

STOCKYARD HILL WIND FARM

GEOLOGY, GEOMORPHOLOGY

&

GEOSCIENCE VALUES

Neville Rosengren

Environmental GeoSurveys Pty Ltd

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Executive Summary

Environmental GeoSurveys Pty Ltd presents this report entitled Stockyard Hill Wind Farm: Geology, Geomorphology, Geoscience Values

Environmental GeoSurveys Pty Ltd was engaged to study the geology and geomorphology of several parcels of land between Beaufort and Skipton in western Victoria identified by Stockyard Hill Wind Farm Pty Ltd as suitable for development as a wind farm. The report describes the geological and landform features of the selected parcels in the context of the broader landscape of western Victoria and outlines the past and present processes that have shaped the landscape.

The area includes landscapes developed on Palaeozoic and Cainozoic sedimentary rocks in the north and extensive areas of Neogene basalt lava flows in the south. Several distinct volcanic eruption points occur and there is one small granitic outcrop.

The study was conducted with an initial desktop literature review and examination of geological and topographical maps, vertical aerial photographs, satellite images and a digital elevation model. Field studies included viewing all the land parcels nominated by Stockyard Hill Wind Farm Pty Ltd as potential windmill sites from adjacent public roads, and a walkover of several properties that provided a representative array of geological and landform features. Particular attention was given to sites of potentially higher geoscience significance. A chartered light aircraft was used for an aerial inspection and photography of key areas of volcanic terrain.

The report identifies areas where geology and/or landforms are sensitive to disturbance, identifies sites of geoscience significance and provides guidelines to avoid or minimize impacts that could degrade these values.

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1 Introduction

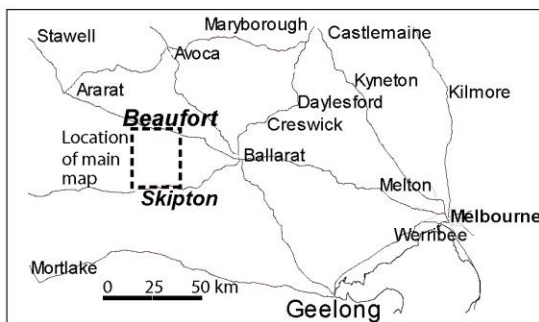
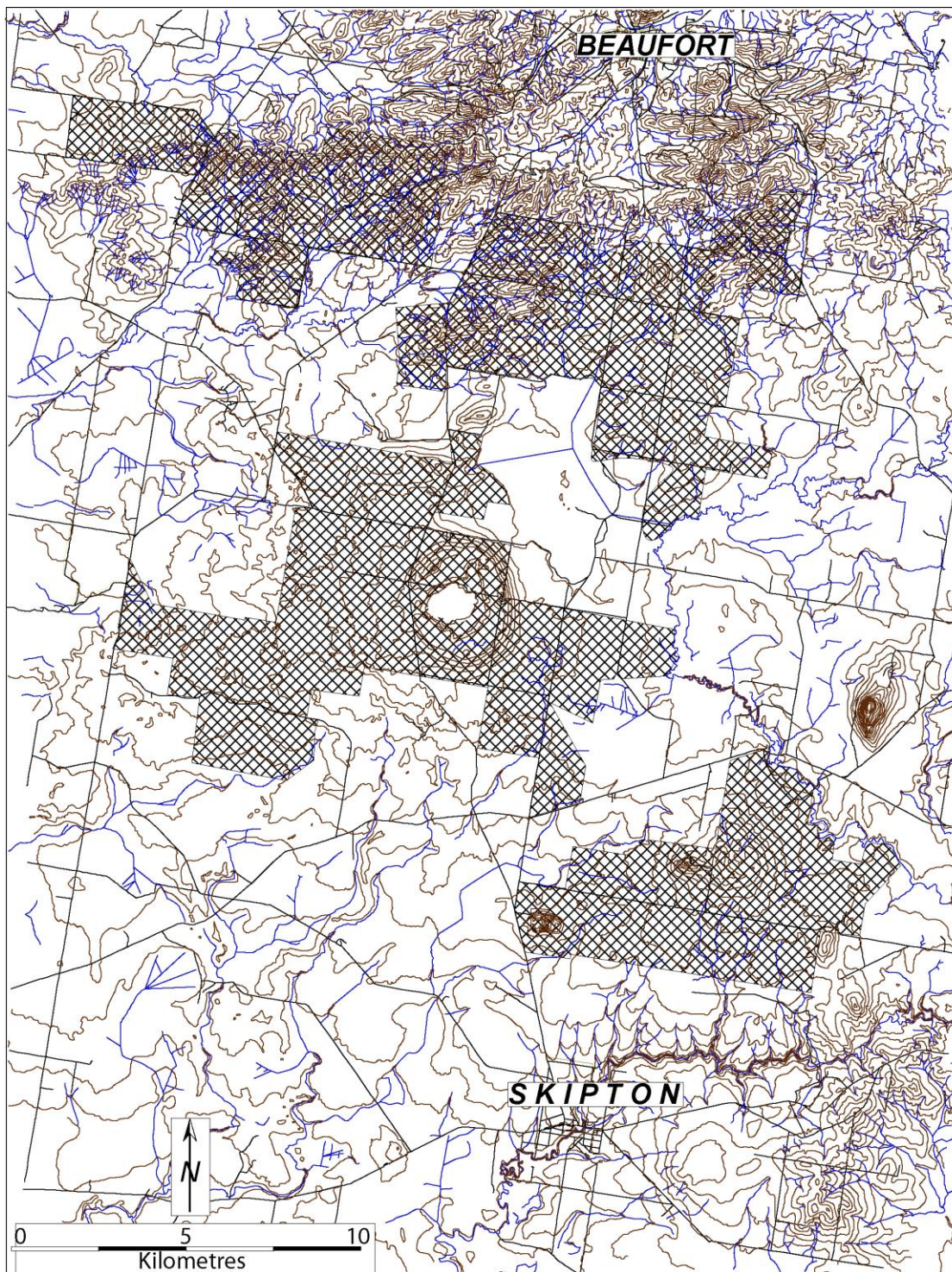
This report was prepared for Stockyard Hill Wind Farm Pty Ltd, the proponent of a wind farm development in the Pyrenees Shire in central western Victoria. The proposed wind farm will involve the installation of approximately 282 horizontal axis wind turbines and associated on-site permanent infrastructure (including substations, cabling and access roads).

The report describes the geology and geomorphology of several parcels of land between the townships of Beaufort and Skipton in western Victoria identified as suitable for development as a wind farm (Figure 1). The principal purpose of the study is to identify sites of geoscience significance and consider the potential impacts of a wind farm development on the values of these sites. This report presents an overview of an area extending about 25 km east-west and 25 km north-south, in the context of the geology and landforms of western Victoria, and outlines the past and present processes that have shaped this landscape. More detailed descriptions are given of the geological and landform features of the land parcels selected for wind tower sites. These parcels amount to about 16,500 hectares.

The information presented in the report is based on desktop studies including review of maps and geo-referenced vertical aerial photographs, three days of site inspection from vehicles and field walking, and a low level flyover in a light aircraft to obtain oblique aerial photographs. The area includes landscapes developed initially on Palaeozoic sedimentary and granitic rocks and subsequently covered by extensive flows of basalt lava. Several volcanic eruption points occur and there are some well-preserved original volcanic features. Deep weathering of many of the rock units has produced a regolith of variable thickness. Lower slopes and valley floors contain thick colluvial and alluvial deposits.

The report identifies sites of geoscience significance and other areas where geology and/or landforms are sensitive to disturbance, and provides guidelines to avoid or minimize impacts that could degrade the values of these sites.

It is considered that the wind farm layout, construction and operation can be structured to take account of and minimise degradation to the significant geoscience features. Recommendations to that end are contained in this report.



Area of detailed study
(land parcels identified
as turbine sites)

Figure 1. Study area between Beaufort and Skipton. Shading shows land parcels that will contain towers and other wind farm infrastructure.

1.1 Terms of Investigation

The terms of this investigation were to:

- Review of available literature and imagery (visual, geophysical) of the site.
- Field inspection to verify some geological boundaries and features.
- Report preparation including:
 - topographical, geological and geomorphological context of the site in terms of land systems of western Victoria.
 - specific topographical, geological and geomorphological features of the site including stream systems, channel form, wetlands, hillslope morphology, outcrop
 - regolith and soil types
 - geological and landform history
 - geological and geomorphological processes.
 - assessment of geoscience significance.
 - potential geomorphological constraints on construction and operation of a wind farm.
 - maps and other illustrations as appropriate for the above.
 - list of references and other relevant material.

1.2 Disclaimer

- *This document is not a geotechnical report.*
- It does not assess the suitability of the site, or the constraints and opportunities for the project, in terms of *engineering* issues. It does not assess limitations or risks due to the strength or stability of geological materials, or potential geological hazards e.g. slope stability, seismic or volcanic risk.
- *This document is not a landscape or visual impact assessment.*
- It does not consider the appearance of the landscape before, during and after construction in aesthetic or cultural terms, or consider the impact on viewsheds from close or distant points.

- This report is a description of the nature and origins of the physical landscape of an area enclosing sites proposed for locating wind generator towers and associated infrastructure (referred to as the wind farm proposal) between Beaufort and Skipton in western Victoria.
- This description provides a basis for assessing features and sites of geoscience significance in the local, regional and broader context.
- The report considers constraints and opportunities for the wind farm proposal in terms of its potential impact on the *geoscientific* or *geoscience* values of the area of the wind farm proposal in the local, regional and broader context. As the geoscience values are mainly based around the occurrence of geologically young lava flows, the report is focused on these features.

1.3 Methodology

This report was researched, written and produced by Neville Rosengren.

Available literature including unpublished reports were accessed and reviewed, along with a study of published geological and topographical maps. Stockyard Hill Wind Farm Pty Ltd supplied digital copies of vertical aerial photographs, maps showing the property boundaries of land parcels to be utilised and nominal locations of proposed turbines, and facilitated access for field inspection. Higher resolution images and layout details were provided on request for Stockyard Hill, Monmot and Nanimia Hill as these were identified as the most sensitive localities of geoscience significance.

Field inspection was made over parts of four days between June 21 and July 13 2008 by traversing the area on public roads adjacent to land parcels, and a walkover of several properties that warranted closer inspection of geological and landform features. A low level aerial inspection in a chartered light aircraft to obtain oblique aerial photographs was conducted on July 26 2008.

2 Geology of Stockyard Hill Wind Farm

2.1 Context

The geological basement of western Victoria is a thick sequence of Lower Palaeozoic (Cambrian to Silurian) predominantly marine sedimentary rocks intruded by extensive bodies of Devonian granite (Figure 2). The proposed wind

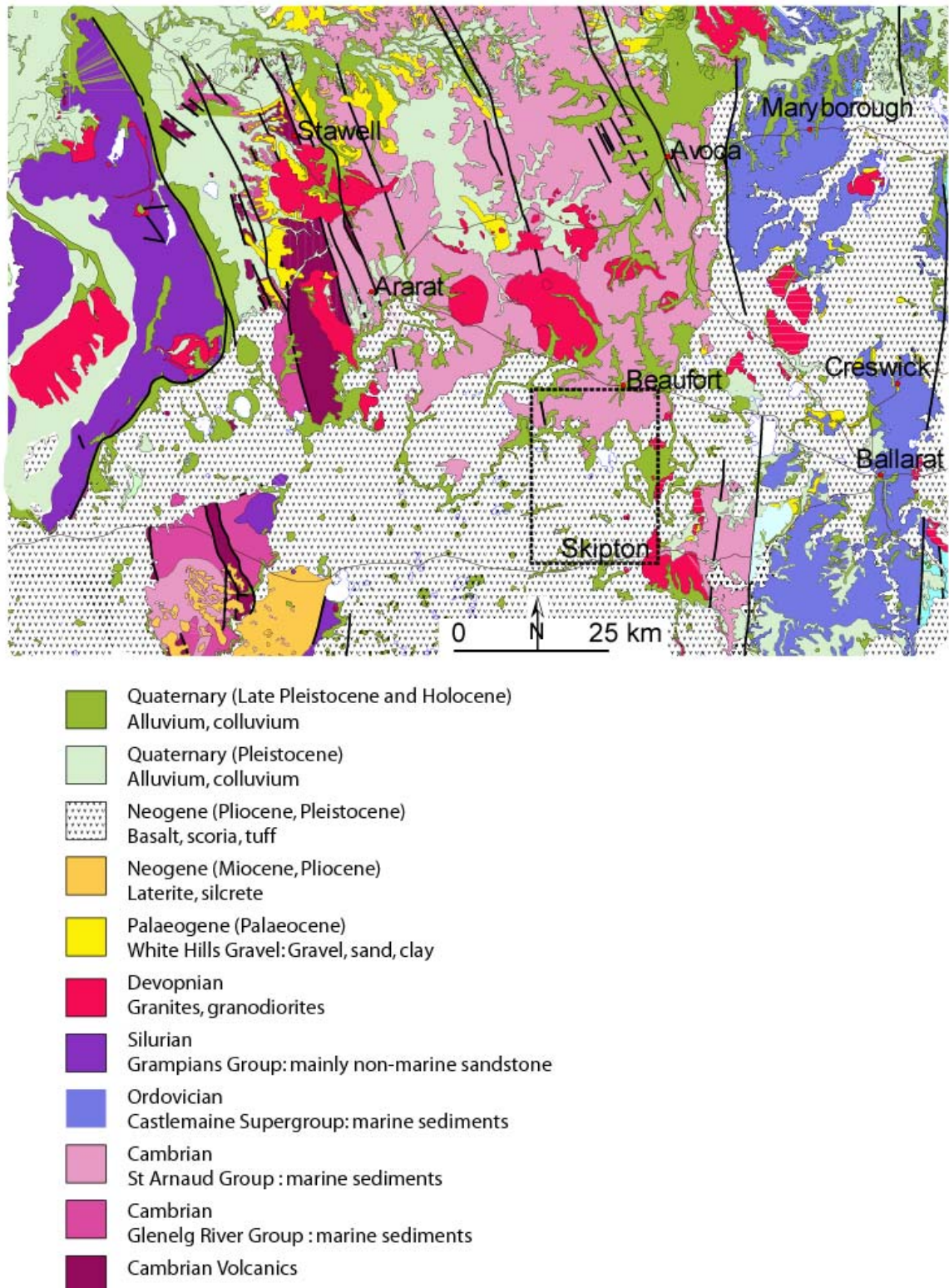


Figure 2. Geology of part of western Victoria surrounding Stockyard Hill wind farm site (modified from GeoScience Victoria 2005).

farm lies in the Stawell (orogenic) Zone at the southern margins of an extensive belt of Cambrian marine turbidite beds referred to as the St Arnaud Group (VandenBerg and Wilkinson 1982). These rocks crop out in the hills around Beaufort and as the hills decline in elevation towards the south, they are covered by broad sheets of Pliocene and Pleistocene basalt lava. Small areas of exposed granitic rocks of Late Devonian age crop out to the east and south of Beaufort and near Skipton. The only other hard rock geological materials in the area of the wind farm proposal are cemented gravels of the White Hills Formation and laterised weathering horizons developed on the Cambrian sediments.

2.2 Geology

The study area enclosing the proposed wind farm comprises five broad geological units (Figure 3).

- (a) In the north are hills and ridges of Palaeozoic (Cambrian to lower Ordovician) marine sedimentary rock
- (b) The north-central, central and southern areas are undulating plains with a surface of olivine basalt ranging from deeply weathered to relatively fresh, blocky, stony-rise lava flows
- (c) There are several volcanic eruption points of coherent lava and scoria forming low hill, some with craters, and with locally steep slopes.
- (d) Small areas of Lower Devonian granitic rocks, surrounded by lava flows, crop out along the east of the study area.
- (e) Drainage features including alluvial valleys and enclosed depressions with active or drained wetlands occur across all landform types.

Further details of the geological materials are described in Chapter 3, Geomorphology.

2.3 Geological history

2.3.1 Cambrian sedimentary rocks

The oldest rocks in the Beaufort–Skipton region record a long episode of marine sedimentation in the early Cambrian resulting in a several kilometre thickness of sandstone, siltstone and shale of the St Arnaud Group. The three formations recognised in the St Arnaud Group are the Pyrenees Formation, the Beaufort Formation and the Warrak Formation (Cayley and McDonald 1995). The rocks are unfossiliferous but structural relationships indicate a Late Cambrian age - approximately 500 million years ago (mya). Subsequent deformation during orogenies later in the Palaeozoic resulted in folding, faulting and regional low-

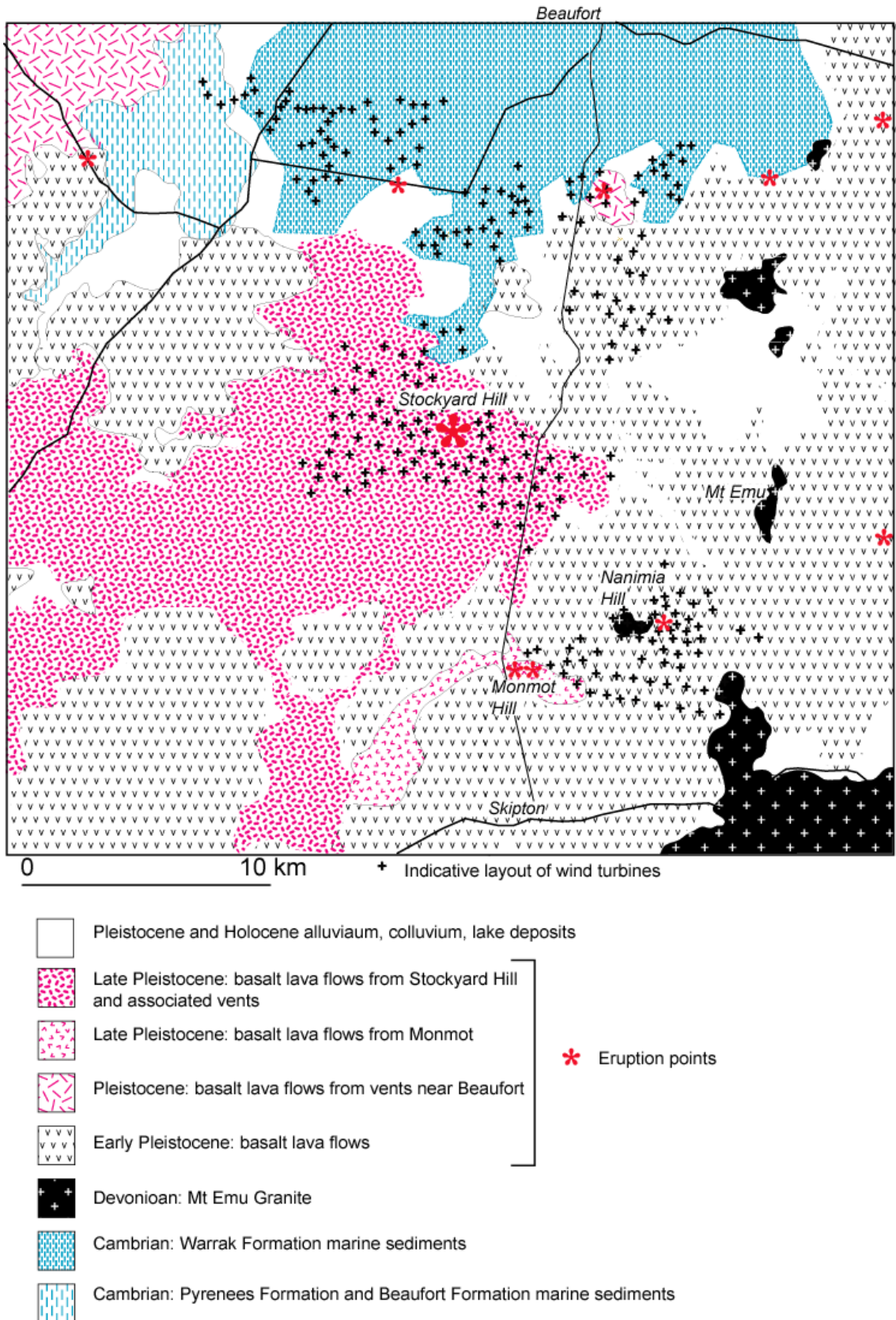


Figure 3. Generalised hard rock geology of wind farm site (After Beaufort and Skipton 1:100 000 geological mapsheets, Geol Survey of Victoria).

grade metamorphism of these rocks and the development of mineralized quartz reefs and veins (Figure 4, Figure 5). The major structures are tight, north-west trending upright folds with closely-spaced faults, and development of cleavage

planes.



Figure 4. Steeply dipping Pyrenees Formation sediments, Beaufort-Skipton Road cutting.



Figure 5. Metre-thick quartz vein in Pyrenees Formation sediments, Beaufort-Skipton Road cutting.

2.3.2 Devonian granitic rocks

Substantial granitic bodies occur in the southern Pyrenees, most with positive relief forming elevated plateaus such as Mount Cole and Mount Buangor. In the study area the Mount Emu Granite crops out intermittently along a 25 km long zone from southeast of Beaufort to Skipton. A small exposure of Trawalla Granite (Cayley and Taylor 1995) occurs 9 km southeast of Beaufort in the valley of Mount Emu Creek but is outside the area of the proposed wind farm. Further south, the granite forms small but prominent hills at Mt Emu and a ridge at Nanimia Hill that is a tower site (Figure 6).



Figure 6. Outcrops of Mt Emu Granite on western slopes of Nanimia Hill.

2.3.3 White Hills Formation

The White Hills Formation is a scattered assemblage of sands, gravel and clay widespread across northern and western Victoria and almost entirely confined to the north of the Main Divide. The Beaufort area is one of the few localities where the formation persists south of the divide. It is a varied sedimentary deposit and contains a wide range of sediment sizes, including coarse sands and gravels with occasional metre size boulders. It is predominantly of quartz but includes occasional lithic pebbles. The size and structure of the deposits indicate deposition in high energy streams from highly weathered uplands with abundant quartz reefs and veins to provide the source of the gravel. In western Victoria, the

White Hills Formation rests unconformably on the eroded surface of the Palaeozoic rocks.

Iron and silica cemented gravels occasionally occur as hilltop residuals indicating relief inversion since the deposition of the formation. Hilltop residuals also provide material for valley deposits and as the White Hills Formation is auriferous, they have been extensively mined and more recently used as sources of sand and gravel. White Hills Formation occurs at Yada holes Hill and Malakoff Hill near Beaufort and small, scattered residuals occur on crests and ridges elsewhere in the Beaufort Hills, e.g. east and west of Skipton Road 3 km south of Beaufort.

The White Hills Formation is regarded as early Palaeogene or even Late Cretaceous in age (between 70 mya and 55 mya) (Cherry and Wilkinson 1994).

2.3.4 Calivil Formation and sub-basaltic sediments

The Calivil Formation is one of several sub-surface former alluvial sedimentary bodies now buried by younger sediments or lava flows. It is widespread in valley in northern Victoria but has limited distribution south of the Main Divide. It was derived from weathering and stream and slope deposition in deeper valleys during times of rising sea level in the Late Palaeogene and early Eocene (35 mya to 25 mya). Much of the material has been derived by reworking the White Hills Formation. The Calivil Formation deposits are now buried by younger alluvial sediments or lava flows and as they are also auriferous, they have been extensively worked as “deep lead” gold mines. In relation to the proposed wind farm, Calivil Formation occurs only in the former gold mining areas around Beaufort.

2.3.5 Pliocene and Pleistocene volcanics

Approximately half of the wind turbine sites are located on volcanic geology between Beaufort and Skipton. The volcanic area is part of the complex referred to as the Newer Volcanic Province of Victoria, an extensive geological unit that extends across parts of the Western Uplands and Western Plains in Victoria to Mt Gambier in South Australia. The volcanic activity occurred intermittently over a period of about six million years and there are at least 350 eruption points known (Rosengren 1994). The youngest period of activity in Victoria is about 30,000 to 50,000 years ago (Tower Hill, Mount Napier, Mount Eccles) and many other obvious and well-preserved volcanic features occur including the present study area.