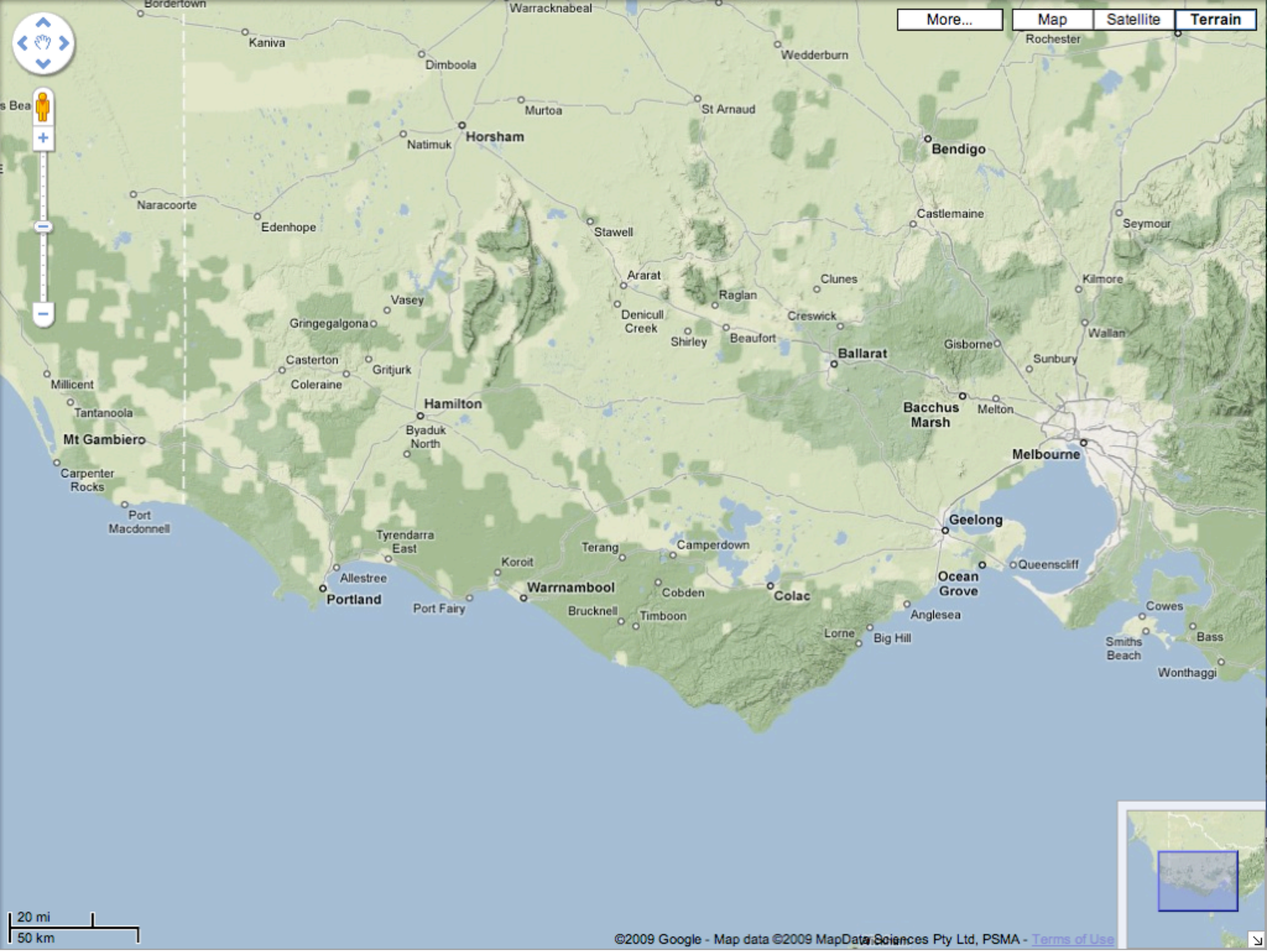

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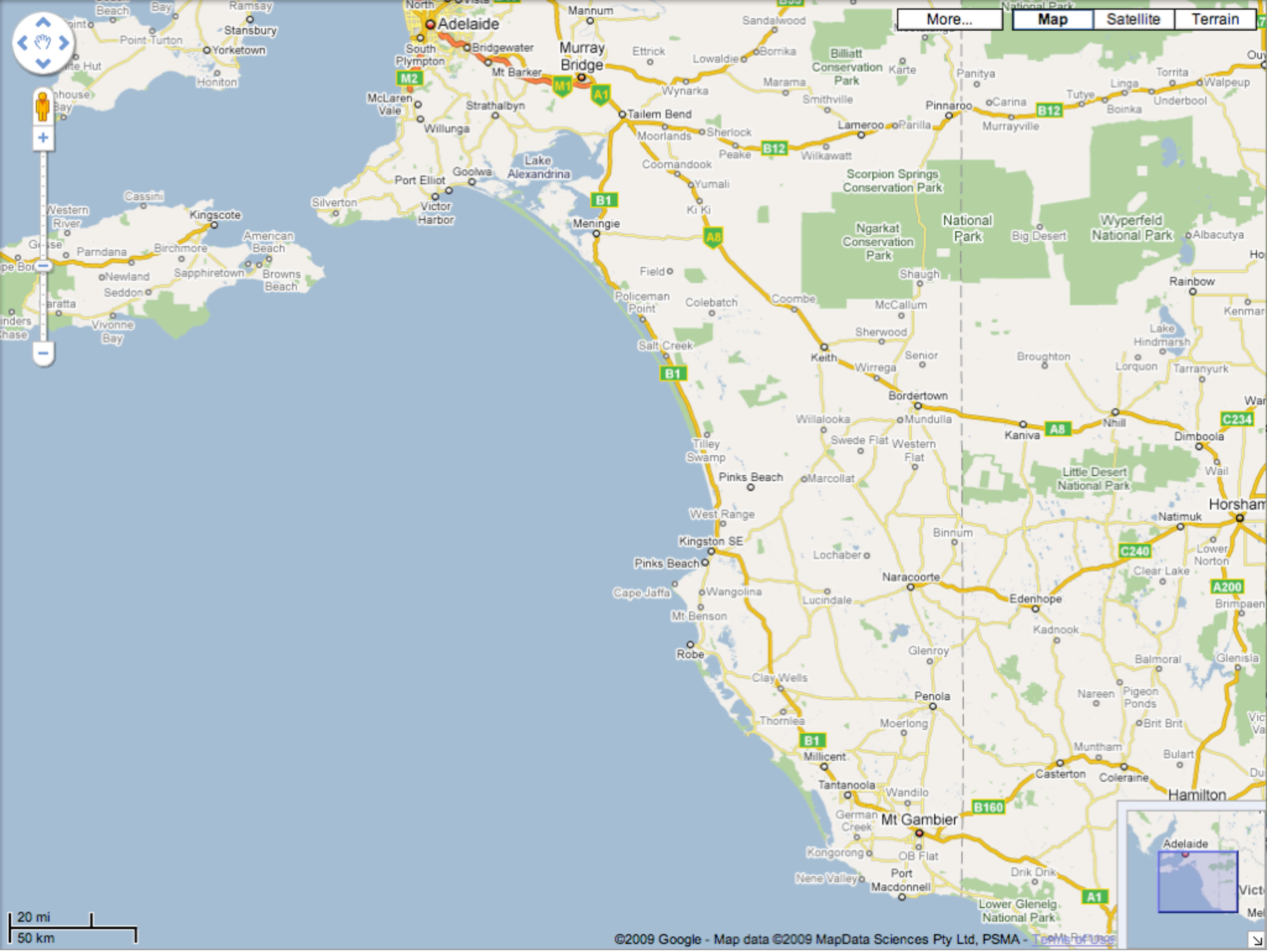
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Wynarka
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Wyperfeld National Park
Albacutya
Cassini
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Kingscote
American Beach
Parndana
Birchmore
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Sapphiretown
Browns Beach
Seddon
Vivonne Bay
B1
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McCallum
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Lorquon
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Keith
Wirrega
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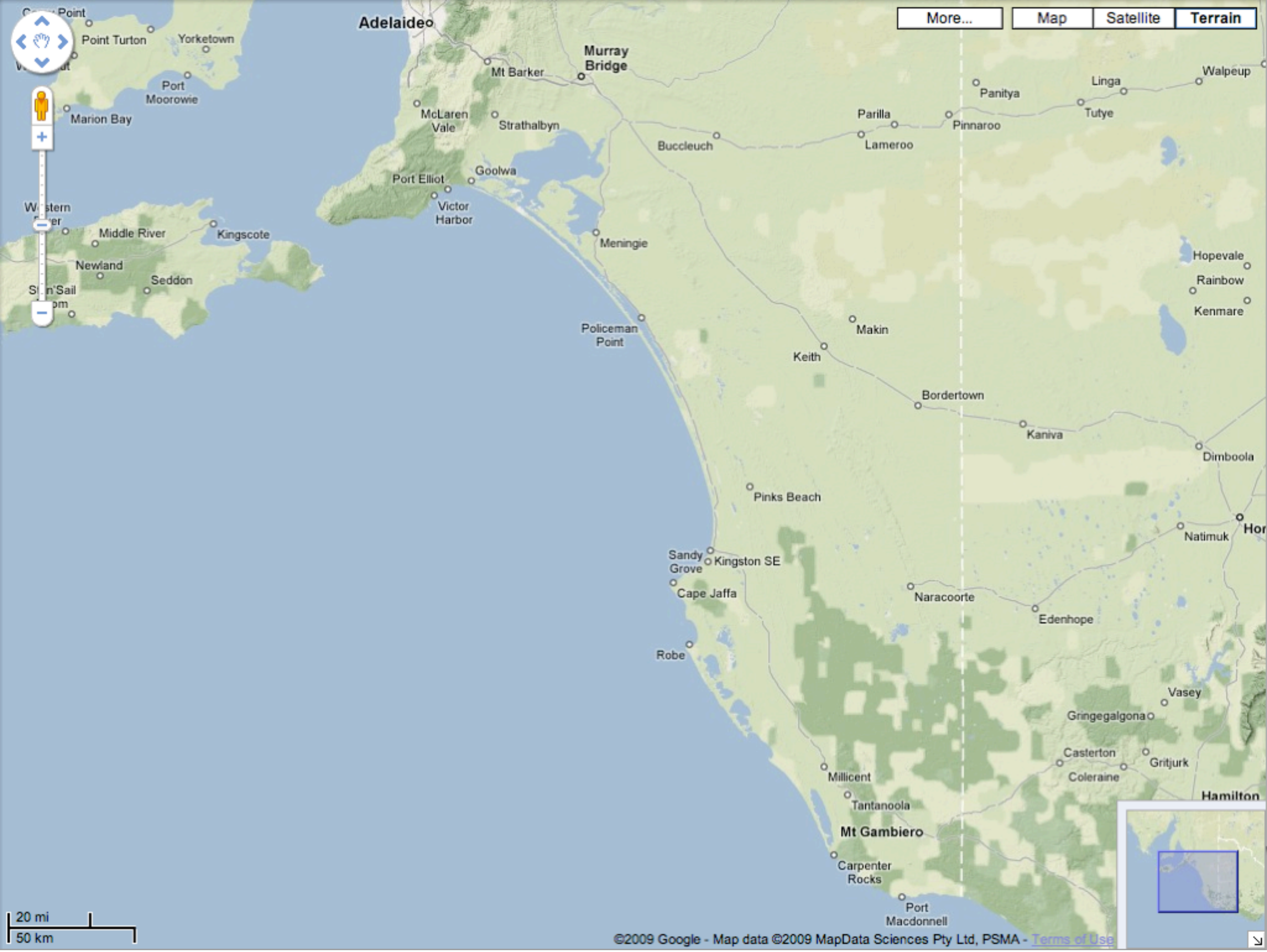
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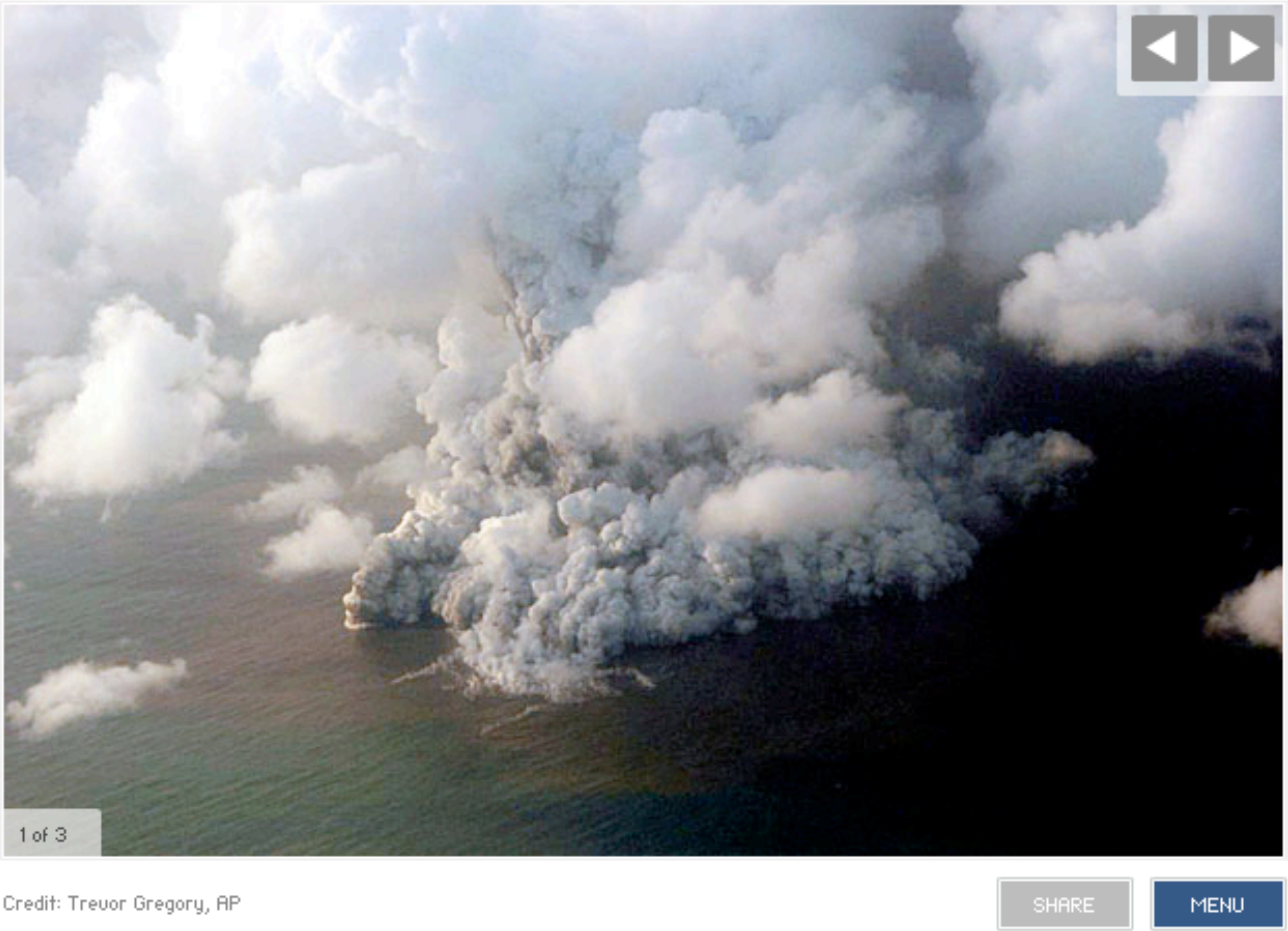
Tuesday, 31 March 2009

Undersea Volcano Erupts Off Tonga Coast

AP

NUKU'ALOFA, Tonga (March 18) - An undersea volcano erupted off the coast of Tonga shooting clouds of smoke, steam and ash thousands of feet into the sky above the South Pacific ocean. An undersea volcano located off the coast of Tonga erupted Wednesday, blowing huge amounts of smoke, steam and debris into the sky above. "It's a very significant eruption, on quite a large scale," said Keleti Mafi, the head of Tonga's geological service.



Credit: Trevor Gregory, AP

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Credit: Trevor Gregory, AP

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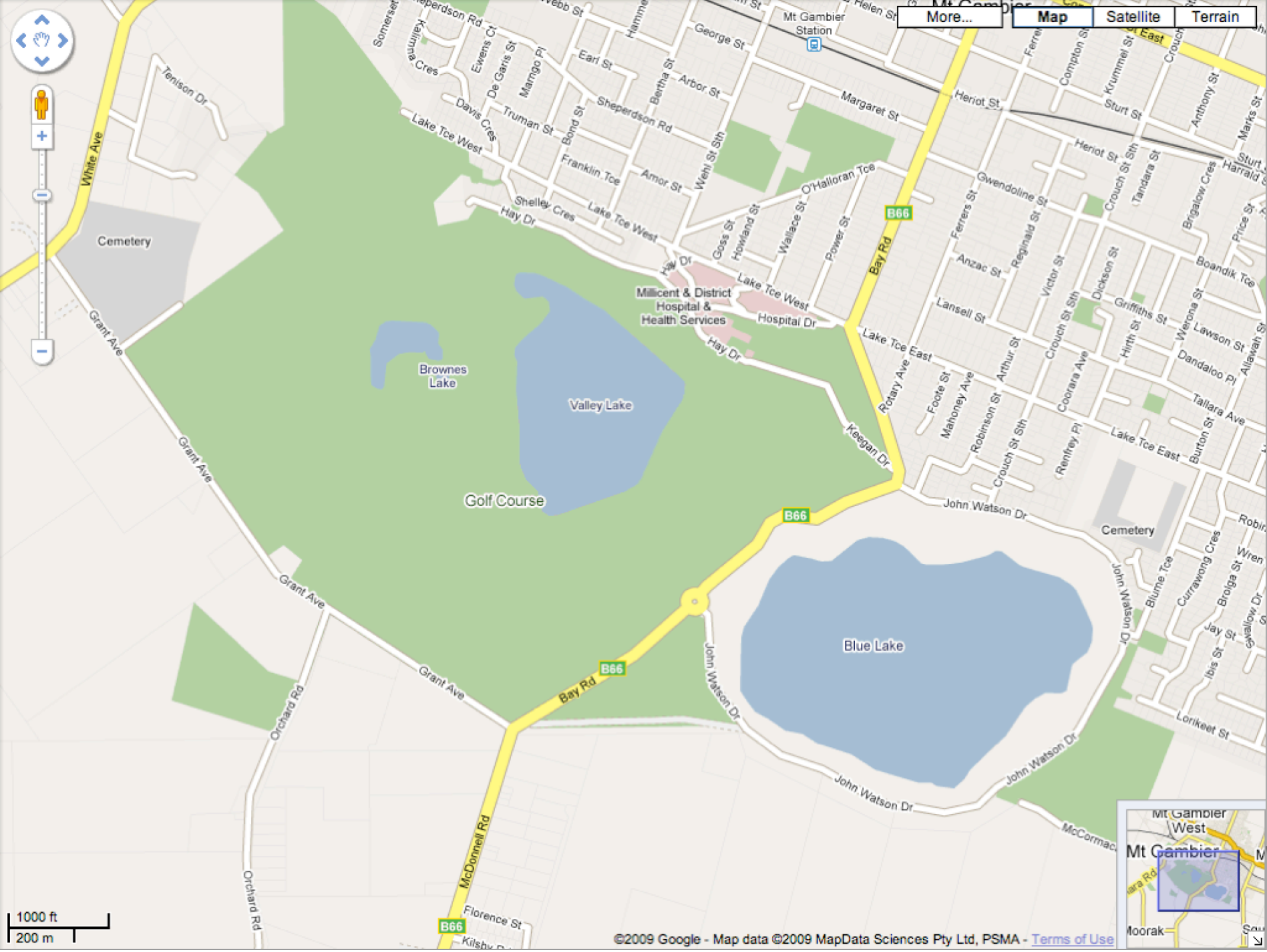

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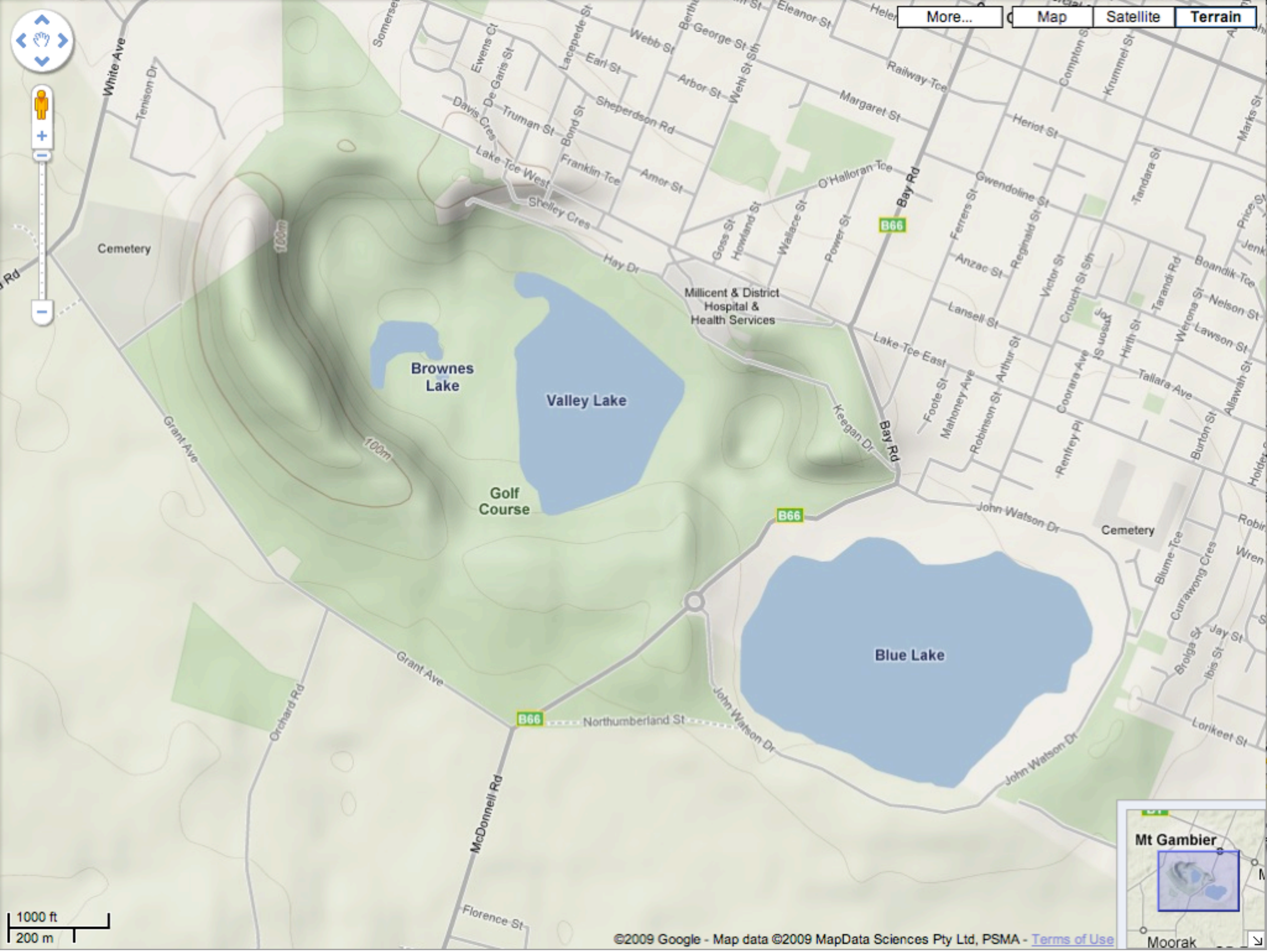

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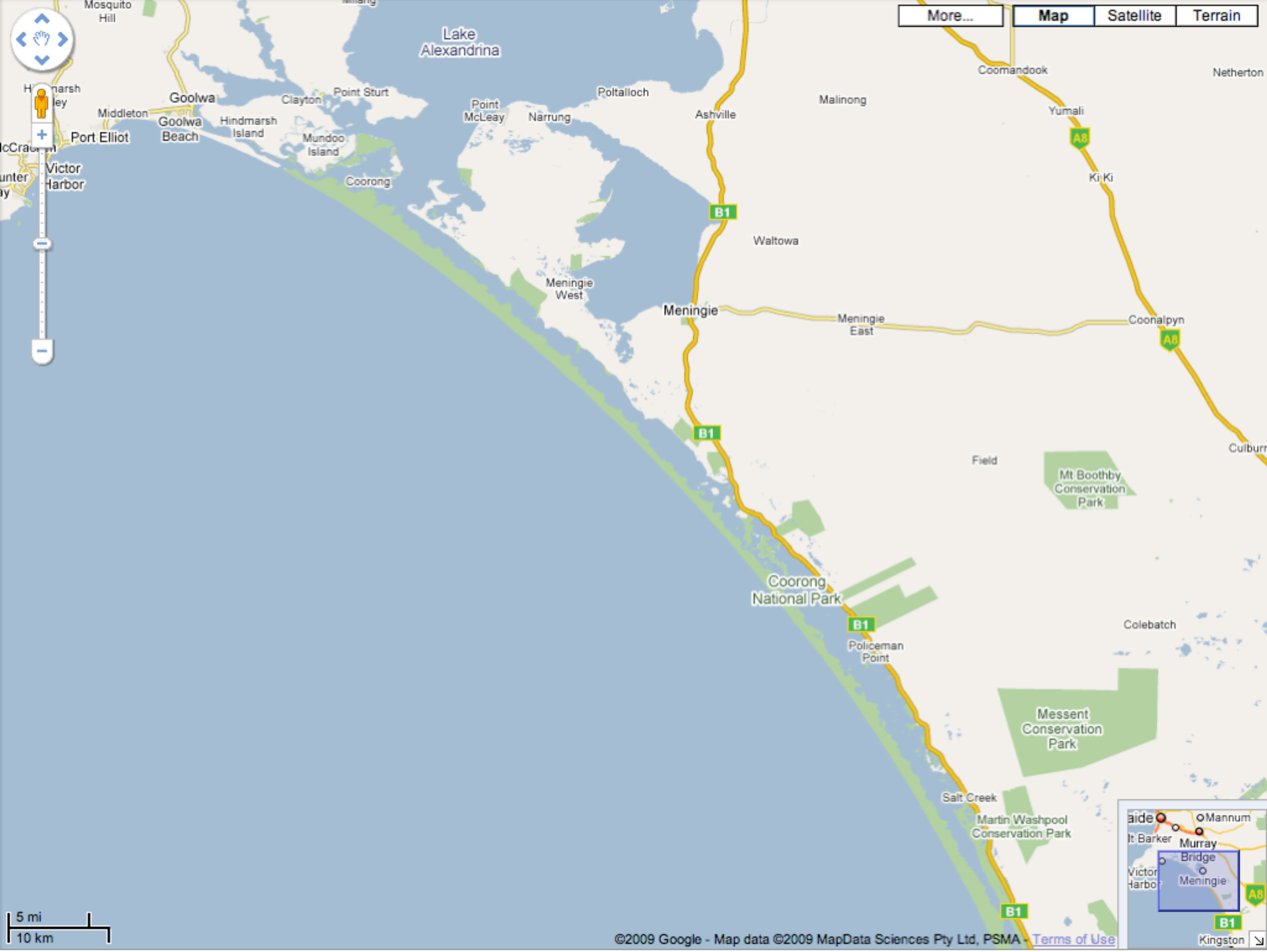

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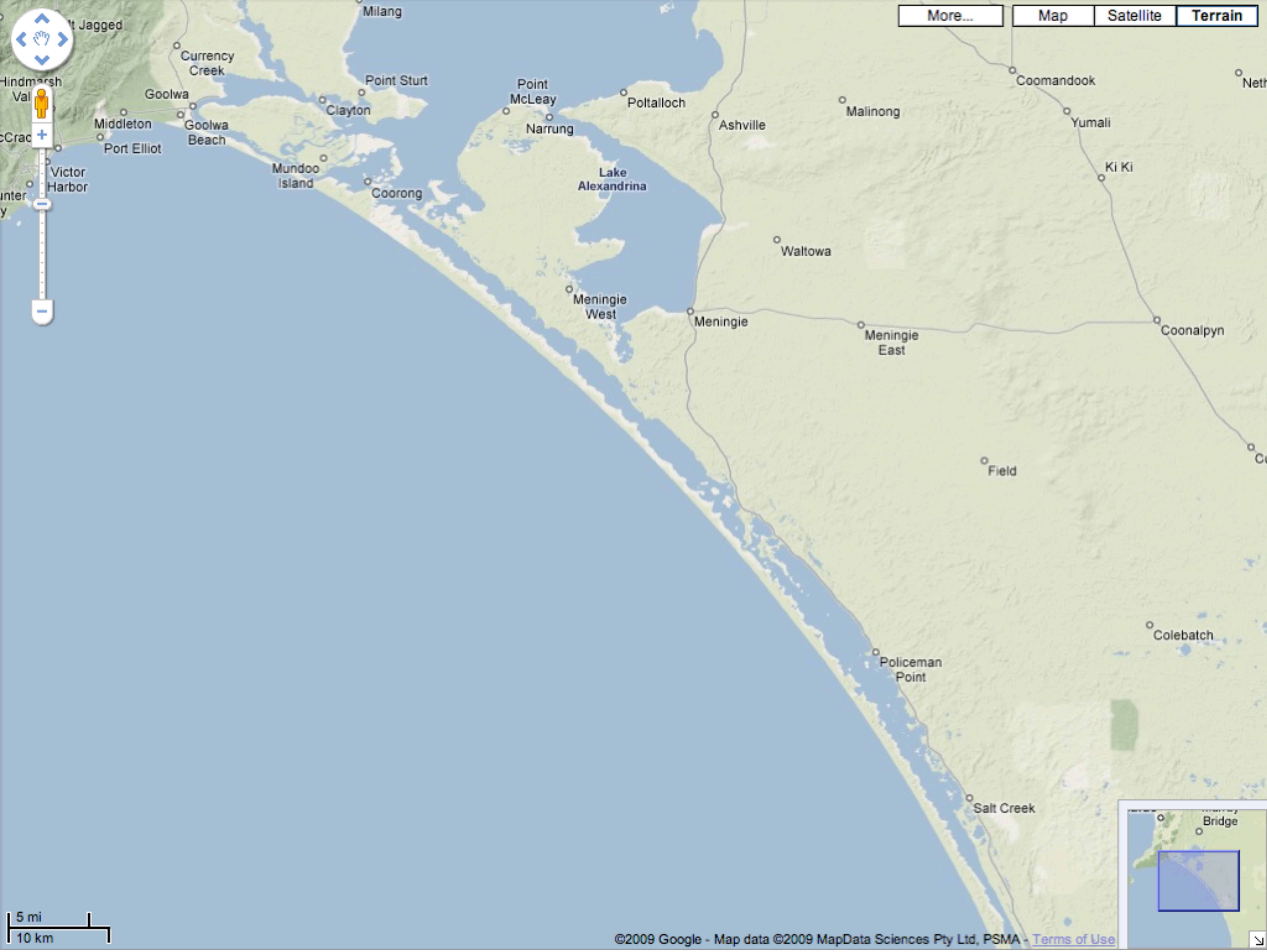

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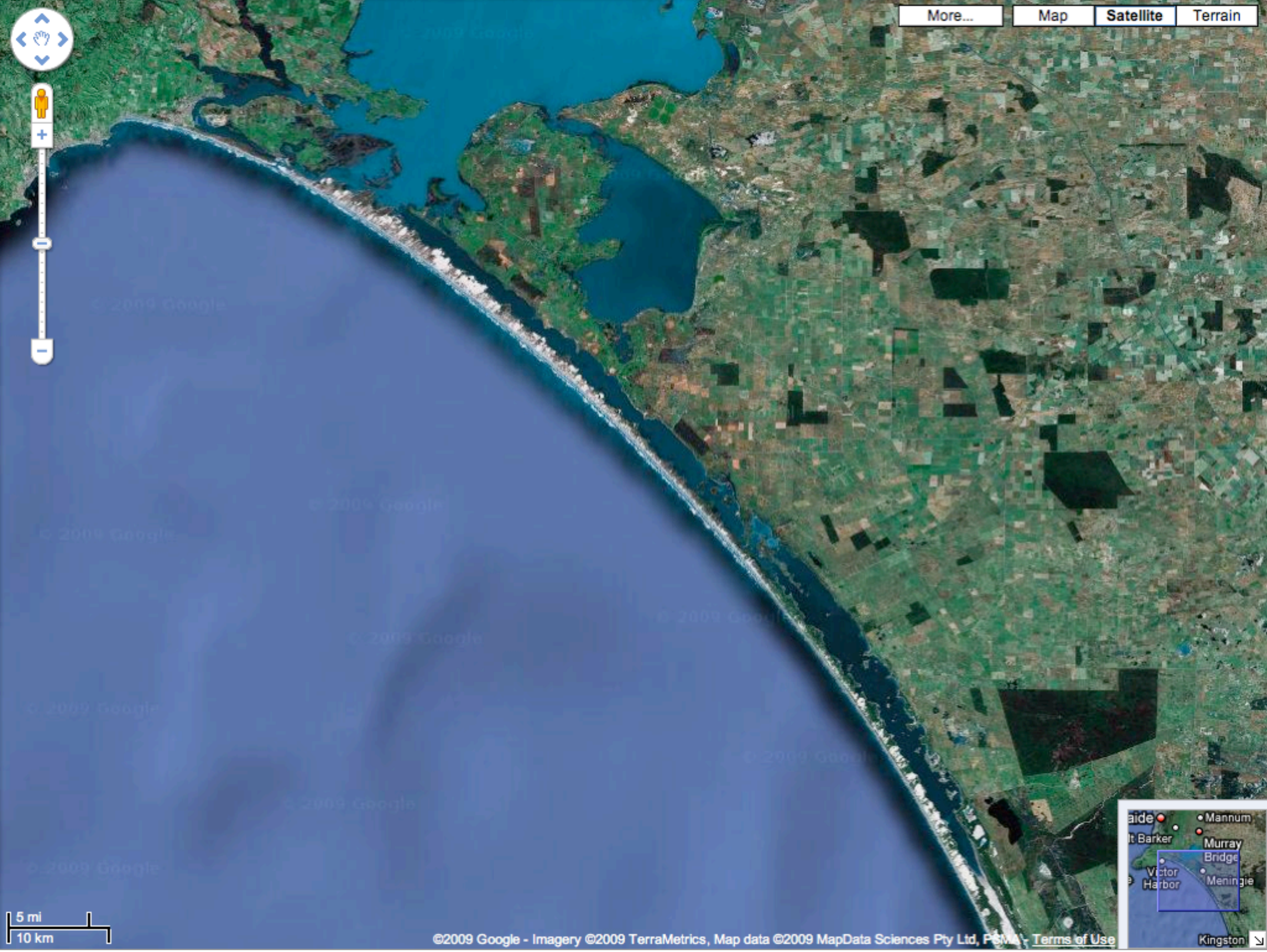
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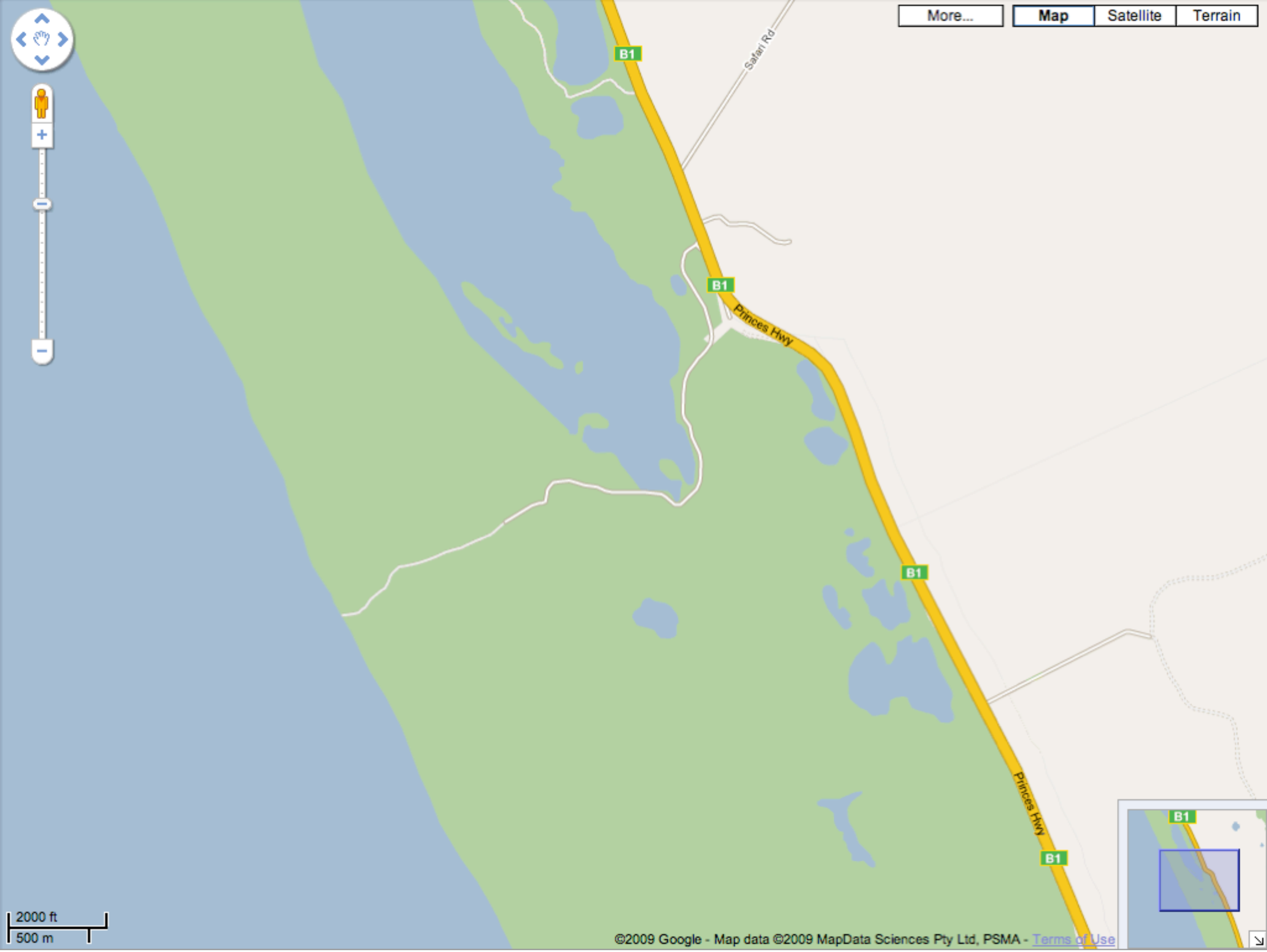

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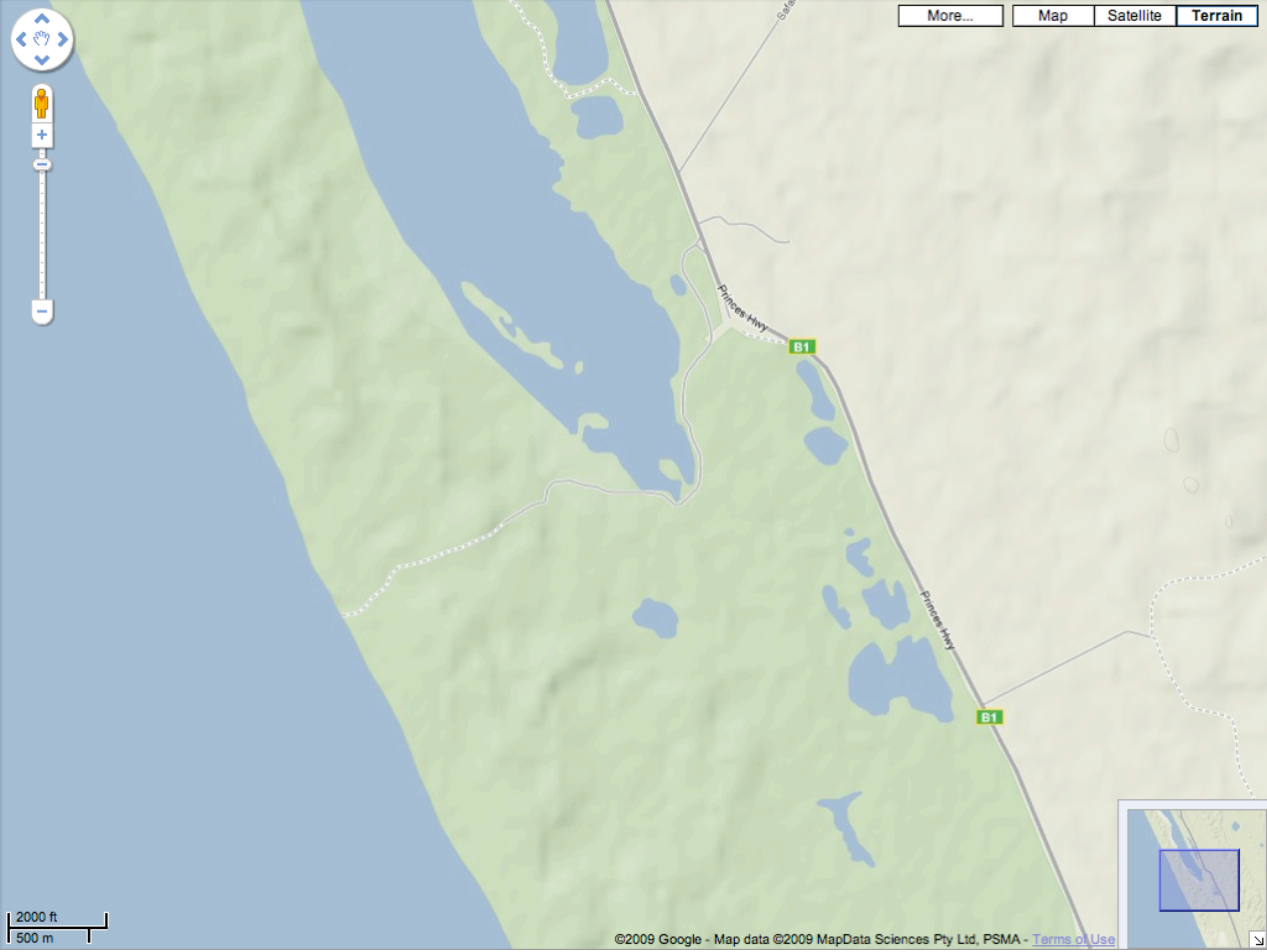

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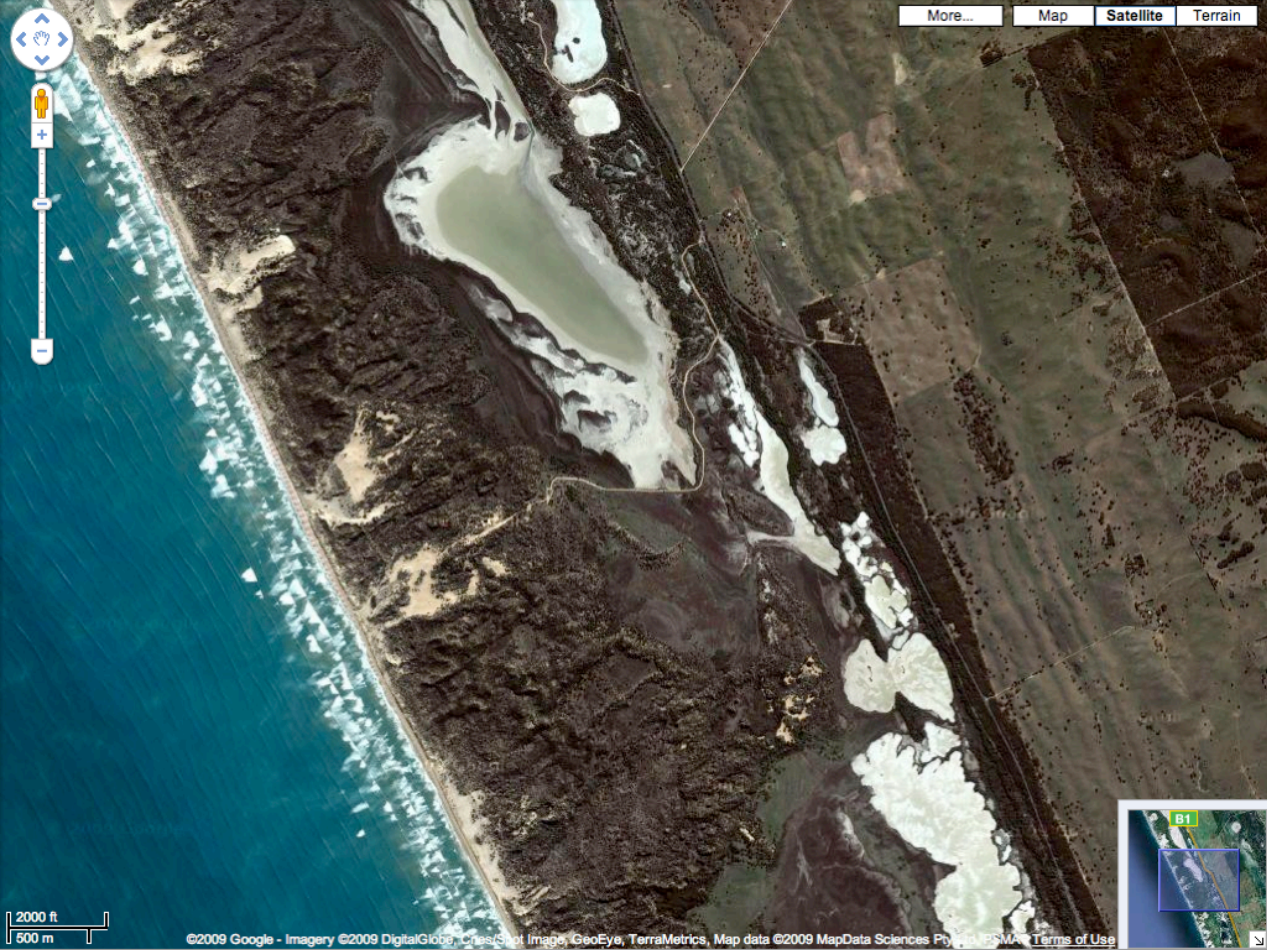
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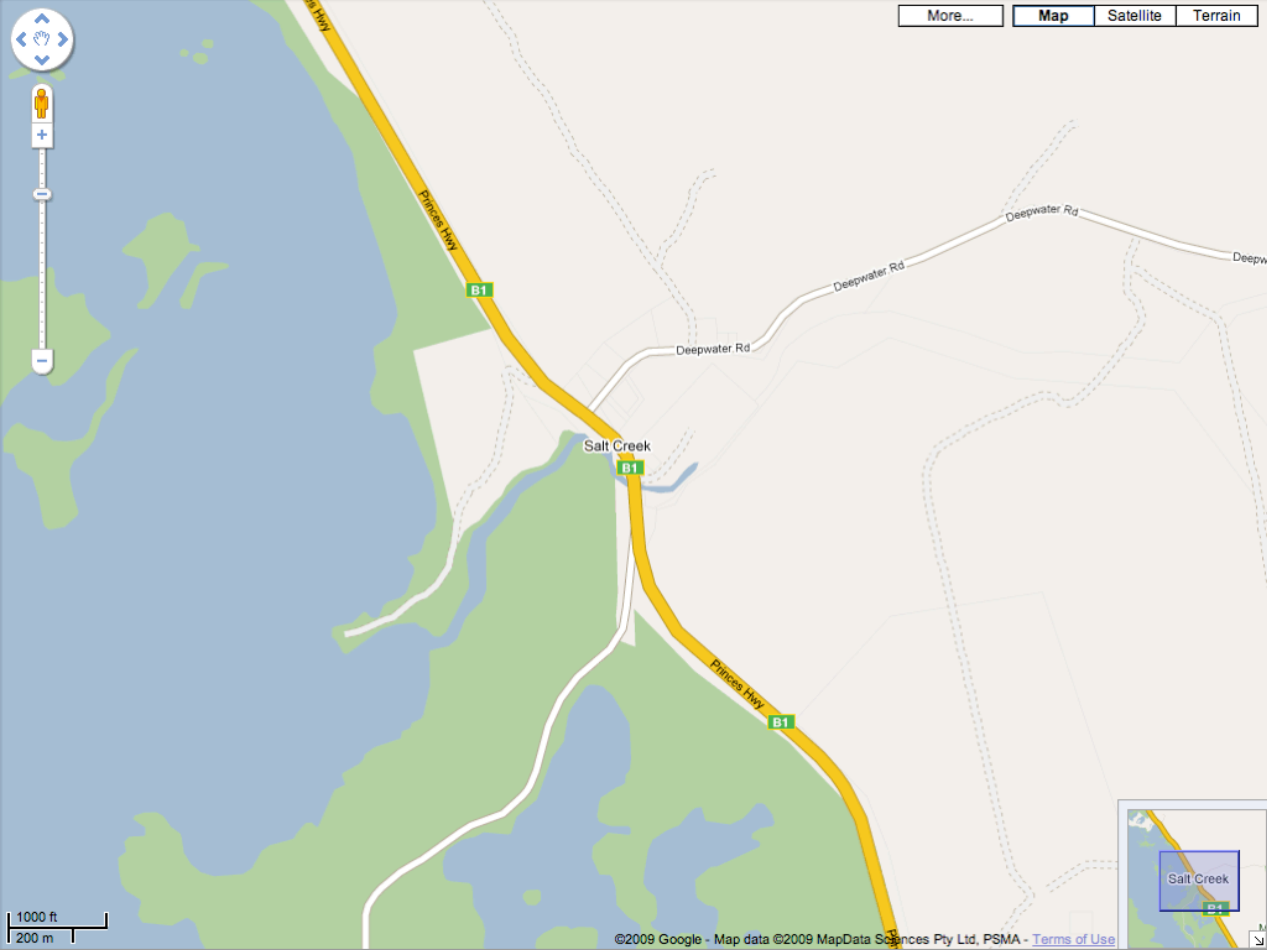

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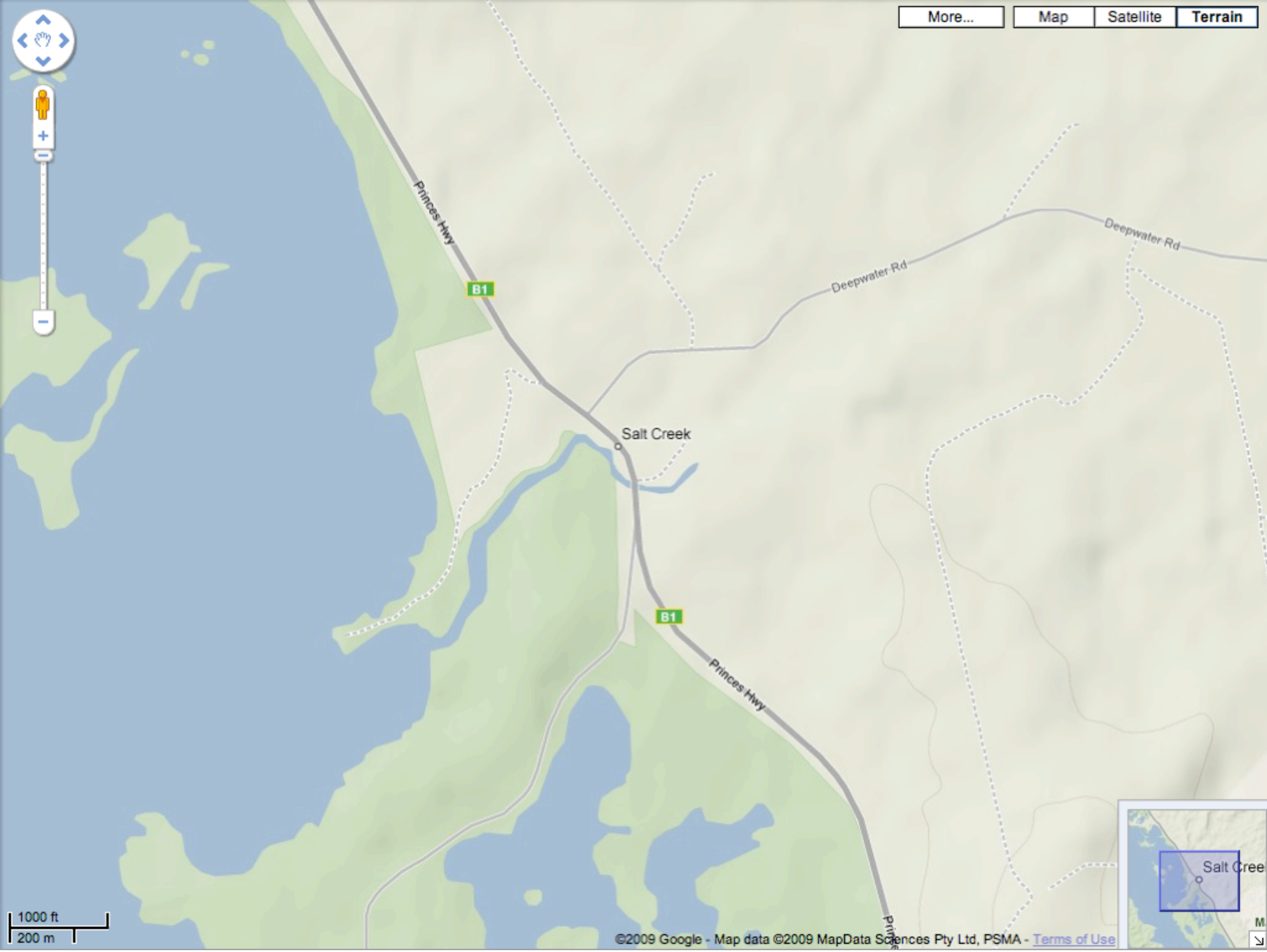

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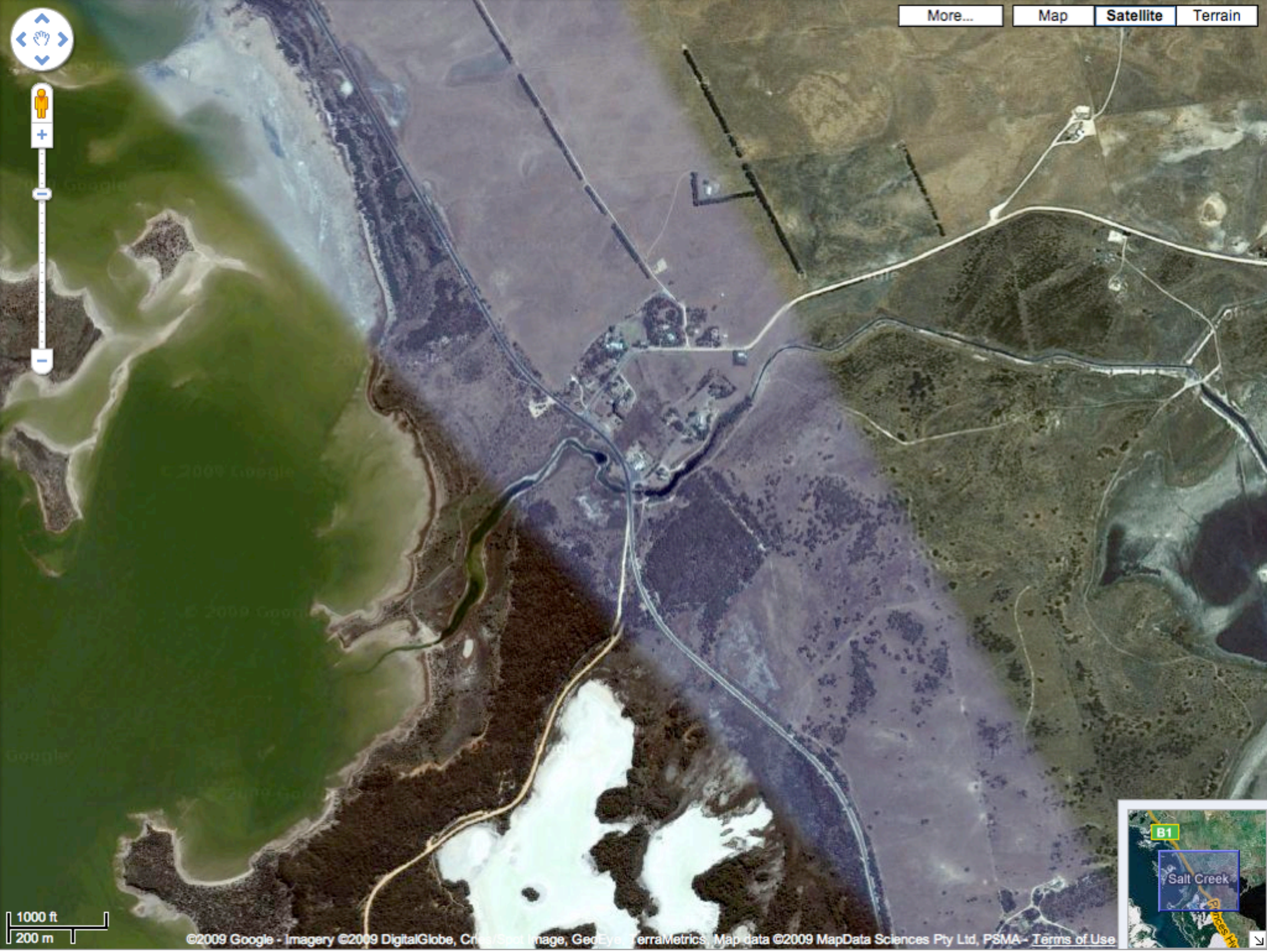

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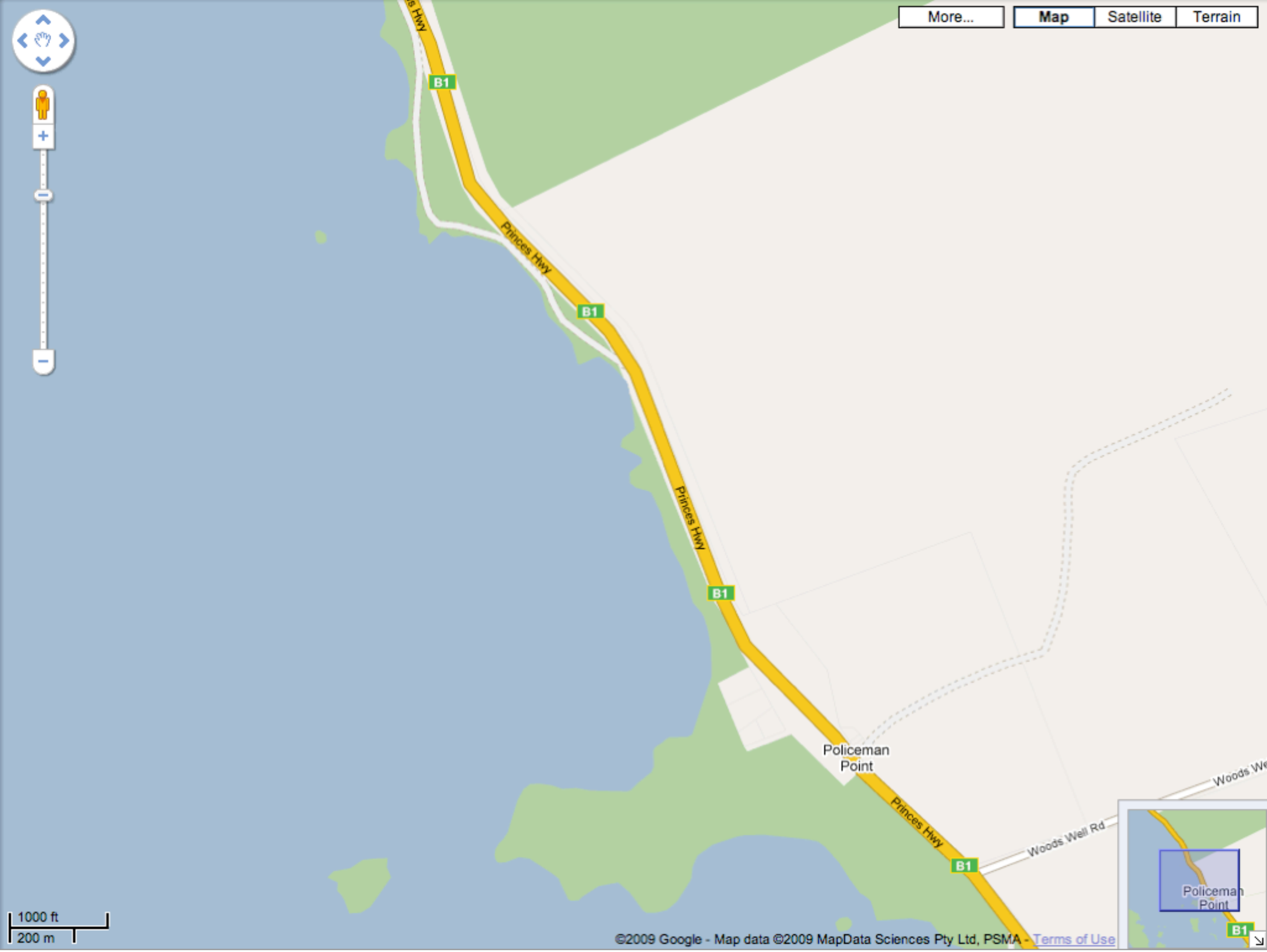
Sample 1
Green. Taken from W. side of Salt Creek; N. of road bridge. Creek appears as fresh (?) water river estuary ; fish, heron, etc.

Sample 2
Blue-green from "island" in green mat of sample 1.



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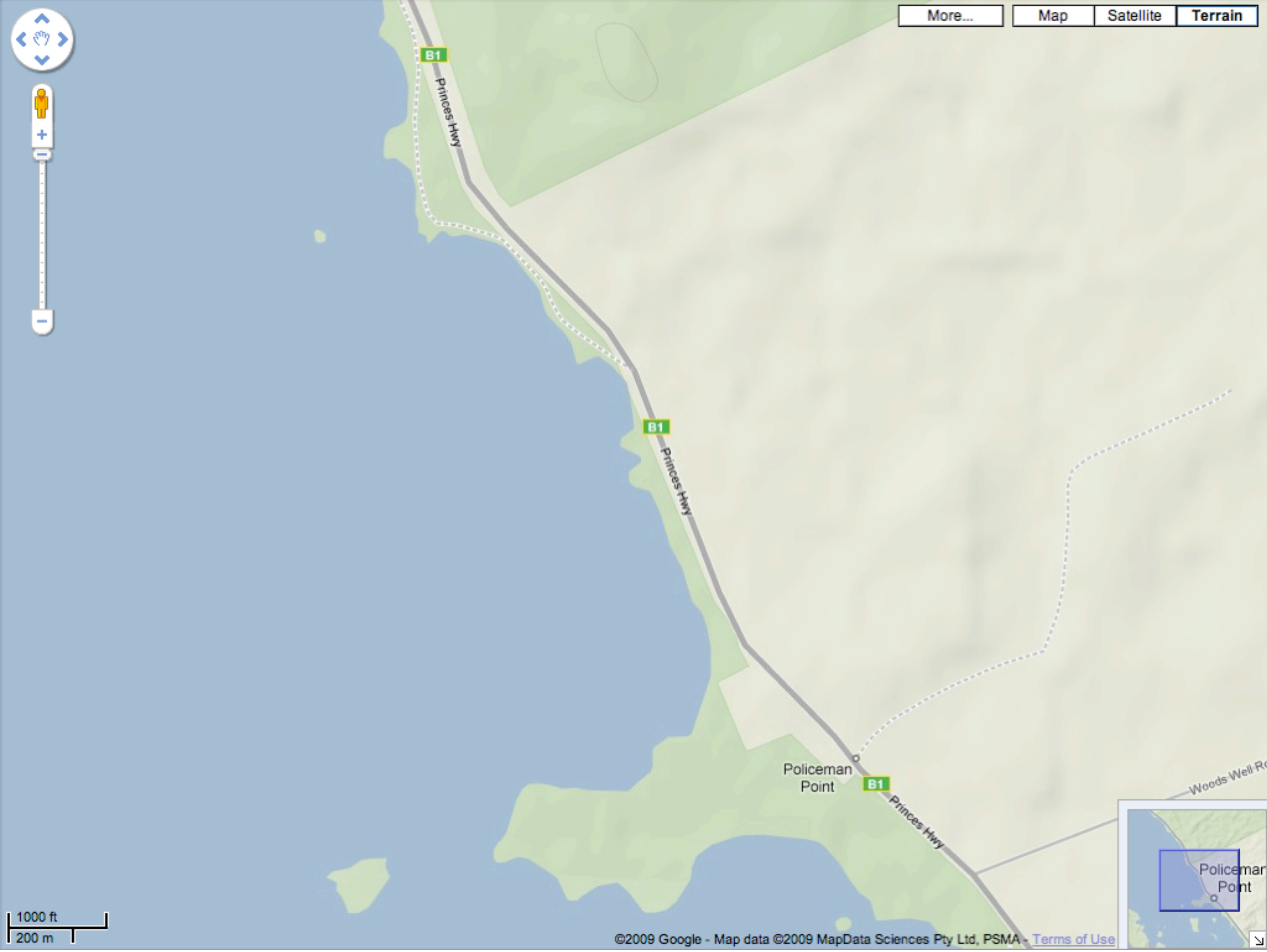

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Sample 3
Black. From narrow black band close to N. shore of Lagoon, a bay adjacent to road and NW of Policeman's Point. No detectable smell. Sticky.

Sample 4
Purple-Pink. Further out from shore. Pink crust above black mat - black colour also exposed at periphery of lagoon (as Sample 3)

Sample 5
Orange. As 4.

Sample 6

Green "island" in pink-orange mat as in 4 and 5.

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