RECONSTRUCTING ICE SHEET SURFACE CHANGES IN WESTERN DRONNING MAUD LAND, ANTARCTICA

by

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Dedicated to my late Grandfather – Desmond Hammerton (17/11/1929 – 27/01/2020)

An inspiration to my academic career, who was so happy to see me following in his footsteps as an adventurous scientist ☺

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ABSTRACT

Understanding climate-driven changes in global land-based ice volume is a critical component in our capability to predict how global sea level will rise as a consequence of the current human-driven climate change. At the last glacial maximum (LGM, which peaked around 20 ka), ephemeral ice sheets covered vast regions of the northern hemisphere while both the Greenland and Antarctic ice sheets were more extensive than at present. As global temperatures rose at the transition into the Holocene, driving the LGM deglaciation, eustatic sea level rose by approximately 125 m. The east Antarctic ice sheet (EAIS) is the largest ice sheet on Earth today, holding an ice volume equivalent to ca. 53 m rise in global sea level. Considering current trends in global climate, specifically rapidly increasing atmospheric CO_2 levels and global temperature, it is important to improve our understanding of how the EAIS will respond to global warming so that we can make better predictions of future sea level changes to guide community adaptation and planning efforts. Numerical ice sheet models which inform projections of future ice volume changes, and can, therefore, yield projections of sea level rise, rely on empirical data to test their ability to accurately represent former and present ice configurations. However, there is a general lack of data on the paleoglaciology of the EAIS along the western Dronning Maud Land (DML) margin. In order to address this situation, the paleoglaciology of western DML forms the focus of the work presented in this thesis.

Together with collaborators within the MAGIC-DML consortium (Mapping, Measuring and Modelling Antarctic Geomorphology and Ice Change in Dronning Maud Land) that provides the funding for this MS project, the author has performed geomorphological mapping across western DML; an area of approximately 200,000 km^2. The results of the mapping presented in this thesis will provide the basis for a detailed glacial reconstruction of the region. The geomorphological mapping was completed almost entirely by remote sensing using very high-resolution (sub-meter in the panchromatic) WordView-2 and WorldView-3 (WV) satellite imagery, combined with ground validation studies during field work. Compared to Landsat products, the improved spatial resolution provided by WV imagery has fundamentally changed the scale and detail at which remote sensing based geomorphological mapping can be completed. The mapping presented here is focused on the glacial geomorphology of mountain summits and flanks that protrude through

the ice sheet's surface (nunataks). In our study area of western DML these nunatak surfaces make up <0.2 % of the total surface area, and the landforms mapped here are generally smaller than can be identified from Landsat products (30 m spatial resolution). The detail achieved in our mapping, across such a vast, remote area that presents numerous obstacles to accessibility highlights the benefits of utilizing the new VHR WV data. As such an evaluation of the WV data, as applied to geomorphological mapping is presented here together with our mapping of the glacial geomorphology of western DML. The results of which provides evidence of ice having overridden sites at all elevations across the entire study area; from the highest elevation inland nunataks that form the coast-parallel escarpment, to low-elevation emerging nunataks close to the coast. Hence from our studies of the glacial geomorphology of this region we can ascertain that, at some point in the glacial history of western DML, ice covered all of the mountain summits that are exposed today, indicating an ice sheet surface lowering of up to 700 m in some places.

CHAPTER 1. INTRODUCTION

1.1 Motivation

Antarctica has the potential to contribute approximately 58 m to global sea level should all 27 x 10^6 km^3 of ice contained within its ice sheets melt (Fretwell et al., 2013). Of this, the equivalent of ~53 m would come from the East Antarctic ice sheet (EAIS). However, there is large uncertainty in predictions of future global sea level rise, with the largest source of uncertainty being the contribution from Antarctic ice melt (Mengel et al., 2018). Within Antarctica, the EAIS presents the greatest ambiguity with regards to how it will respond to current climate change and consequently contribute to global sea level rise (IMBIE team, Shepard et al., 2018). Reducing these uncertainties is critical to improving predictions of future sea level rise and to planning- and adaptation strategies. Reconstructing the response of Antarctica to past changes in global climate is, therefore, a crucial step towards improving the confidence with which we are able to forecast its future contribution to sea level rise. Empirical data can help quantify Antarctic ice sheet responses to prior periods of global warmth; this in turn can be used to constrain numerical ice sheet models. The ability of a given model to reproduce past changes in Antarctic ice sheet configurations driven by paleoclimatic records yields confidence in predicted model responses to ongoing warming. Empirical ice history reconstructions require spatial and temporal data on past ice sheet configurations. The spatial element is achieved through geomorphological mapping of modern ice-free areas. The product of this mapping is a spatial dataset, in which identification, analysis, and distribution of glacial landforms provides insight to past configurations of a previously expanded ice sheet. Understanding when the ice was last more extensive, as well as the longer-term chronology - determining periods of ice sheet growth and down-wasting- towards its current configuration, is the temporal element of an ice sheet reconstruction. This is commonly achieved using cosmogenic nuclide (CN) surface exposure dating. CN surface exposure dating is a geochronological tool that has been developed and utilized over the past ~30 years leading to considerable advances in our understanding of geomorphic processes and landscape evolution (Granger et al., 2013). It has quickly become the method of choice for establishing the temporal component of studies in paleoglaciology and glacial geomorphology (Stokes et al., 2015). Applied to glacial geomorphology, CN exposure dating enables us to infer the timing of glacial extent, rate of retreat or down-wasting, as well as establishing erosion rates.

Bathymetric mapping and ice sheet modelling have established that the EAIS advanced close to the continental shelf edge in most places at its last maximum lateral extent during the global last glacial maximum (LGM) – also referred to as Marine Isotope Stage 2 (MIS2) which peaks ca. 20 -18 ka (Lisiecki and Raymo, 2005; Mackintosh et al., 2014; Railsback et al., 2015). However, global changes in post-LGM land-based ice volume (as established from empirical reconstructions and numerical modelling) disagree with inferred coeval sea level rise (Fairbanks, 1989; Lisiecki and Raymo, 2005; Dutton et al., 2015). This suggests that current empirical ice sheet reconstructions do not capture the full extent or volume of the LGM ice sheets (Lambeck et al., 2014). Some of this 'missing ice' is considered to result from an underestimate of the thickness of the EAIS at the LGM. In many ways this mismatch can be attributed to a lack of information on changes in the thickness of the ice sheet (Lambeck et al., 2014). This highlights the need for additional detailed reconstructions of the timing and rate of changes in the vertical extent (and therefore thickness) of the EAIS.

1.2 Objectives

Dronning Maud Land (DML), and in particular the western DML margin of the EAIS, presents a critical gap in what is already a limited empirical dataset on changes in the vertical extent of the EAIS (Mackintosh et al., 2014; Small et al., 2019), and for this reason western DML forms the focus region of this study (Fig.1.1, inset). The work presented here, contributes to MAGIC-DML (Mapping, Measuring and Modelling Antarctic Geomorphology and Ice Change in Dronning Maud Land). The principal objective of MAGIC-DML is reconstructing the long-term pattern and timing of changes in ice-sheet elevation (ice thickness, and therefore ice volume) across key coast-to-inland transects (Fig. 1.1) as the basis for constraining numerical models. Within the international MAGIC-DML consortium, a combination of geomorphological mapping, field investigations, cosmogenic nuclide analyzes, and numerical ice sheet modelling are being used iteratively to test the hypotheses that:

- the ice sheet has experienced long-term reductions in ice-surface elevation since the Pliocene (from ~5.3 Ma to present);

- the ice sheet margin last retreated from its maximum after ca. 20 ka (around the peak of the LGM), at which time the ice surface was hundreds of meters higher near the coast, but no higher and perhaps lower at the inland end of our transects (Fig 1.1);
- the pattern and timing of ice surface elevations change derived from field evidence provide constraints for numerical model reconstructions that allow for new insights into EAIS behavior.

A critical component of MAGIC-DML is the integration of empirical data into the numerical ice sheet model (an upgraded version of Bernales et al., (2017), with a nested high-resolution component across DML using the ELMER/Ice model (Gagliardini et al., 2013)). Therefore, the first step is to produce a detailed empirical reconstruction of the DML glacial history that can be used to constrain the modelling. Towards this effort, the work presented in this thesis contributes to an empirical ice sheet reconstruction for western DML; providing the geomorphological mapping (Chapters 2 and 3) which has guided sample collection for CN surface exposure dating over two field campaigns, will complement the results yielded from these samples, and will aid our interpretation of these results to infer the glacial history of western DML.

1.3 Study Area and Background

Dronning Maud land (sometimes referred to as Queen Maud Land) is the sector of Antarctica positioned between 20°W and 45°E (Fig. 1.1). It has some of the most extreme bed relief in east Antarctica (Fretwell et al., 2013), and is characterized by a prominent passive-margin escarpment ~200 km inland from the grounding line and trending SW-NE (Fig. 1.2). The escarpment is predominantly subglacial, though it includes extensive nunatak ranges (mountains protruding through the ice sheet) along its extent in our study area, including the Heimefrontfjella and Kirwanveggen ranges (Figs. 1.1 and 1.2). In western DML, the near-vertical cliffs of the escarpment constitute a major impediment to ice flow, resulting in up to 500 m difference in ice surface elevation between the polar plateau ice (Amundsenisen) and the downstream ice (Ritscherflya) (Figs.1.1 and 1.2). There are a number of additional nunatak ranges which protrude through the Ritscherflya in different sectors. As a consequence of the pronounced bed topography in the region, DML boasts one of the highest concentrations of nunataks within Antarctica, making it an ideal location to study changes in the vertical extent of the ice. Glacial landforms such as cirques and over-deepened troughs, which compose an alpine subglacial landscape in western

DML, were likely formed by mountain glaciers prior to a permanent ice sheet cover ~14 Ma (Holmlund and Näslund, 1994; Stroeven and Kleman, 1999).

Modelling of the long-term Antarctic ice sheet history highlights the mountainous landscape of DML as a probable nucleation site for the growth of the continent-wide ice sheet at the Eocene-Oligocene boundary ~34 Ma (DeConto and Pollard, 2003), and that until ~14 Ma DML acted as a seeding site, remaining ice covered while the rest of Antarctica fluctuated between ice-free states and ice covered (Jamieson et al., 2010). The EAIS has remained as a permanent and relatively stable feature since ~14 Ma (Näslund, 1997). Empirical ice sheet reconstructions have focused on its most recent history - the Pliocene and Quaternary. The overall trend observed is a general thinning of the ice sheet in Dronning Maud land since ~3 Ma. This view was first presented from field observations and age estimates based on the degree of weathering of glacial features such as tills on the exposed nunatak surfaces (Matsuoka, 1995; Lintinen and Nenonen, 1997) and has been supported by CN dating of nunataks in eastern DML (Altmaier et al, 2010; Suganuma et al., 2014; Strub et al., 2015; Yamane et al., 2015). The general thinning of the ice sheet since ~3 Ma appears to be consistent across the continent with cosmogenic nuclide surface exposure dating showing similar antiquity of exposed summits along almost all the ice sheet margins (e.g., Schäfer et al., 1999).

The current state of the ice sheet relates to its response to climate changes through the last glacial cycle and particularly the transition from the LGM (~20 ka) to today. There persists a degree of ambiguity with regards to both the DML ice sheet extent and its thickness at the LGM. It appears that during the LGM the DML sector behaved differently from the rest of the EAIS because there was not a significant advance of grounded ice offshore. In fact, according to Anderson et al. (2002) the ice sheet was only slightly extended from its present-day location. The vertical extent of the ice sheet surface (and therefore ice thickness) at the LGM is similarly disputed. At the eastern extent of the escarpment in DML, CN surface exposure dating constrains a maximum post-LGM thinning of tens of meters (Altmaier et al., 2010; Suganuma et al., 2014). Below the escarpment, near the present-day grounding line, estimates of vertical change in the ice sheet surface vary substantially. Based upon field observations of tills and unweathered boulders at Vestfjella (Fig. 1.1) Lintinen and Nenonen (1997) suggested the ice sheet was up to 700 m thicker here during the

LGM. Similarly, from their numerical modelling results Näslund et al. (2000) propose that at the LGM the ice sheet was hundreds of meters thicker near the grounding line. Preliminary modelling within the MAGIC-DML project however, indicates a thinner-than-present ice sheet for much of DML at the LGM. Because chronological constraints from CNs on the history of the DML sector of the EAIS during the LGM are very limited (Mackintosh et al., 2014), and lacking in western DML, these estimates remain inconclusive. Within this work to reconstruct the ice sheet history in western DML since the Pliocene, a key objective is to provide geomorphic, and geochronological evidence of its vertical extent during the LGM. In doing so we seek to remove some of the ambiguity surrounding post-LGM changes in ice sheet thickness in this region of the EAIS.

1.4 Methods

This thesis provides a snapshot of the work performed to date towards a complete empirical reconstruction of the glacial history of the EAIS in DML. The central emphasis of the thesis is the remote sensing-based geomorphological mapping and ground validation of this mapping for western DML. Two field campaigns have been completed as part of this project with the goals of sampling for CN surface exposure dating and conducting ground truthing of the mapping. The first field season was completed during the 2016-17 austral summer and focused on transect 3 (Fig. 1.1). The second field season during the austral summer 2017-18 targeted transect 1 (Fig. 1.1). This field work was guided by the geomorphological mapping (Chapters 2 and 3) which took advantage of access to very high-resolution WorldView (WV) satellite imagery (sub-meter, spatial) resolution to identify and map small-scale landforms at the individual nunatak-scale, for example, individual boulders on nunatak surfaces. Chapter 2 is a methodological manuscript evaluating the application of WV satellite imagery as the basis for remotely sensed geomorphological mapping. Chapter 3 presents the results of the geomorphological mapping which facilitated the selection of potential sample sites for CN surface exposure dating. Finally, Chapter 4 provides a summative conclusion of the work presented in this thesis and details the direction of future work planned within the MAGIC-DML project.

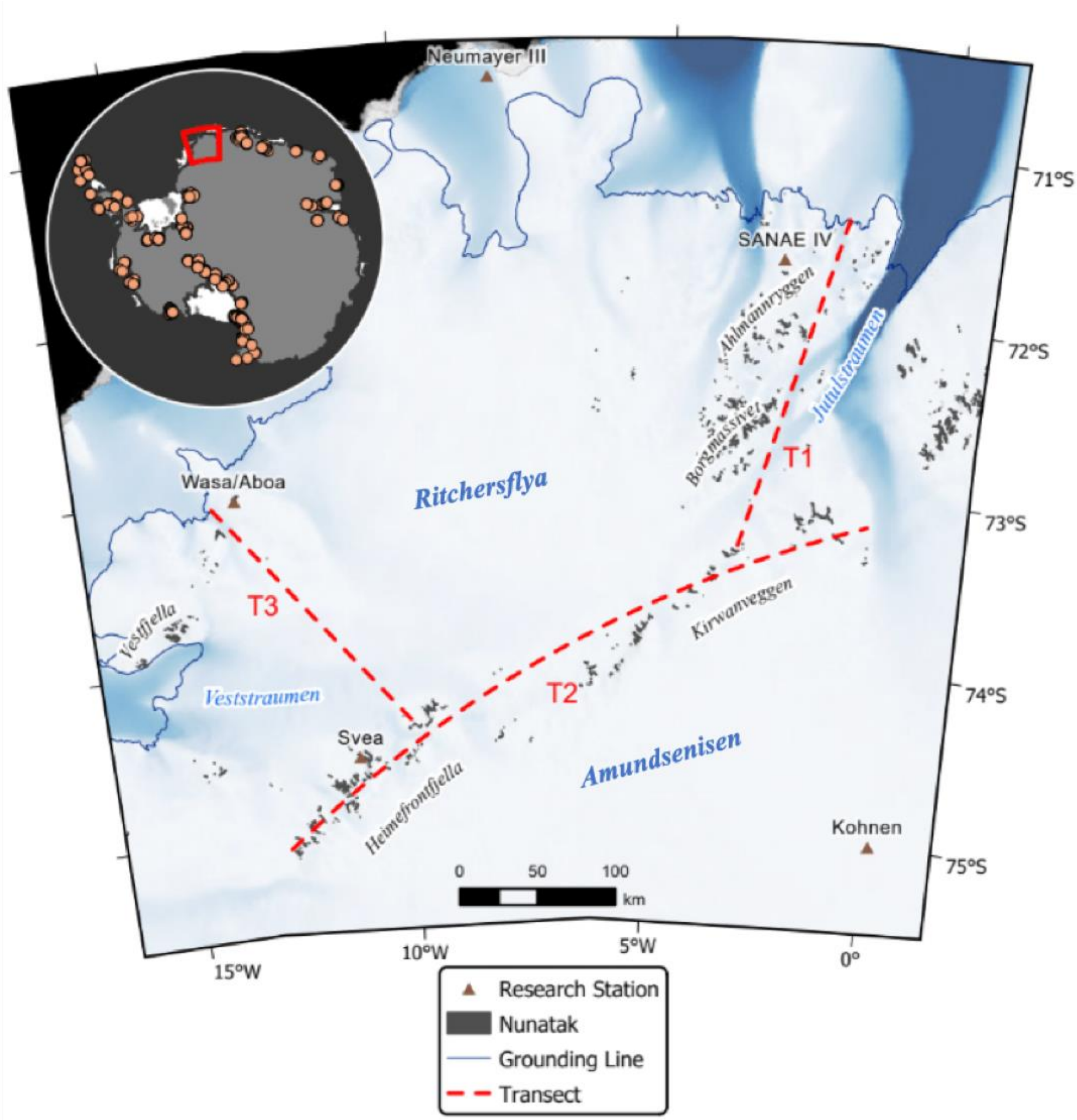

Figure 1.1 Study Area: western Dronning Maud Land

Map of the MAGIC-DML study area highlighting the three transects along which the study is focused. Geographical place names are indicated by italic text. The main nunatak ranges and ice streams mentioned throughout all chapters of the thesis are shown here. The two main bodies of ice (which are separated by the escarpment are also labelled. The MODIS satellite imagery is used for the base-map with the ice streams and glaciers in the study area indicated in blue – with deeper blues indicating higher velocities. Inset: Location of the study area within Antarctica (red polygon) with locations of published CN surface exposure dating results, highlighting the lack of data from DML.

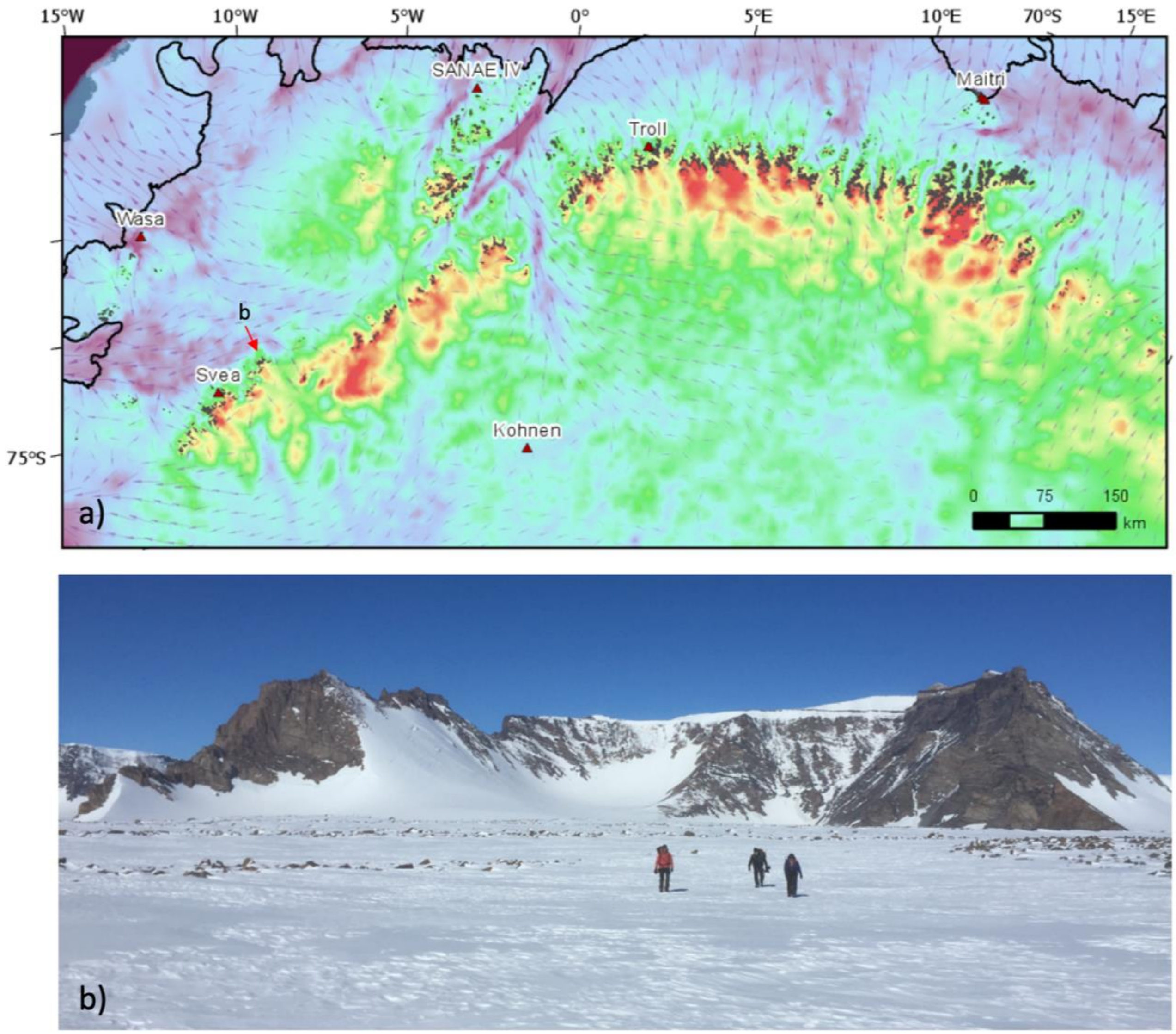

Figure 1.2 The physiography of Dronning Maud Land

Figure 1.2a shows the bedrock topography for DML taken from the Bedmap-2 dataset (Fretwell et al., 2013). The prominence of the escarpment is clearly seen. The purple arrows indicate direction of ice flow and the size of arrows represents the ice velocity (MEaSUREs (Rignot et al., 2017). It can be noted that the fastest flowing ice (ice streams) lie within the subglacial troughs. The location of b is denoted by the red arrow by Svea. b is a field photograph looking at the steep cliffs of the escarpment as seen from the Ritchersflya ice body at Milorgfjella. Photo: Neil Glasser.

CHAPTER 2. EVALUATING THE APPLICATION OF VERY-HIGH-RESOLUTION WORLDVIEW-2 AND -3 SATELLITE DATA TO THE REMOTE SENSING-BASED MAPPING OF ANTARCTIC GLACIAL GEOMORPHOLOGY

A version of this chapter is in manuscript form for submission to Remote Sensing – special issue on Geomorphological Mapping and Process Monitoring Using Remote Sensing.

2.1 Introduction

Historically, the spatial extent at which geomorphological mapping has been performed was limited, with field mapping efforts generally focussed on scales upto tens of square kilometers. Thus it required studies over many years to build up towards a more comprehensive understanding of larger areas, especially in regions the present considerable logistical challenges for fieldwork, such as Antarctica. This was primarily due to a limited availability of appropriate remote sensing data sets (Smith and Pain, 2009). With the advent of readily available satellite data providing widespread imagery coverage, it has become possible to complete glacial geomorphological mapping over much larger areas (e.g. Clark et al., 2004; Evans et al., 2005; Jansson, 2005; Glasser et al., 2008; Stroeven et al., 2013; Blomdin et al., 2014; Chang et al, 2015; Ely and Clark, 2016). However this was often at the expense of detail due to the limited spatial resolution of the available data (Smith et al., 2006). As technology evolves, the spatial and spectral resolution of satellite sensors continues to improve, delivering data which enables remote-sensing-based geomorphological mapping to be completed with greater detail (Smith et al., 2006; Napieralski et al., 2007; Smith and Pain, 2009), to the point that remote sensing is perhaps now the the best source of data for large scale applications.

In concert with rapid advancement in available satellite data, recent advances and evolution of glacial geomorphic methods (e.g. Kleman and Borgström, 1996; Kleman et al., 1997; Fabel and Harbor, 1999; Gosse and Phillips, 2001; Stokes et al., 2015) have driven a demand for the acquisition and utilisation of glacial geomorphological data spanning extensive areas. Remote and inhospitable environments, such as Antarctica, in which large-scale geomorphological mapping efforts are often focused point to another key advantage of such remote-sensing-based applications.

Critical and costly challenges in accessibility are key considerations for ground-based field geomorphological mapping studies.
Glacial geomorphological mapping is often applied to paleoglaciological reconstructions (Harbor, 1993; Kleman et al., 1997), and as Blomdin et al., (2014) emphasize, regional mapping is important for the consistency of such reconstructions across vast regions. Remote sensing-based mapping from aerial photographs and satellite data provides an effective solution to overcome this challenge, particularly when there is the possibility to combine the remote sensing work with field-based ground validation.

MAGIC-DML (Mapping, Measuring and Modelling Antarctic Geomorphology and Ice Change in Dronning Maud Land) is an international consortium with key objectives to produce an empirical-based reconstruction of the glacial history in Dronning Maud Land (DML), Antarctica - focusing on ice sheet thickness - and then use these data to train and constrain numerical ice sheet models. The main focus of the modeling is to produce a transient run of the last glacial cycle, therefore it is fundamental that our empirical reconstruction provides information on the extent and timing of ice configuration during this period. The reconstruction is focused on the coastal region of western DML between 15 °W and the Prime Meridian (Fig. 2.1). Given the vast extent of the study area (2.005×10^5 km^2) and limited accessibility of sites for field work, the geomorphological mapping must rely predominantly on remote sensing from satellite imagery and aerial photographs. Few aerial photographs exist for the study area at a sufficient quality and resolution for the purpose of geomorphological mapping at the level of detail required for ice sheet reconstruction. Until recently, the highest available spatial resolution of satellite imagery over DML was 30 m, from the Landsat 7 and 8 sensors. Landforms that can provide evidence of former ice sheet expansion in DML include glacially transported boulders (erratics), till deposits, and 'fresh' glacially polished bedrock. These features are generally smaller than can be identified from 30 m resolution imagery. New sub-meter resolution WorldView (WV) satellite imagery provides the opportunity to test mapping at the detail required for these glacial landforms. Our goal is therefore to combine remote sensing mapping with field validation to assess the ways in which the WV satellite data provides significant improvements over Landsat products in the context of glacial geomorphological mapping in Antarctica. Our evaluation of utilizing these new datasets in mapping glacial geomorphology can be applied to other regions of the world , as well as to different research fields where there is a need for higher resolution satellite imagery to identify features of interest. We also illustrate the invaluable asset this dataset proved to be for field safety and route planning in challenging and potentially dangerous remote regions such as Antarctica.

2.1.1 Study Region and Context

Dronning Maud Land (DML) was selected as a key region requiring ice sheet reconstruction since this part of the Antarctic margin has very little data pertaining to past glacial extent (Mackintosh et al., 2014; Small et al., 2019), but a relatively good abundance of ice-free terrain in the form of mountain summits protruding through the ice sheet surface (nunataks). Nunataks are an essential requirement for both geomorphological mapping and for the dating of glacial landforms using cosmogenic nuclide surface exposure techniques to provide the chronological component for ice sheet reconstruction (Fabel and Harbor, 1999; Gosse and Phillips, 2001; Stokes et al., 2015; Small et al., 2019).

The DML margin of the EAIS is characterized by an ancient coast-parallel passive margin escarpment approximately 200 km inland from the ice sheet grounding line. The escarpment is mostly buried by the ice sheet, but its highest summits create a string of nunataks which abut the edge of the polar plateau (cf. Heimefrontfjella and Kirwanveggen, Fig. 2.1). Ice velocities are generally below ~5 m yr^{-1} across the study area, except in the two named ice streams shown in Fig. 2.1 (Rignot et al, 2017) where velocities are generally in excess of 100 m yr^{-1}, and up to ~1000 m yr^{-1} in the Jutulstraumen. This ice flow pattern results from the ice sheet being predominantly cold-based, with warm-based erosive ice limited to the ice streams (Näslund et al., 2000).

MAGIC-DML completed two field seasons during the austral summers of 2016-17 and 2017-18. The two field campaigns were based from the Wasa (Sweden) and SANAE (South Africa) field stations, respectively. The primary objective of the field work was sampling for cosmogenic nuclide surface exposure dating. Ground validation studies were also completed at a number of sites across the field area (Fig. 2.1). During the first field season work focused along the Heimefrontefjella range. The second field season targeted the Ahlmannryggen and Borgmassivet ranges. As detailed in Chapter 2.4, general observations were recorded at all visited sites, in addition to the detailed ground validation study locations (Fig. 2.1). As the detail at which we can study the glacial geomorphology is so great (surficial features on individual nunataks) it is not possible to discuss in detail all the ground validation results here. Instead we present general themes/trends for the entire region, and select the nunataks which best exemplify the improvements/limitations that are discussed. It should also be noted here that, of all the nunataks studied in the pre-field work remote sensing, Vestfjella (Fig. 2.1) appeared most promising for the potential of well-preserved evidence for recent glacial change, and for sampling glacial erratics. It is also the only nunatak range in the study area that appeared to have moraine topography, and was thus identified as a key site for ground validation. Unfortunately, however, it was not possible to get to Vestfjella to complete field investigations and ground-truthing because snow conditions prevented travel to the nunatak during the field season.

2.1.2 Previous Work

Studies of Antarctic geomorphology are commonly site-specific investigations based on detailed field observations (e.g. Prentice et al., 1998; Hall and Denton, 2005; Carrivick et al., 2012; Suganuma et al., 2014). Regional remote sensing-based surficial mapping has generally focused on ice surface features such as longitudinal surface structures (Ely and Clark, 2016) and blue ice areas (Winther et al., 2001). Extensive field- and remote sensing-based geophysical surveys assessing the subglacial landscape, and lakes across the continent have been compiled to produce the BEDMAP-2 Antarctic-wide bed topography dataset (Fretwell et al., 2013). In DML, Holmlund and Näslund (1994) completed radio-echo sounding surveys across the ice sheet between (and including) Heimefrontfjella and Vestfjella (Fig. 2.1). Based on these they mapped the subglacial landscape and concluded that the glacial landforms identified indicate that the subglacial landscape here was formed prior to the inception of the EAIS by warm-based glaciers during alpine glaciations. There are few regional remote sensing-based glacial geomorphological studies across Antarctica that focus on features exposed above the ice surface. This is likely due to the limited ice-free land exposed for such studies across the continent, and the resolution of remote sensing data being insufficient for geomorphological mapping. Chang et al. (2016) mapped nunatak morphology across western DML from Landsat 7 ETM+ imagery (Table 2.1) and highlighted the limitations they faced in determining large-scale features. At the resolution of the Landsat imagery it was not possible to differentiate a broad ridge from an arete, and they discuss the difficulty they faced to ascertain morainal topography on either ice or nunatak surfaces, even with the aid of higher resolution aerial photographs. Chang et al., (2016) illustrate that from Landsat imagery it is possible to delineate nunatak extent and so large-scale glacial landforms such as cirques which are observed in the nunatak morphology are the limit of Landsat based mapping.

2.2 Methods

2.2.1 Data

The WorldView 'constellation' is a series of Earth imaging satellites, operated by DigitalGlobe, with hyperspectral capabilities that collect very-high-resolution images. A combination of Worldview-2 (WV-2) and Worldview-3 (WV-3) panchromatic and multispectral images were utilized in this work. The panchromatic sensors on WV-2 and WV-3 collect in the 450-800 nm wavelength range at a spatial resolution of 0.46 m and 0.31 m, respectively. The wavelength specifications of the 8 multispectral sensor bands for WV-2 (1.84 m spatial resolution) and WV-3 (1.24 m spatial resolution) are listed in Table 2.1.

For remote-sensing-based geomorphological studies, satellite data is ideally complemented by other data sources such as digital elevation and/or radar. However, at the time of completing this work, there were no such data products available for our study area. The RAMP DEM (Liu et al., 2001) was used to produce contours, which, together with orthorectified topographic maps, provided some information on elevation and slope. However, the resolution of these elevation products was too low (RAMP DEM has a spatial resolution of 200 m) to be appropriate for being integrally combined in the workflow. During the mapping process, Google Earth was occasionally relied upon for its 3-D and perspective viewing capabilities which provided a reasonable sense of slope. However, the resolution was again too low to be appropriate for the detail at which we were mapping, and the error associated with the Google Earth elevation data too high to be relied upon. As such, it should be emphasized that the evaluation of the advantages and limitations of using WV imagery as the basis for studying glacial geomorphology is based entirely on the satellite imagery alone.

In September 2018 the reference elevation model of Antarctica (REMA) was released – an 8 m resolution DEM product derived from WV stereo-pairs (Howat et al., 2019). Although these data were not available during the remote-sensing-based mapping discussed here and in Newall et al., (2020), the REMA dataset is a DEM at the appropriate resolution (2 m resolution is available on request) to be combined with the WV satellite imagery for future mapping efforts.

A range of Landsat data has been utilized as a basis for comparison, both to the WV images, and also to previous remotely sensed geomorphology studies (Chang et al., 2016, and in-house, unpublished Landsat-based mapping). The Landsat Image Mosaic of Antarctica (LIMA) is a mosaic product with a pan-sharpened 15 m spatial resolution which was produced using Landsat-7 ETM+ imagery (Table 2.1). The first iteration of the remotely sensed geomorphological mapping was based on LIMA imagery. Later updates, and an expansion of the mapping, first utilized the Landsat-8 OLI imagery. Landsat-8 OLI is the newest and most advanced of the Landsat satellites (Table 2.1), however, it was apparent that despite the increased spectral resolution (8-bands, plus panchromatic and SWIR) provided by Landsat 8 OLI, the spatial resolution of this Landsat product was still insufficient for our objective to identify and map evidence of previous ice sheet expansion onto the nunataks. Given the reduced use of the Landsat 8 OLI data in this study, the comparison we present (Section 2.3.1) is between the Landsat 7 ETM+ imagery from LIMA and WorldView (WV-2 and WV-3) imagery.

2.2.2 Data Processing

Over 4500 orthorectified WV scenes from the multispectral sensors, and a combination of individual scenes and composite mosaic tiles in panchromatic were obtained (Fig. 2.2), with acquisition dates between 2012 and 2016. A visual quality check on each image provided an initial filter, and then the best images were selected manually. Around 30% of the images were thus found to be of insufficient quality due to a combination of cloud cover, overexposure, and the presence of striping (an artifact of the initial image processing). An effort was made in this selection process to use images with similar timestamps, though this was not always possible and, for the purpose of this work, image quality was prioritized. From the selected WV images, we created a full area single-coverage mosaic dataset from both the multispectral and panchromatic imagery covering the most prominent nunatak ranges (Fig. 2.2). It should be noted that the WV-3 imagery was not mosaicked due to the incomplete coverage and was instead merely utilized on a nunatak-by-nunatak comparison basis. The incomplete coverage of the WV-3 satellite imagery most likely results from the fact that the satellite was launched in August 2014, and earliest data collection over our area is from 2015. A complete list of the WV scenes utilized in this work is provided in Appendix B.

The satellite images were interpreted manually with a focus on glacial geomorphology and surficial stratigraphy. General observations were noted and ten categories of glacial landforms and deposits were visually identified and mapped (Chapter 3). Manual digitization of identified features, and insertion of point observations, were completed using ESRI ArcGIS software. Various combinations of the multispectral bands were experimented with guided by optimal wavelengths and color composites identified from previous remote sensing mapping in glacial regions (Jansson and Glasser, 2005). For the identification of glacial geomorphological features, the images were studied in the panchromatic band and three different color composites (Fig. 2.3); 'natural color' – 5,3,2 (R, G, B), 'standard false color' – 7,5,3 (NIR1, R, G), and 'modified false color' – 7,3,2 (NIR1, G, B). The standard false color composite (Fig. 2.3b) was optimal for mapping ice features since it enhances the contrast between snow and ice, and blue ice areas stand out as a brighter cyan blue. Textures, patterns, and features smaller than ~0.5 m (such as individual boulders) were often best viewed in the panchromatic (Fig. 2.3c), and the modified false color composite (Fig. 2.3d) enhanced subtle color differences in the darker blacks, browns and reds therefore was utilized in distinguishing different surficial units.

2.2.3 Geomorphological mapping

The remote sensing-based investigations and mapping of the glacial geomorphology and surficial stratigraphy in western DML were completed over 3.5 years through a number of pre- and post-fieldwork iterations, during which the set of features mapped were refined to a total of ten categories for inclusion in the final map product (Chapter 3). Throughout all generations of the mapping, attention was focused on features which provide an indication of recent changes in the ice thickness and its downwasting (resulting in the exposure of nunatak surfaces) such as till deposits and glacial erratics. A till is formed by the erosion, transportation, and deposition of glacially eroded substrate (bedrock and sediments (Benn and Evans, 2010)). The resulting deposit typically consists of unsorted sediment - a mixture of lithologies, and clast sizes ranging from clay to boulders. Clasts within a till tend to be sub-angular to sub-rounded and elongated clasts may have a tendency to attain a preferential orientation. Tills can be deposited with a range of morphologies including thick till 'blankets', moraine ridges, hummocky moraine, and streamlined landforms such as drumlins. A thin (< ~1 m) cover of till is considered to be a till veneer. A glacial erratic is a glacially transported clast (anything pebble-sized or larger) of a lithology different from that of the bedrock upon which it sits. The largest erratics we observed during the field work measured ~4 m at their longest axis. As such, these features are too small and subtle to be identified from Landsat imagery. In the following sections (Sections 2.2.4 and 2.3.2 in particular) we evaluate the ability to correctly identify these features (and other glacial landforms) from the WV satellite imagery.

While just ten landform categories were included in the final map, many other features were included in the study of the glacial geomorphology and/or the early generations of the mapping. Ahead of the first field season we had around 20 different feature classes which were then refined and amalgamated based on a) ground-truthing completed during the two field campaigns, and b) the significance of the features to the paleoglaciological reconstruction. Some features that were omitted from the final map are discussed here in the context of evaluating the implementation of the WV satellite imagery to remote sensing glacial geomorphological studies. The feature class *sediment cover* which was adopted for the published map resulted from the grouping of ‘till’, ‘till veneer’, ‘talus’, ‘felsenmeer’, and ‘regolith’ into one category after the ground truthing revealed an inability to apply the contextual assumptions employed to differentiate between such deposits in the remote sensing analyzes. These assumptions were employed in an attempt to determine glacially derived deposits, and were:

1) Where patterned ground is observed (polygons or stripes) the surficial material is a till deposit.

2a) Where an individual boulder is observed on a flat or gently sloping surface far from any cliffs it must be a glacial erratic.

2b) Where a scattering of erratics is observed over a plateau summit this can be classified as a till veneer.

3) Sediment cover at the base of a slope or cliff is a talus (or scree slope) deposit.

4) Where a surface appears to be homogenous in terms of its texture and/or color it is bedrock – the texture defining its classification as either polished bedrock, felsenmeer, or regolith.

5) That heterogeneity in the color and/or texture observed in the satellite imagery could be interpreted as a depositional feature such as till.

2.2.4 Ground validation

Direct field-based observations (ground-truthing) are used to validate remotely sensed interpretations. Field-checking that reality and the observations made from satellite images agree provides an assessment of the accuracy of remote-sensing-based interpretations and can allow for assumptions (such as discussed in Section 2.2.3) to be extrapolated regionally.

As described in detail earlier, two field campaigns were completed in which we worked to validate the the remote-sensing-based mapping and completed additional studies to classify surficial material. To complete the ground validation studies we used GPS enabled Getac field tablet computers with ArcGIS Desktop® 10.3 in the field. This enabled inspection of the satellite images and mapping in real time. It also provided the capability to navigate to specific locations that had been desktop-flagged for sampling, ground-truthing, and further investigation. A point feature class was created for this purpose, allowing us to highlight and visit areas of uncertainty or interest, observed at the time of mapping. The ability to view the imagery and site conditions at the same time was an asset to the ground validation and to an overall evaluation of what features are accurately identifiable from the WV satellite imagery. General observations and field checking of the mapping were recorded at all nunataks visited during the fieldwork, with detailed studies carried out at Basen (Wasa/Aboa stations), Milorgfjella, Huldreslottet, and Grunehogna (Figs. 2.1 and 2.2). These detailed studies also included observations beyond the scope of this paper, such as sediment facies analysis, boundary tracing, and clast counts.

2.3 Results

2.3.1 Increased detail of glacial geomorphological mapping

The order-of-magnitude improvement in the spatial resolution of WV compared to that of LANDSAT imagery proved to be a highly valuable resource for the remote-sensing-based analysis of the glacial geomorphology in western DML. Landforms were identifiable with unprecedented clarity and, although classification of surficial material proved challenging, the detail provided by the WV imagery meant it was possible to distinguish and map differences in the surficial material. Figure 2.4 shows a comparison of the Landsat imagery to the WV imagery, illustrating the improvement in the detail that can be seen in the WV imagery.

The scale at which an image becomes pixelated (reflecting spatial resolution) is the limiting factor in the size of features which can be identified. As shown in figure 2.4, the LIMA images become pixelated when viewed at any scale beyond 1:40,000. In comparison, the WV multispectral images become pixelated at around 1:2,500, and the panchromatic images at around 1:800. This substantial improvement has enabled sub-meter-sized features and boundaries to be observed in the WV imagery thus significantly increasing the number and types of features that can be identified by remote sensing (e.g. Fig. 2.5). Features that were not identifiable from the Landsat imagery were easily distinguished in the WV images. Here we illustrate two examples of where the WV imagery enabled us to overcome the challenges discussed (in Section 2.1.2) when mapping from the Landsat imagery; determining supraglacial from surficial deposits (Fig. 2.6), and differentiating units of surficial cover (Fig. 2.7).

Differentiating between surficial and supraglacial material was a substantial challenge and source of error (in the form of inaccuracies) for the LIMA-based studies (Chang et al., 2016). Figure 2.6 illustrates the fact that this challenge is almost completely removed when mapping from the WV imagery. As discussed in Section 2. 2.1 perspective viewing (3-D visualization) was occasionally problematic since suitable topographic data (DEM) was not available, but in those instances the contextual information was often enough to distinguish the nunatak-ice boundary. The only setting in which it was not possible to determine the nunatak-ice boundary (and therefore distinguish surficial from supraglacial material) is where the lack of perspective was combined with significant shadowing.

In the LIMA-based studies differences in the texture and color of the nunatak slopes were not visible. This is due to both the reduced spatial and spectral resolution of the Landsat-7 ETM+ sensor. Landsat-8 OLI's increased spectral resolution enabled a slightly improved detection of such differences in surficial cover, but the spatial resolution made it difficult to distinguish any boundaries between different units of surficial material. Figure 2.7 demonstrates how textural and color differences can be seen clearly in the WV imagery, at a scale which enables different units of surficial material to be mapped.

2.3.2 Ground validation

The field check on the mapping provides a fundamental and objective evaluation of the benefits and limitations of the WV satellite imagery in remote sensing studies of Antarctic geomorphology. Substantial changes were made to the remotely sensed mapping following the field investigations. These changes were almost entirely due to the amalgamation of a range of deposit types into the sediment cover feature class, as the ground-truthing showed that attempts to differentiate glacial deposits from highly weathered bedrock, regolith, or talus deposits from the satellite imagery were not successful. It would perhaps appear that the ground validation revealed a limited capacity for the detailed geomorphological mapping of nunatak surfaces based on WV satellite imagery. However, except for the challenge in classifying sediment cover, the WV imagery-based mapping was accurate. On the few occasions where features (other than sediment cover) were mis-identified we can attribute this to either overinterpretation or a lack of elevation data at a sufficient resolution to accompany the satellite imagery. The following discussion of specific observations from the ground truthing presents examples of, and evidence for, these factors being dominant in the misidentification of features.

Emergent nunataks (Fig. 2.8) were of great interest since it was considered that they presented the best potential for well-preserved evidence of recent glacial cover and subsequent ice recession. Additionally, in the context of the overall project they appeared to be prime potential sampling sites. Emergent nunataks were identified in initial mapping iterations based on observations of relatively small (less than ~0.5 km^2) isolated areas of 'snow speckled' rock which appear to be relatively flush with the surrounding ice surface – as determined by lack of shadowing on the ice.

These mapped features were interpreted to be nunatak surfaces that had emerged from a lowering ice surface relatively recently. The ground check of these features showed that in reality the surface material on the nunataks was almost always highly weathered bedrock, often with ventifact faces and pitting on individual clasts, suggesting an antiquity to these surfaces which challenges our interpretation of them as being ‘emergent’.

Additionally, despite sharing common observational criteria in the satellite imagery, each of the “emergent” nunataks we visited were in fact quite different from one another; a common misidentification problem was that a number of mapped “emergent” nunataks, which appeared in the imagery to be small areas of bare weathered rock flush with the ice surface, actually had considerable above-ice relief (Fig. 2.8). In contrast, Fossilryggen – a nunatak which in reality fits the criteria of an emergent feature was not identified as such in the remote-sensing since the full criteria established for mapping an “emergent” nunatak were not met at this site. Such misidentifications would be reduced with more detailed elevation data.

Patterned ground (Fig. 2.5) is an important landform to map since it forms in unsorted sediments that in this context would be typical of glacial origin (rather than physical weathering), therefore providing convincing evidence of ice formerly covering the site. It was also a fundamental landform in our geomorphological investigations as it forms the basis of the first contextual assumption used in the classification of a till deposit (Section 2.2.3). Ground-truthing revealed that patterned ground observed from the satellite imagery was often misinterpreted. The majority of the mapped patterned ground units we visited in the field were in fact, the surficial expression of bedrock structure. The patterned ground feature class was therefore significantly reduced following ground validation. Access to the imagery in the field allowed us to identify subtle textural characteristics in the correctly identified units of patterned ground such that we were able to expand these observations to correct the feature class across the entire study area. Of the 108 individual units of patterned ground initially identified, 37 remain after ground truthing, yielding an increased confidence in accuracy for this feature class.

Steep ground, and the gradient, aspect, and morphology of nunatak slopes in general, was not always evident from the satellite imagery. The 2-D imagery made it difficult, at times, to establish perspective. For example, vertical cliffs could look like gentle, accessible slopes and arete-like ridges often appeared as if they were much broader. Shadows were normally a reliable indication of ridge morphology and steep cliffs. Given the fundamental implications of the interpreted nunatak morphology to all observations made from the satellite imagery and the fact it underlies a number of the contextual assumptions, this realization from ground validation again emphasizes the need for reliable elevation data in geomorphological studies.

Glacial erratics were elusive, in the sense that many large glacially transported boulders were observed in the WV imagery (Fig. 2.5) and in the field. However true erratics (composed of a distinctly different lithology from the underlying bedrock) were rarely observed, and the majority of the glacially transported boulders were in fact local erratics – in that the bedrock directly underneath the boulder was lithologically different, but the boulder lithology could be found nearby. The geology of the field area meant finding unequivocally far-traveled "true" glacial erratics was difficult. The escarpment nunataks are composed of vertically jointed sequences of the Proterozoic Maudheim province basement crystalline rocks (gneisses and quartzites). The orthogneiss in particular exhibited a wide compositional and textural variability. This resulted in a range of repeating rock types exposed across short distances. Thus it was often almost impossible to ascertain if the source rock of an apparent erratic was the unit exposed far upstream or from a nearby source. Nunataks in the coastal regions were typically composed of the Ritcherflya supergroup (meta-sedimentary units) or of Triassic basalts and intrusives. No erratics of the basement lithologies were found on these nunataks, and again there was ambiguity as to the source of the potential erratics we did encounter since often the lithology was exposed nearby. From the satellite imagery alone it is not possible to determine the lithology of a large boulder, or even if it differs from the underlying bedrock. It is also not possible to determine whether or not a boulder identified in the satellite imagery was glacially emplaced – that requires contextual assumptions (Section 2.2.3) which the ground validation showed to be broadly correct. As such, whether "true" or "local", glacial erratics are emplaced by the ice and therefore both provide evidence of the ice sheet having formerly covered the site.

2.4 Discussion

2.4.1 Application of WV satellite imagery to remote sensing studies of glacial geomorphology

Our results illustrate the increased detail at which remote sensing-based geomorphological mapping can be achieved by using WV satellite data. Certainly, for remote and harsh environments such as Antarctica, where it is not practical (or even possible) to complete widespread field-based studies, the ability to utilize remote sensing techniques is a key advantage. The enhanced remote-sensing-based mapping of geomorphic features facilitated by the WV satellite imagery proved invaluable in terms of the greater detail at which we could study the nunatak surfaces.

The ground validation work, however, highlights some important limitations which need to be overcome ahead of a widespread application of geomorphological mapping at the nunatak-scale, especially in regards to the classification of surficial deposits. The composition (whether clast lithology is heterogenous or homogenous), and character (clast size and angularity) of a deposit are key criteria upon which sediment deposits are classified. However, this is not information that can be obtained through studying satellite imagery in the traditional way. Such information is acquired through field investigations and can only be applied regionally if there is a consistent and unique appearance to the deposit in the satellite imagery. Our field investigations showed that till was rarely observed in our field areas, and that where it was observed it was not widespread. The composition, characteristics and morphology of each of the tills observed in the field differed from one site to the next therefore it was not possible to correlate any particular appearance in the satellite imagery to be representative of a till. As such the identification of a till from satellite imagery can only currently be based upon its morphology and context, as per the classification assumptions (Section 2.2.3) that were applied prior to ground-truthing.

We suggest that the limitations identified in our study do not represent inadequacies of the WV imagery as applied to the observation and identification of geomorphic features, but instead show that the depositional features targeted in our work are generally lacking from the study area. The basal thermal regime of an ice sheet acts as a critical control on the erosive power of the ice and whether it modifies or preserves the landscape it flows over (Kleman,1994). As is mentioned in Sections 2.1.1, and 2.1.2, the ice sheet in DML is cold-based, and likely has been since the EAIS became a permanent feature ~15 Ma (Näslund et al., 2000). The only exception to the cold-based ice sheet being within ice streams, deep subglacial troughs, and some of the glacial breaches along the escarpment where selective linear erosion focuses warm-based erosive ice along structural lineations (Sugden, 1978). It is therefore not surprising that we find minimal evidence on the nunatak surfaces for cover by warm-based ice since the minimal exposed surfaces (rock exposures make up just 0.17% of the study area) that we can study are exclusively the landscape summits. These nunatak surfaces are the interfluves in the selective linear erosion model and therefore have been covered almost exclusively by cold-based ice which acts to preserve the underlying landscape. Both the field-, and remote-sensing-based investigations did however reveal limited glacial deposits and features such as striations (only identifiable in the field), "true" and "local" glacial erratics and till deposits, indicating that these surfaces have been covered by erosive ice at some point in the glacial history. This implies that the basal thermal regime has not been exclusively cold-based, and that some periods of cover by warm-based, erosive ice have occurred. The result is a palimpsest landscape, a predominantly ancient landscape with the occasional scattering of younger landforms (Kleman, 1992). The age of these younger landforms is being determined through cosmogenic nuclide surface exposure dating of samples collected during the fieldwork.

2.4.2 Use of WV satellite imagery in field planning and safety

An important aspect of the use of remote sensing in Antarctic science is to guide selection of study sites and safe routes across the ice to these sites. The remote sensing work presented here guided the choice of sites ahead of the two field campaigns during the austral summers of 2016-17 and 2017-18, based on suitability for ground truthing and sampling for cosmogenic nuclide dating. While accessibility analysis and safe route planning were part of target site ranking protocols, it remained very much a secondary application of the WV satellite imagery. However, because it proved to be invaluable to logistical planning and field safety, we offer a short discussion of the application of WV satellite data to polar logistics. We identify three key means by which the WV satellite imagery proved invaluable to field planning and logistics: (1) field safety, (2) sample site selection, and (3) accessibility analysis and route planning.

Field safety – The utilization of WV satellite data in the detailed planning of the field routes has its largest benefit in terms of increased field safety. Crevasses are one of the biggest dangers for field teams working in glacial environments. The ability to identify (through mapping) the presence of crevasses was instrumental in route planning and enabled site visits that otherwise would have been deemed as unsafe. GPS tracks of established routes were overlain on the imagery to double-check their safety, and new routes drawn from the WV satellite imagery were entered as target 'paths' in the GPS device to guide safe maneuvering. While not infallible in identifying all crevasses, the panchromatic imagery enabled potential dangers (primarily the largest crevasses) to be identified and avoided.

Sample site selection – The selection of sample sites ahead of field work provided significant improvements in efficiency and thus optimized our use of limited field time. Potential sampling sites were identified from the mapping, and then filtered down to target sites following accessibility assessment and considerations of logistical challenges. This process increased the efficiency of the field teams which is of great importance given the expense of Antarctic expeditions, limited time available to conduct field work (short summer with even shorter 'windows of opportunity' of good weather), and the harsh working environment.

Accessibility analysis and route planning – Since the target field sites were selected prior to going into the field it was possible to plan optimal routes (considering time and fuel) to visit them. The establishment of new routes is often slow and expensive. This can be limiting to science (and present a bias in the data collected) when there is a need to explore beyond established routes. Given that crevasse detection and avoidance is a major task in the establishment of new routes the ability to detect them from the WV imagery enables much of this work to be completed prior to going into the field and reducing the ground-time required to establish new routes. This route planning and accessibility analysis allowed for an optimal and less biased access of sampling sites.

2.5 Conclusions

The spatial and spectral resolution of the WV satellite data provides the potential for remote sensing geomorphology studies to be completed at an unprecedented level of detail. This is not unexpected, given that WV satellites provide imagery at a resolution which is an order of magnitude better than any satellite imagery available previously for general scientific use. Landforms and deposits that were previously undetectable are now observed with exceptional clarity. We show that the limitations we faced result from the fact that there actually is quite limited evidence to be detected (whether by remote sensing or by field investigations) for surface glacial geomorphology on nunataks in western Dronning Maud Land. We emphasize the fact that the need for ground-truthing is not removed, despite the detail and clarity seen in the WV imagery. We suggest the WV satellite data opens up a great potential for Antarctic-wide detailed geomorphological mapping, which can be utilized in reconstructing the ice sheet history. Additionally, we would highly recommend the use of WV data by polar logistical programs in their preparation and planning of polar fieldwork. Antarctica is an expensive and harsh environment to work in. For field safety and cost reduction of field-work it is optimal to utilize remote sensing where possible both in data collection and in field planning. We have shown that the WV satellite data offers significant improvements in our ability to do this. Overall, we show the WV data to be a valuable resource to aid and advance the capabilities of remote sensing based geomorphological studies.

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Table 2.1 Sensor band specifications and resolutions

Landsat 7 ETM+			**Landsat 8 OLI**			**WorldView-2**			**WorldView-3**		
Launch Date		15/04/1999	Launch Date		11/2/2013	Launch Date		8/10/2009	Launch Date		13/08/2014
Orbit Altitude		705 km	Orbit Altitude		705 km	Orbit Altitude		770 km	Orbit Altitude		617 km
Band	Wave-length (nm)	Resolution	Band	Wave-length (nm)	Resolution	Band	Wave-length (nm)	Resolution	Band	Wave-length (nm)	Resolution
Panchromatic (Band 8)	520-900	15m	Panchromatic (Band 8)	503-676	15m	Panchromatic	450-800	0.46m	Panchromatic	450-800	0.31m
1-Blue	450-520	30m	1-Ultra Blue	435-451	30m	Costal	400-450	1.84m	Costal	400-450	1.24m
2-Green	520-600	30m	2-Blue	452-512	30m	Blue	450-510	1.84m	Blue	450-510	1.24m
3-Red	630-690	30m	3-Green	533-590	30m	Green	510-580	1.84m	Green	510-580	1.24m
4-NIR	770-900	30m	4-Red	636-673	30m	Yellow	585-625	1.84m	Yellow	585-625	1.24m
5-SWIR 1	1550-1750	30m	5-NIR	851-879	30m	Red	630-690	1.84m	Red	630-690	1.24m
6-Thermal	-	-	6- SWIR 1	1566-1651	30m	Red Edge	705-745	1.84m	Red Edge	705-745	1.24m
7-SWIR 2	2090-2350	30m	7-SWIR 2	2107-2294	30m	NIR 1	770-895	1.84m	NIR 1	770-895	1.24m
			9-Cirrus	1363-1384	30m	NIR 2	860-1040	1.84m	NIR 2	860-1040	1.24m

NIR = Near infrared, SWIR = Shortwave infrared. The WorldView-3 satellite also has 8 SWIR sensors (3.7 m resolution) and 12 CAVIS - Clouds, Aerosol, (water) Vapour, Ice and Snow - sensor bands (30 m resolution), but these are omitted from the table since this data was not obtained or used in our work. Similarly, Landsat 8 OLI also has two thermal infrared sensor bands in addition to the multispectral bands listed here.

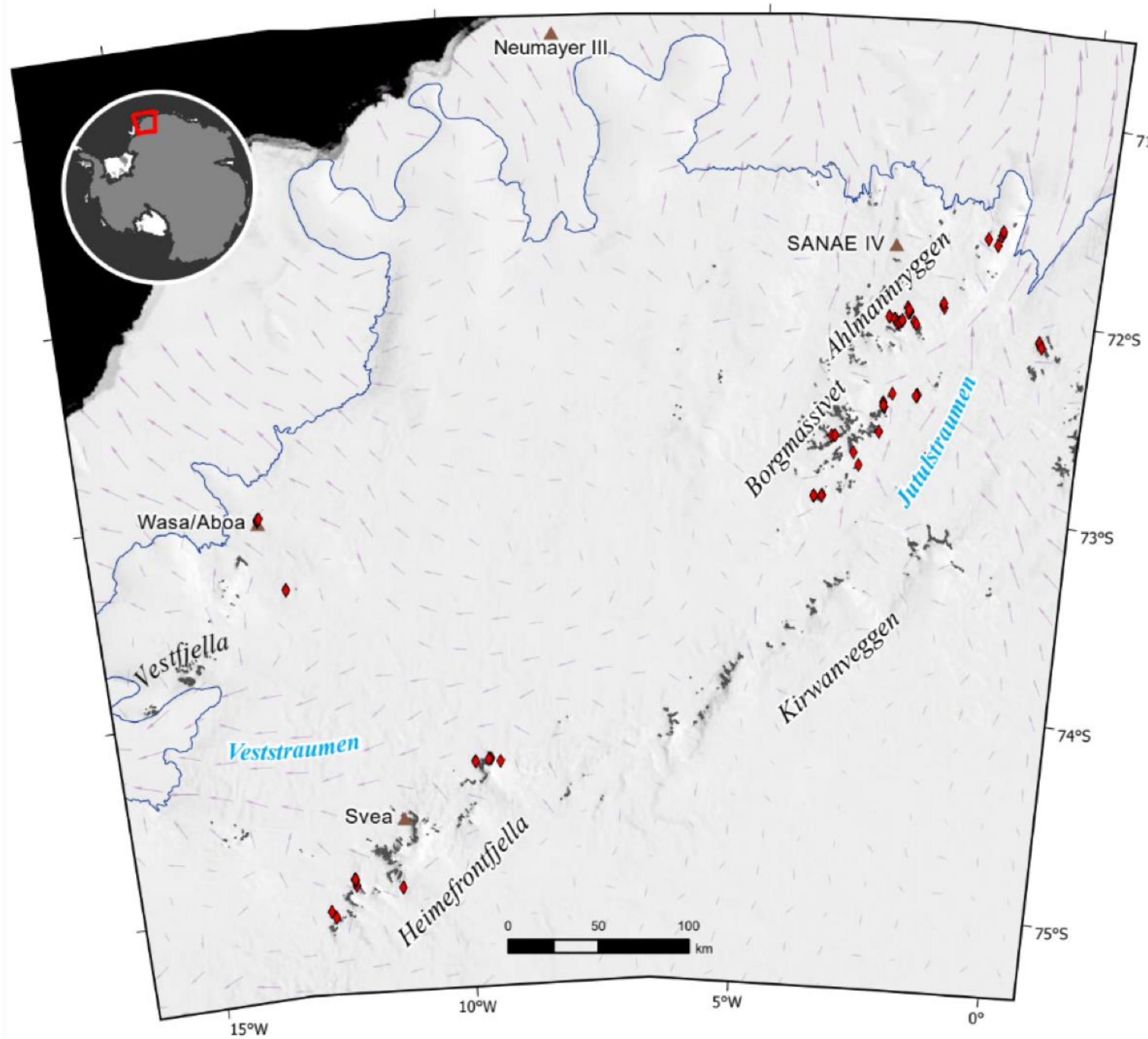

Figure 2.1 Study area indicating sites visited during fieldwork

The study area of western Dronning Maud Land, Antarctica (inset) is shown with bases (brown triangles), key nunatak ranges (black italic text), and ice streams (blue italic text) labelled. The modern grounding line (blue line), and ice flow direction and velocity (purple arrows - MEaSUREs dataset, Fretwell et al., 2017) are shown to illustrate the present extent and flow regime of the ice sheet in this region. Sites for ground truthing during field seasons 2016/17 and 2017/18 are denoted by the red diamonds. Inset indicates the location of the study area within Antarctica

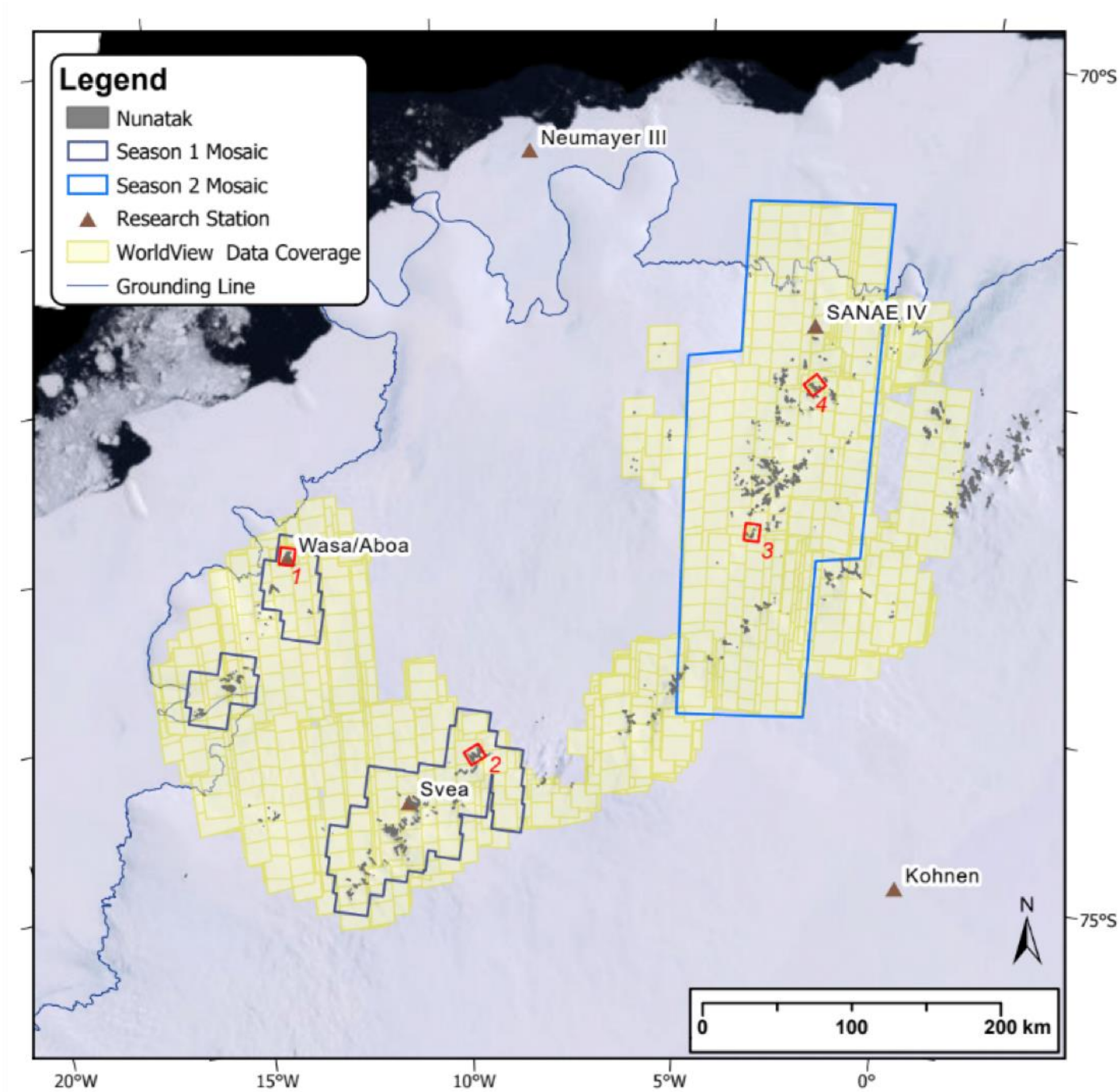

Figure 2.2 WorldView satellite data coverage

Figure 2.2 Shows the spatial coverage of the WV satellite data utilized in this work and the extent of the mosaic datasets created for the two field areas. Red boxes denote the location of the nunataks discussed in section 2.2.4 as the field sites where detailed ground truthing was completed: 1- Basen, 2- Milorgfjella, 3- Huldreslottet, 4- Grunehogna. The LIMA mosaic is used as the basemap.

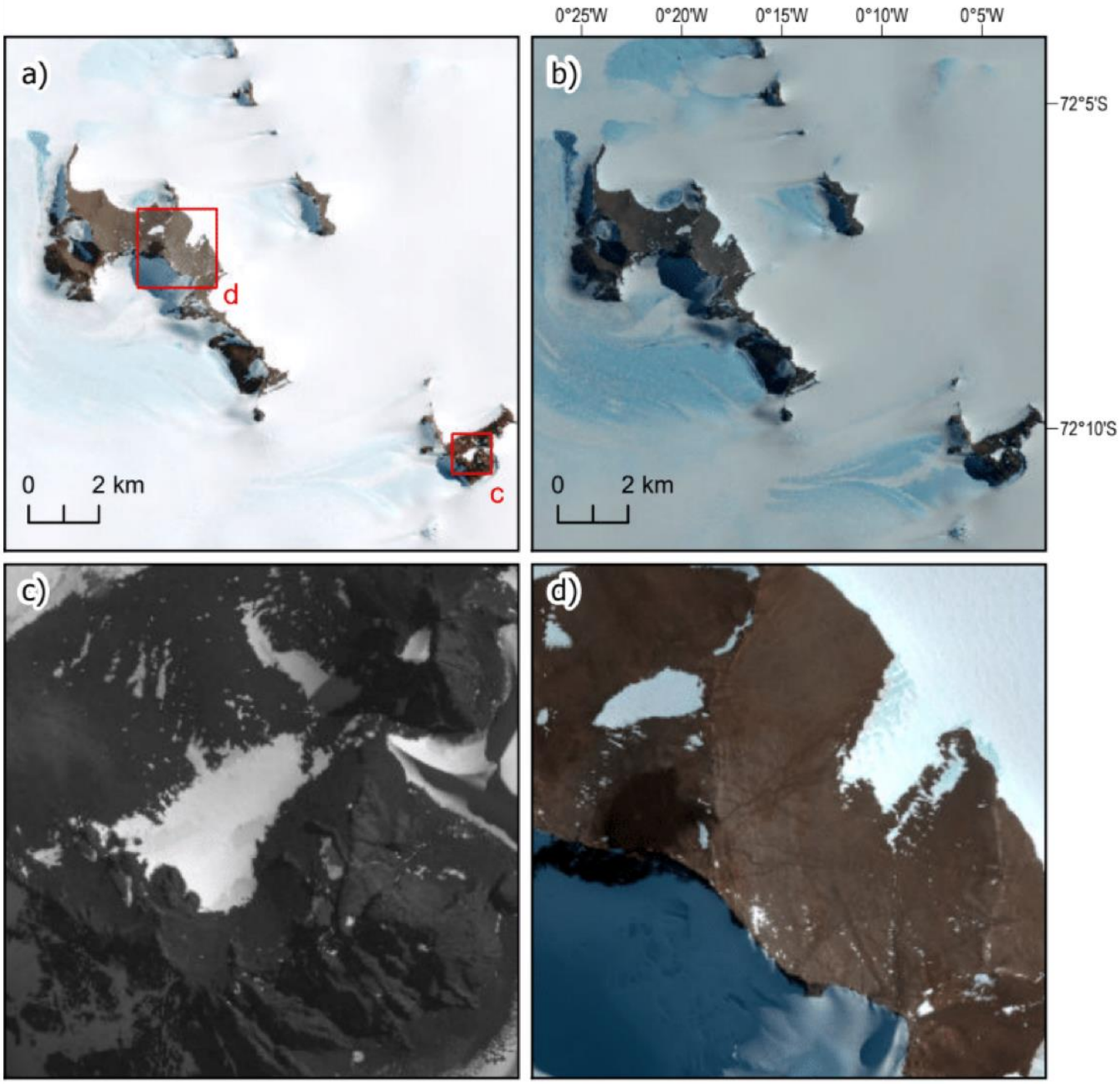

Figure 2.3 WorldView color composites

The four panels show the spectral band combinations used: a) natural color, b) standard false color, c) panchromatic, and d) modified false color. The red boxes in panel a show the extent of c, and d. The standard false color (b) emphasizes ice features, and blue ice areas stand out in this color composite. Smaller features such as boulders, surface texture, and morphology (such as ridges) are best observed in the panchromatic (b). The modified false color composite (d) enhances subtle color differences such as the changes in the bedrock seen in the nunatak slope in the center of the image, and the 'pocket' of sediment on the summit.

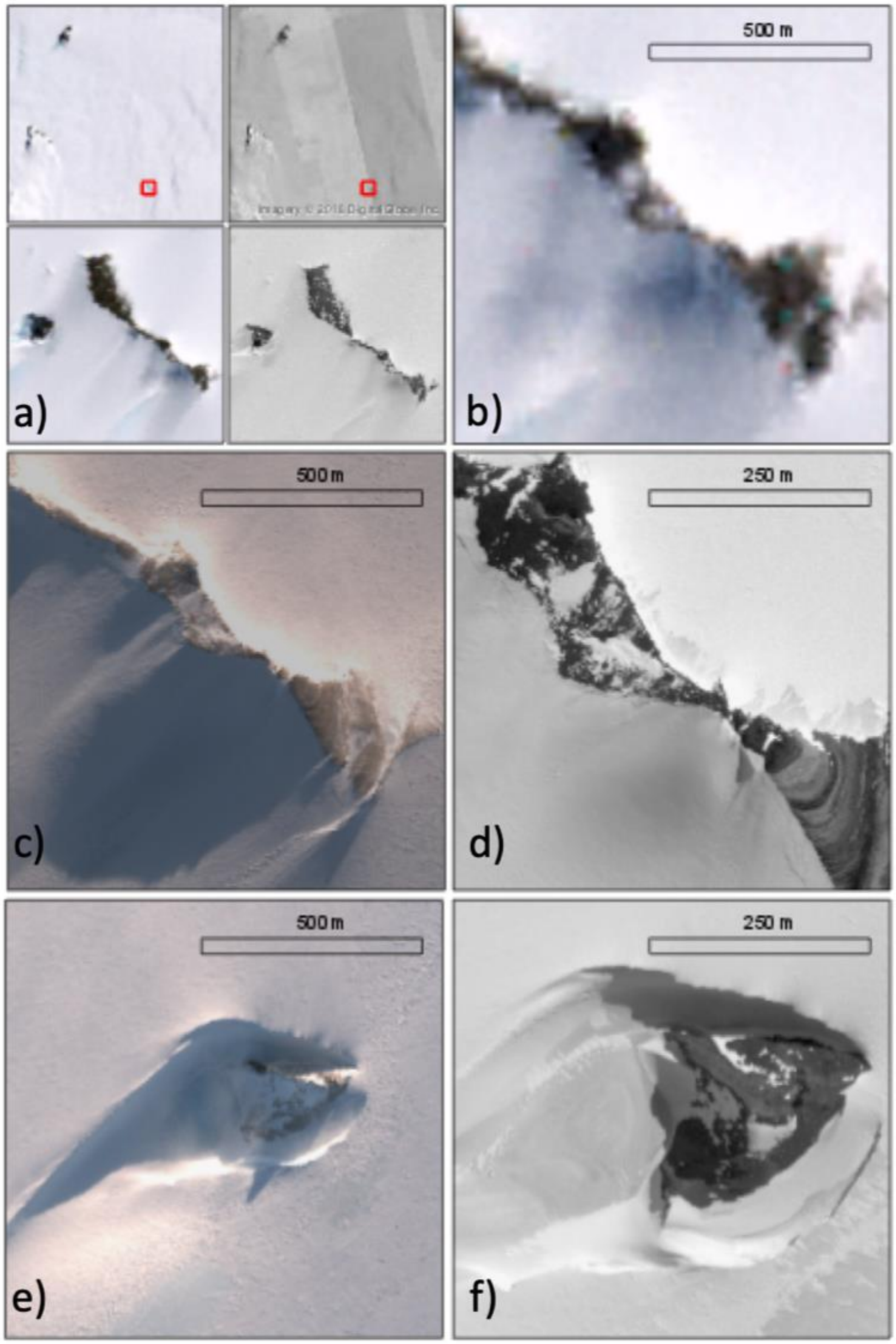

Figure 2.4 A comparison of the LIMA and WV-2 satellite imagery and the detail they depict.

In panel a) top the images show regional appearance of the LIMA (left) and WV-2 panchromatic (right) imagery at 1:250,000, covering a 50 km x 50 km area in the north west of the study area. Red squares denote the extent of the bottom images (which show LIMA (left) and WV-2 panchromatic (right) imagery covering this small ~3 km-long nunatak, Fossilryggen, at a scale of 1:50,000 which is where the LIMA imagery begins to pixelate. Panels b), and c) show the southern end of Fossilryggen at identical scales, demonstrating how the LIMA image (b) is completely pixelated while the WV-2 natural color image (c) is clear with detail easily depicted. Panel d) shows the same part of Fossilryggen but at a scale of 1:5,000 in the panchromatic. Panels e) and f) show the small nunatak to the west of Fossilrygen (see panel a) at the same scales as c) and d) respectively.

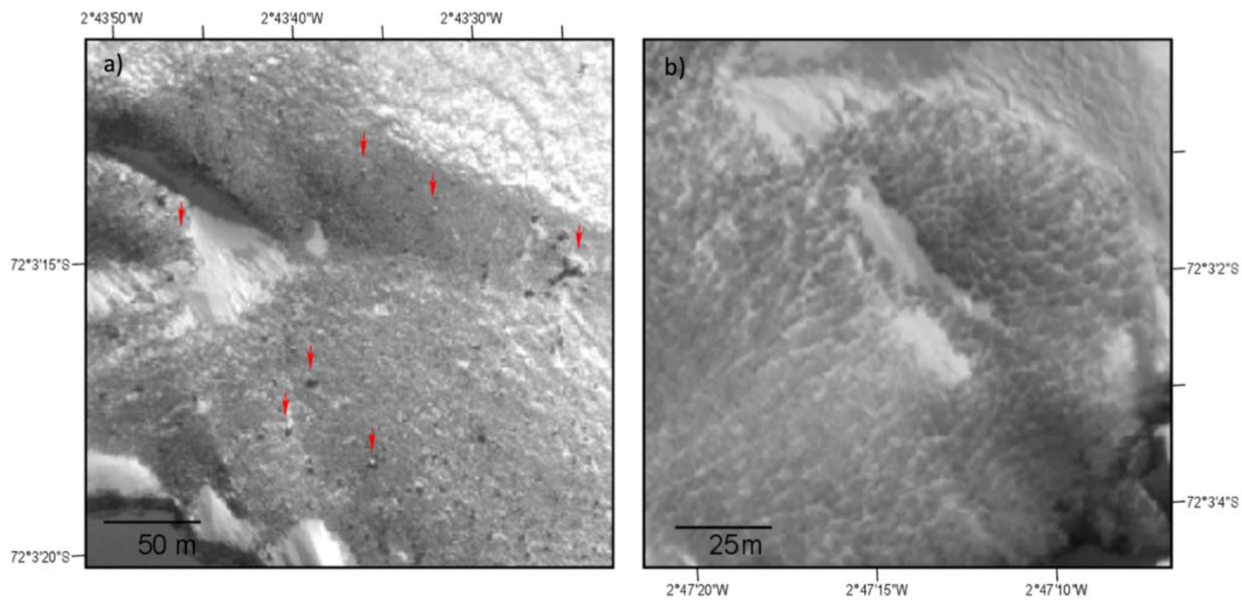

Figure 2.5 Examples of the higher definition seen in the WorldView imagery

Figure 2.5 a) and b) illustrate the clarity at which small scale features can be observed and identified from WV satellite imagery; a) individual boulders can be observed by their '3D' appearance due to the shadow they cast (a number of examples are indicated by red arrows, although many other boulders can be seen in the image). b) Patterned ground as seen in this WV-2 panchromatic image; in the center patterned ground appears to be polygonal but becomes more 'striped' towards the south west corner

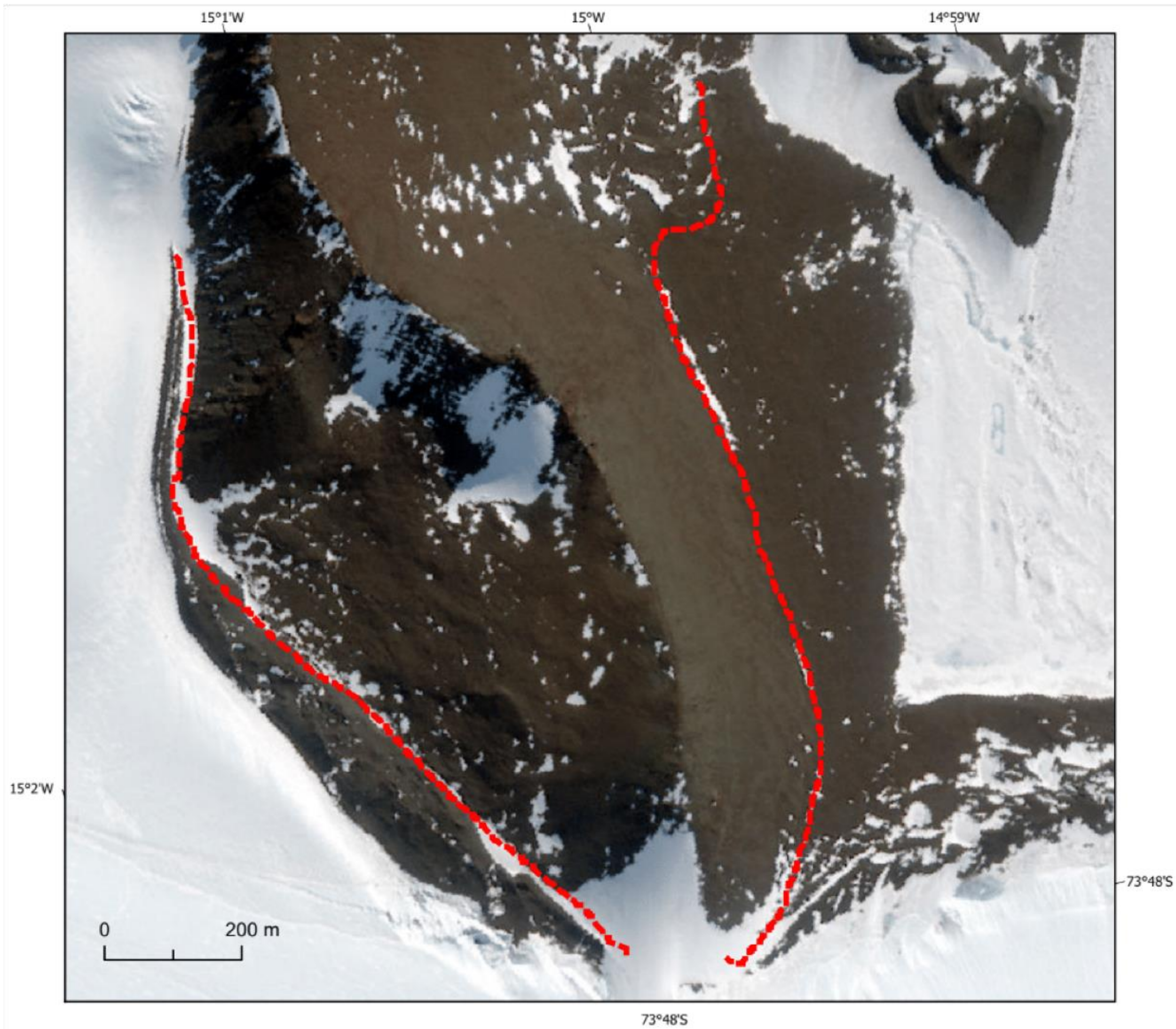

Figure 2.6 Delineation of supraglacial and surficial deposits

Determining the boundary between supraglacial and surficial material was highlighted as a challenge when mapping from Landsat imagery. The image shown here is WV-02 modified false color. The boundary between the supraglacial material (outside the red dashed line) and the nunatak bedrock and regolith (inside the red dashed line) can be seen by the subtle differences in color and texture.

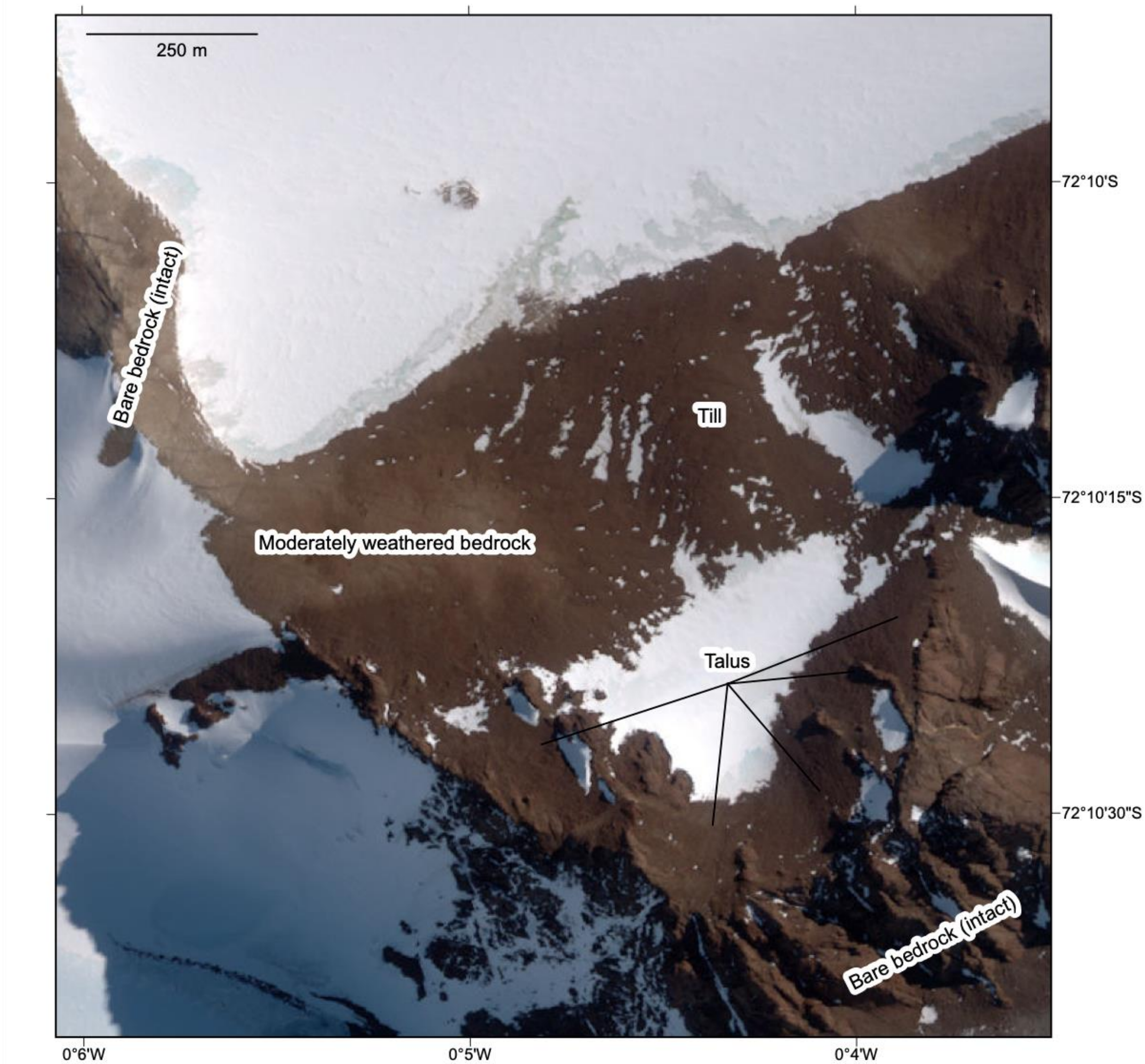

Figure 2.7 Textural, and color differences used to denote differing surficial deposits

Figure 2.7 shows a WV-2 modified false color image. The textural and color differences that can be seen in this image enables differentiation between units of surficial material to be identified (as labelled on the figure).

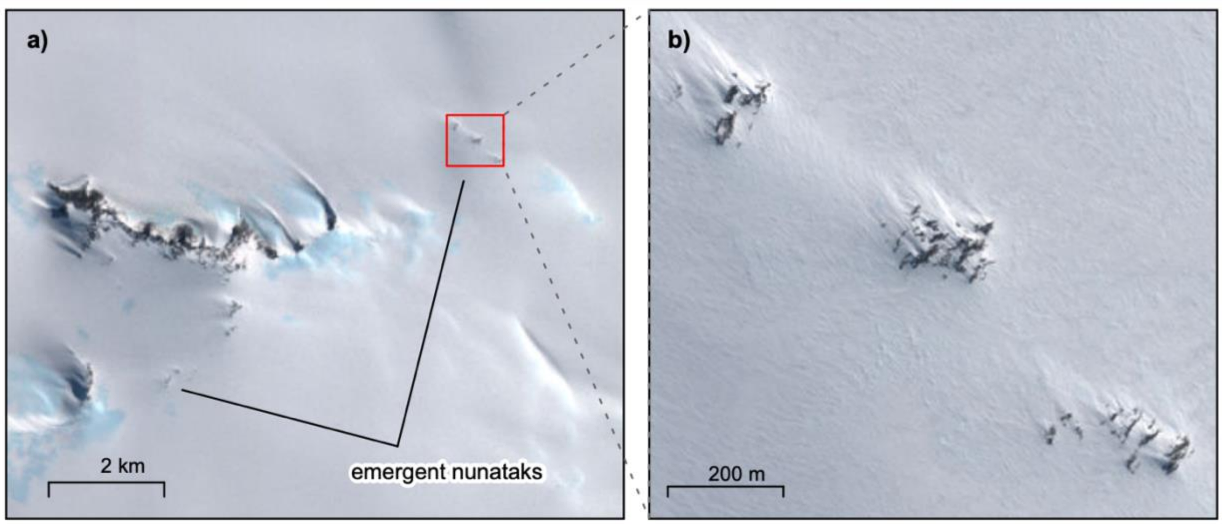

Figure 2.8 Mapping emergent nunataks

Emergent nunataks as they appear in WV-2 natural color Images. They are generally small (no larger than ~0.5 km at the longest axis) and therefore barely detectable at scales less than 1:100,000. Panel a) shows 1:100,000 scale image illustrating how the emergent nunataks appear different both texturally (faint and mottled) and in their relatively flat apparent topography. The red box in a) indicates the extent of b) which shows a 1:10,000 scale image of the emergent nunataks. They appear to be flush with the ice surface, and relatively fresh since they have no significant shadows, moderate wind tails and no windscoops.

CHAPTER 3. THE GLACIAL GEOMORPHOLOGY OF WESTERN DRONNING MAUD LAND

A version of this chapter has previously been published in the Journal of Maps.

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3.1 Introduction

The mapping of areas currently and formerly covered by glaciers and ice sheets is a key component in reconstructing past ice extent and assessing potential future responses to a changing climate (e.g. Heyman et al., 2008; Fu et al., 2012; Stokes et al., 2015; Blomdin et al., 2016; Stroeven et al., 2016; Clark et al., 2018). With models predicting that Antarctica will contribute >1 m to global sea-level rise by 2100, and >15 m by 2500 if greenhouse gas emissions continue to increase throughout the 21st century (DeConto and Pollard, 2016), it is important to improve our knowledge of how Antarctic ice behaved in response to past periods of climate change. Geologically-constrained ice sheet reconstructions are critical to determining the response of Antarctic ice to changing atmospheric and ocean temperatures. This is because these ice sheet reconstructions inform numerical ice sheet models and improve their ability to predict the timing and pattern of future ice reduction and consequent sea-level rise. Dronning Maud Land (DML), particularly western DML forms the focus of our mapping because it presents a significant data gap for constraining changes in the vertical extent (and therefore ice thickness) of the East Antarctic Ice Sheet (EAIS) (Bentley et al., 2014; Mackintosh et al., 2014). Detailed mapping of glacial deposits and landforms on nunataks –mountain summits protruding through the ice sheet surface– was performed to investigate and quantify the past vertical extent of the EAIS in this area, and to guide sample collection for cosmogenic nuclide (CN) surface exposure dating to constrain the timing of ice thickness fluctuations. The vast area and harsh environment present significant accessibility challenges, therefore the mapping has been completed predominantly by remote sensing from very high-resolution satellite imagery, together with field visits to several ground validation locations.

3.1.1 Study area and previous work

Our study region covers ~200,000 km^2 at the western DML margin of the EAIS (Fig. 3.1). Detailed mapping was completed on all nunataks protruding the grounded ice sheet north of 76°S and between 16°W and the Prime Meridian (Fig. 3.1). General ice surface features (such as blue ice areas) and larger-scale erosional landforms (such as cirques) have been mapped, however, the focus was to perform detailed mapping of nunatak surfaces. These exposed rock surfaces comprise less than 0.2% of the study area. The map presented here (supplementary material) builds on, and extends, mapping by Serra (2017) and Dymova (2018). We utilise new sub-meter resolution WorldView-2 and WorldView-3 satellite imagery, enabling a level of mapping detail not previously possible across such a vast region.

The ice sheet in western DML drapes an ancient passive margin escarpment which trends in a SW-NE direction, roughly coast-parallel at around 200 km inland from its grounding line. This predominantly subglacial escarpment produces substantial and complex bed relief which impedes ice flow and results in the presence of several nunatak ranges, forming the edge of the polar plateau. Downstream of the escarpment there are nunataks both in isolation and as part of additional mountain ranges (Fig. 3.1; Vestfjella, Borgmassivet, and Ahlmannryggen). The relatively high concentration of nunataks (compared to elsewhere in the EAIS) in a sparsely investigated region makes western DML ideal for an empirical glacial reconstruction study. The physiography of the region is described in detail in Chang et al. (2016) whose mapping of the subaerial and subglacial geomorphology of DML indicates a largely alpine landscape under the ice sheet. They could not, however, map surficial deposits on nunataks because of the coarse resolution of the available imagery (Chang et al., 2016). Numerical ice sheet modelling indicates that western DML has hosted a predominantly cold-based ice sheet since the mid-Miocene maximum ~14 Ma (Jamieson et al., 2010) which has acted to largely preserve the alpine landscape (now largely subglacial) formed during the early Cenozoic (Näslund et al., 2000; Näslund, 2001). Macro-scale geomorphological features such as cirques were therefore likely formed prior to the inception of the EAIS ~34 Ma, and so do not provide insight into more recent–Late Neogene and Quaternary–

changes in ice sheet thickness and extent. Hence, to detect more recent modifications to the landscape we focus on mapping depositional features, such as glacially-displaced boulders (erratics), sediment cover (including till, till veneer, talus, and regolith), and field observations of features that yield ice flow directional information, such as striations.

3.2 Methods

3.2.1 Map production

The remote sensing-based mapping of glacial geomorphology in western DML was completed using sub-meter resolution WorldView-2 (WV-2) and WorldView-3 (WV-3) satellite data. Landforms were visually identified (Section 3.2.3) and manually digitized using ESRI ArcGIS software. An iterative approach combining remote sensing mapping and fieldwork was used to ensure interpretation integrity. The first iteration of mapping was completed ahead of the 2016-17 field season to guide sampling for CN surface exposure dating. Thus, mapping was limited to the field area of the first field season (based from Wasa and covering the Heimefrontfjella; Fig. 3.1) and focused on sites that were realistically accessible. Detailed ground validation was completed at two locations and general observations were recorded at all sites visited during the first field campaign. The experience and insight gained during the first field season were incorporated into second generation mapping which was completed between the two field seasons (Serra, 2017; Dymova, 2018). This produced detailed coverage over the entire Ahlmannryggen and Borgmassivet nunatak ranges (Fig. 3.1), provided a first-order reconstruction of the glacial history, and guided CN sampling for the 2017-18 field campaign. During the second field campaign detailed ground truthing was conducted at four additional locations and, again, general observations were recorded at all sites visited. The final stage of the mapping was to collate, combine, and extend the different mapping efforts across the study area. A key challenge in producing the final map product was to achieve a clear presentation of the detailed nunatak-scale mapping of landforms across such a vast study area. The map product is intended as a representation of the glacial geomorphology across western DML and readers are guided towards the shapefiles (supplementary material) in order to study in detail the glacial geomorphology of this region.

3.2.2 Data and data processing

The surficial mapping presented here uses very high-resolution commercial WorldView satellite data. WV-2 has a spatial resolution of 0.46 m in panchromatic and 1.84 m in 8 multispectral bands, while WV-3 has a spatial resolution of 0.31 m and 1.24 m in the panchromatic and multispectral bands, respectively (Table 3.1). For identification of glacial geomorphological features, images were studied in panchromatic and 3 different color composites; natural, false, and modified false band combinations (Fig. 3.2). Ice features were mapped from imagery in 'standard false color' which enhances the contrast between snow and ice (Fig. 3.2c). Surficial mapping of nunataks was completed using imagery in 'modified false color' as the combination of the invisible Near-Infrared (NIR) and visible spectrum bands enhanced visual differentiation between different surface materials and geological features, especially where these differences are subtle. The modified false color composite was particularly useful in identifying bedrock boundaries and distinguishing between different surface sediment covers (Figs. 3.2d and 3.2f). Textures and patterns appeared most clearly in the panchromatic (Fig. 3.2e). The 'natural color' was often used to distinguish between differently colored sediment cover and bedrock.

Given the purpose of this work, and the large storage requirement per image, WV satellite imagery was only requested for the field campaign areas and any adjacent regions containing nunataks. The extent of the WV data coverage is shown in Figure 3.1. In total ca. 4500 orthorectified scenes were provided, with image acquisition dates ranging from 2012-2016. This collection of WV images was manually filtered to select from austral summer imagery the best quality scenes to provide single-coverage over the investigation area. Almost 3000 out of the ~4500 scenes were unsuitable due to under/overexposure, the presence of striping, or cloud cover obscuring nunataks.

The reference elevation model of Antarctica (REMA) is an 8 m resolution digital elevation model (DEM) derived from WorldView imagery pairs (Howat et al., 2019) that was released in September 2018. Hence, it was not used in the first two iterations of our mapping. It was, however, utilized during the collation, combining, and checking of the mapping.

3.2.3 Glaciological features and glacial deposits

From the remote sensing we identified ten landform categories for inclusion in the mapping. The identification criteria, mapping scale, optimal color composite, and paleoglaciological significance of each mapped feature class is discussed here.

Windscoops are well defined, generally concave, hollows in the ice surrounding a nunatak (Fig. 3.3). They commonly have blue ice at their base. The crest of a windscoop is flush with the ice surface, concealing a significant drop (tens of meters) towards the nunatak forming the lee side. Windscoops were mapped at scales from 1:10,000 to 1:2000 using standard false color composites and could be clearly identified due to the shadow they cast in the snow/ice surrounding a nunatak (Fig. 3.3) as well as the presence of basal blue-ice areas (BIAs). Windscoops form due to channelling of the wind around a nunatak and therefore provide information on dominant wind direction and ice surface slope direction.

Crevasses are open cracks in the ice sheet surface that form under extensional stress (Benn and Evans, 2010). They can be tens of meters to kilometers in length and range from a few meters to over 50 m wide. Crevasses were mapped as individual line features at scales from 1:10,000 to 1:1500. Crevasses appeared clearest in the standard false color composite where snow-bridges were whiter than their surroundings, and had shadows where snow-bridges had collapsed (Fig. 3.3c). They were also distinct in the panchromatic. Crevasses are generally dynamic features which do not persist through changes in ice configuration or flow. As such the information they provide relates to present-day ice flow conditions. Additionally, and importantly, crevasses are one of the greatest safety concerns for field teams and the mapping of crevasses proved to be invaluable to route planning and field safety.

Longitudinal surface structures (LSSs) are flow-parallel curvilinear structures on the ice surface, often occurring as continuous subtle 1-2 m-high ridges. They typically occur within ice streams and indicate either irregularities in the bed topography or laterally compressive ice flow (Glasser and Gudmundsson, 2012; Ely and Clark, 2016). LSSs were mapped as line features at scales between 1:500,000 and 1:100,000. They typically appear as a slightly darker blue in standard false color (Figs. 3.3a and c), and their ridge structure was clearest in panchromatic imagery. LSSs primarily provide information on present ice flow conditions, however, they are long-lived features and so also have the potential to provide information on changes in flow direction (Glasser and Gudmundsson, 2012).

Blue ice areas (BIAs) are regions of bare-ice occurring in a range of settings, though commonly on the downstream side of nunataks or on the crest of convex structures in the ice sheet surface. BIAs are wind-scoured surface ablation centers that are generally dominated by vertical ice-flow, often contain some supraglacial debris, and are renowned for concentrating meteorites (Bintanja, 1999; Fogwill et al., 2012; Spaulding et al., 2012). Whereas the ice sheet surface normally appears white in WV imagery, BIAs appear as expanses of blue ice. BIAs were best identified using the 'standard false color' composite where their blue color is distinct and the contrast between blue and white is enhanced (Fig. 3.3). BIAs were digitized as polygons at a mapping scale of 1:10,000 to 1:2500. All BIAs observed were mapped, and there was no minimum or maximum size for inclusion. Small BIAs (< 100 m^2) were commonly found at the base of windscoops or over crevasse fields. More extensive BIAs typically occur at the base of escarpment cliffs. They often have indistinct boundaries, in which case determining the extent of the BIA in the mapping was subjective. BIAs provide information about bed relief, past and present glacier mass balance, ice flow conditions, and predominant wind patterns. They are considered to be persistent and stable features that can survive through glacial/interglacial cycles (Bintanja, 1999; Fogwill et al., 2012; Zwinger et al., 2014; Kehrl et al., 2018).

Boulders are by definition any fragment of rock >25.6 cm (Wentworth, 1922), however, in our mapping we focus on large boulders (with diameters of ~1.5 m up to 10 m). Individual boulders were recognized by their three-dimensional appearance resulting from casting a shadow. They were mapped as point features at scales of 1:1000 to 1:500. Due to the relatively small size of the boulders they were best identified using the sub-meter resolution of the panchromatic imagery, though very large boulders can be observed in all imagery (Fig. 3.2e). Where we have mapped large individual boulders on the summits and flanks of nunataks (where a rockfall origin can be ruled out), they are considered to be ice-transported boulders and thus indicate that the nunatak surface at this location was at some point overridden by the ice sheet (Fabel et al., 2012).

Striations are linear grooves on a rock surface formed as sediments embedded in the basal ice 'scratch' the rock surface as the ice flows over it (Benn and Evans, 2010). Striations are far too small scale to be picked up in satellite imagery. Mapped striations are therefore from field observations, with their orientation measured. Striations provide crucial information of past ice cover and orientation of flow (Stroeven et al., 2016). They were observed and measured at several sites during the field campaigns and, given their significance to glacial history, are included on the map.

Cirques are semi-circular depressions cut by ice in the nunatak slopes. They appear as arcuate steep cliffs forming the headwall to a bowl-shaped floor. However, cirques mapped here are ice filled and therefore only identified by the arcuate morphology of their headwalls. They range in width from a few hundred meters to kilometers. They are clearly seen in all the imagery at scales between 1:500,000 to 1:250,000. They were mapped at scales ranging from 1:50,000 to 1:6000, and digitized as line features tracing the headwall cliffs. It is generally considered that cirques indicate erosion by wet-based local glaciers (Evans and Cox, 1974; Benn and Evans, 2010), and in DML these features have often been interpreted to pre-date the inception of a permanent EAIS (Näslund et al., 2000; Näslund, 2001; Jamieson, 2010). However, it should be noted that Andrews and LeMasurier (1973) argue that cirque headwall retreat occurs under present-day freezing conditions in Antarctica through albedo induced freeze-thaw cycles at the headwall. Evidence that this might be an important process was seen both in the field (direct observations of meltwater) and in the WV imagery (refrozen meltwater pools and channels). Thus, the mapped cirques were likely formed during the early Cenozoic, but may still be developing slowly under present conditions in areas where seasonal meltwater is present.

Supraglacial debris refers to sediment lying on the surface of the ice. This includes blue-ice moraines, talus deposits, and areas containing a high concentration of scattered boulders. Supraglacial debris was easy to identify in all imagery since it is a distinctly darker speckled region on the white-blue ice surface (Fig. 3.4). However, where there was thick supraglacial debris at or across the ice sheet-nunatak boundary it sometimes proved challenging to ascertain this boundary and therefore the limit of the supraglacial debris. Supraglacial debris was mapped as a polygon feature class at scales ranging from 1:20,000 to 1:2000. Where there was a distinct ridge or structure within the supraglacial debris this was mapped as a line feature *supraglacial debris structure* (Fig. 3.4d). Supraglacial material was observed exclusively at the base of nunatak slopes or within BIAs (where they are mapped as overlapping units). The supraglacial material mapped on BIAs ranged from a scattering of boulders to dense deposits (Fig. 3.4). Generally, where less than ~10% of the surface area was covered by debris, it was not included. Blue-ice moraines are considered to form by compressive ice bringing material from the base of the ice up to the surface (Hättestrand and Johansen, 2005; Fogwill et al., 2012). They therefore provide information on local ice flow patterns, in particular the locations where there is/has been vertical ice flow. Where supraglacial debris continues as a till veneer on nunatak slopes this indicates that the ice was thicker in the past.

Sediment cover is an amalgamation of various different types of observed surficial sediment covering nunatak bedrock (including till, till veneer, talus, and regolith) which were initially mapped as different units based on contextual assumptions (Newall et al., *in submission*). Ground validation revealed that the contextual assumptions were not reliable in differentiating these different types of sediment cover classes and they were, therefore, combined into one feature class – sediment cover. Sediment cover is observed on most nunatak plateau surfaces and non-vertical slopes and is identified primarily by a different texture and/or color than the bedrock. Mapping of sediment cover was carried out at scales ranging from 1:5000 to 1:500, and is best identified in the modified false color composite (Figs. 3.2f, and 3.4). Large concentrations of boulders are most easily identified in panchromatic imagery (Fig. 3.2e), and denote sediment cover. Therefore, a combination of both the modified false color and the panchromatic imagery was used to positively identify sediment cover from bedrock. 'Blankets' of apparently thin sediment cover were most commonly identified, as were small 'pockets' of sediment between bedrock outcrops. Where sediment cover can be determined as being glacially emplaced (a till, for example), this indicates the site has been overridden by a formerly thicker ice sheet.

Patterned ground is marked by polygonal or striped patterns in the sediment cover found on flat plateau summits and gently sloping nunatak flanks (Figs. 3.4a, b). Patterned ground was mapped as a polygon feature class at 1:2000 to 1:500 scales. It is clear in the panchromatic imagery, especially where a thin snow cover enhances the patterns (Fig. 3.4c). A number of mechanisms have been proposed for the formation of patterned ground in glacial environments, and all require the presence of unconsolidated diamict sediments and freeze-thaw cycling (Ballantyne and Harris, 1994). The presence of patterned ground provides information on the type of surficial material and, because the formation of patterned ground is a subaerial process and it develops gradually through periglacial processes it indicates that the nunatak surface has been exposed above ice for an extended time during which conditions were similar to, or even warmer than present (Kleman and Stroeven, 1997; Clarhäll and Kleman, 1999; Sugden et al., 2005; Goodfellow et al., 2008).

3.2.4 Mapping consistency and completeness

The work presented here was completed over several years by multiple researchers. Smith and Wise (2007) highlight observer skill and experience as a source of bias and inconsistency in glacial geomorphological mapping. Inconsistency between mappers is also demonstrated and quantified in Hillier et al. (2015). To remove such bias, and to minimize inconsistency from numerous mappers, Newall and Stroeven were engaged in all of the mapping activity, and Newall undertook the final map compilation which included a rigorous consistency check across the full study area. The final map presents a complete and detailed inventory of the ten mapped landforms and deposits across the study area, where they occur on or within the vicinity of a nunatak. A possible exception to mapping completeness may occur within ice surface features (crevasses, LSSs, and BIAs) where they exist distal to any nunatak, or if they occur in the pockets of the study area that are not covered by the WV satellite data acquired for the mapping (Fig. 3.1).

3.3 Discussion

3.3.1 Glacial history

Remote sensing and field observations both identify surficial evidence for ice cover across the full range of elevations and topographical settings (cliffs, plateaus, emergent nunataks, and ridgelines) that have been mapped. This indicates that all of the nunatak surfaces have, at some point in time, been covered by ice. The substantial spatial variation in the distribution of depositional features, and an inconsistent relationship between the presence of glacial deposits and either absolute elevation, relative elevation, or distance inland from the coast, indicate that the current complex topography in this region exerts a strong control on ice sheet configuration, dynamics, and response to external driving factors such as climate. Generally, the ice surface features are consistent with long-term stability of the flow regime. LSSs all coincide with present-day ice velocity patterns and therefore support the conclusion of Glasser et al. (2015) that the ice streams in Dronning Maud Land (and the rest of Antarctica) have been active with little to no change to flow configuration for thousands of years, possibly since the end of last glacial cycle.

3.3.2 Ground Validation

Ground validation is used to verify and validate remotely sensed mapping. By checking the mapping against ground observations, mapping accuracy can be assessed and identification criteria can be evaluated to enable the mapping of landforms to be extended regionally, beyond the sites visited. Ground truthing, conducted during the field campaigns (Chapter 2) revealed that the contextual assumptions used to classify the different mapped units of sediment cover were not consistently correct. Using the colour composites selected for this work (Section 3.2.2, and Table 3.1) it was not possible to determine the type of sediment cover from remote sensing alone. Differentiation of sediment cover proved to be challenging even in the field; experienced glacial sedimentologists found it difficult to ascertain whether a heterogenous sediment cover was a till stripped of fines or a talus deposit sourced from heterogenous bedrock lithologies. Clast angularity can be a key criterion in classifying sediments (Lukas et al., 2013), however, across both field campaigns, almost all the clasts we encountered were angular, characteristic of both tills and regoliths stripped of fines. Therefore, clast angularity was not a reliable deterministic characteristic as to whether or not mapped sediment cover is of glacial origin. While attempts were made to map different types of sediment cover and differentiate between sediment deposits (such as till) and in-situ sediments (regolith) in the WV satellite imagery, the ground truthing showed that the methodology used here did not allow for accurate differentiation of the type of sediment cover, only to observe and map where changes in the colour and/or texture of the surficial material indicates different units of sediment cover.

The ground truthing also showed that not all mapped boulders were necessarily glacial erratics. In fact, few of the isolated boulders we mapped turned out to be true erratics (with a lithology different from the local bedrock), or showed evidence of glacial transport (e.g., striations, rounded surfaces). Boulders mapped on nunatak surfaces were considered to be quasi-erratics (ice-transported boulders) because, whereas the lithology was not strictly foreign, they could only have been transported to their particular location by ice. Hence, the mapped boulders on nunatak summits or flanks (where it can be ascertained through contextual assumptions that they do not originate from rockfall) still provide evidence of a thicker-than-present ice sheet. It should be noted that large individual boulders are also mapped on the ice surface in blue ice fields either as scattered boulders, or on supraglacial moraines. Given their proximity to the base of steep nunatak flanks they are more likely of rockfall origin as opposed to having been subglacially exhumed.

3.4 Conclusion

Detailed mapping of nunataks and nearby ice areas was completed over a 200,000 km^2 study area covering western Dronning Maud Land. Acquisition of sub-meter resolution WorldView satellite imagery enabled the mapping to focus on surficial features which provided information of former ice inundation. We conclude that all nunataks in western Dronning Maud Land have, at some point in time, been covered by the ice sheet and therefore provide evidence for a vertically more extensive ice sheet.

Geomorphological mapping with this level of detail was not possible previously due to the limited resolution of remote sensing products available prior to the launch of the WorldView satellites. We show that the detection of different surficial deposits is possible, however, more work is required to positively identify the type of deposit (classification). A growing area of research is the use of very high spectral resolution satellite data in developing composition-based spectral indices (e.g. Pour et al., 2019) and weathering indices (e.g. Kanamaru et al., 2018). Future work in this direction would improve the accuracy with which we are able to classify sediment covers, however, for now ground validation is still a crucial requirement to accurately differentiate a glacial deposit from in-situ weathered bedrock.

This mapping supported the efforts of two field campaigns collecting samples for CN dating which will provide the chronological data required to build an empirical reconstruction of ice sheet thinning at the DML margin of the EAIS.

3.5 Acknowledgements

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Table 3.1 Sensor band specifications and resolution for the WV-2 and -3 satellites

Band	**Wavelength (nm)**	**Resolution (WV-2)**	**Resolution (WV-3)**
Panchromatic	450-800	0.46 m	0.31 m
Coastal	400-450	1.84 m	1.24 m
Blue	450-510	1.84 m	1.24 m
Green	510-580	1.84 m	1.24 m
Yellow	585-625	1.84 m	1.24 m
Red	630-690	1.84 m	1.24 m
Red Edge	705-745	1.84 m	1.24 m
NIR 1	770-895	1.84 m	1.24 m
NIR 2	860-1040	1.84 m	1.24 m
Table footnotes - NIR = Near infrared. The WorldView-3 satellite additionally has 8 SWIR sensors (3.7 m resolution) and 12 CAVIS - Clouds, Aerosol, (water) Vapour, Ice and Snow - sensor bands (30 m resolution), but these are omitted from the table since this data was not obtained or used in our work.			

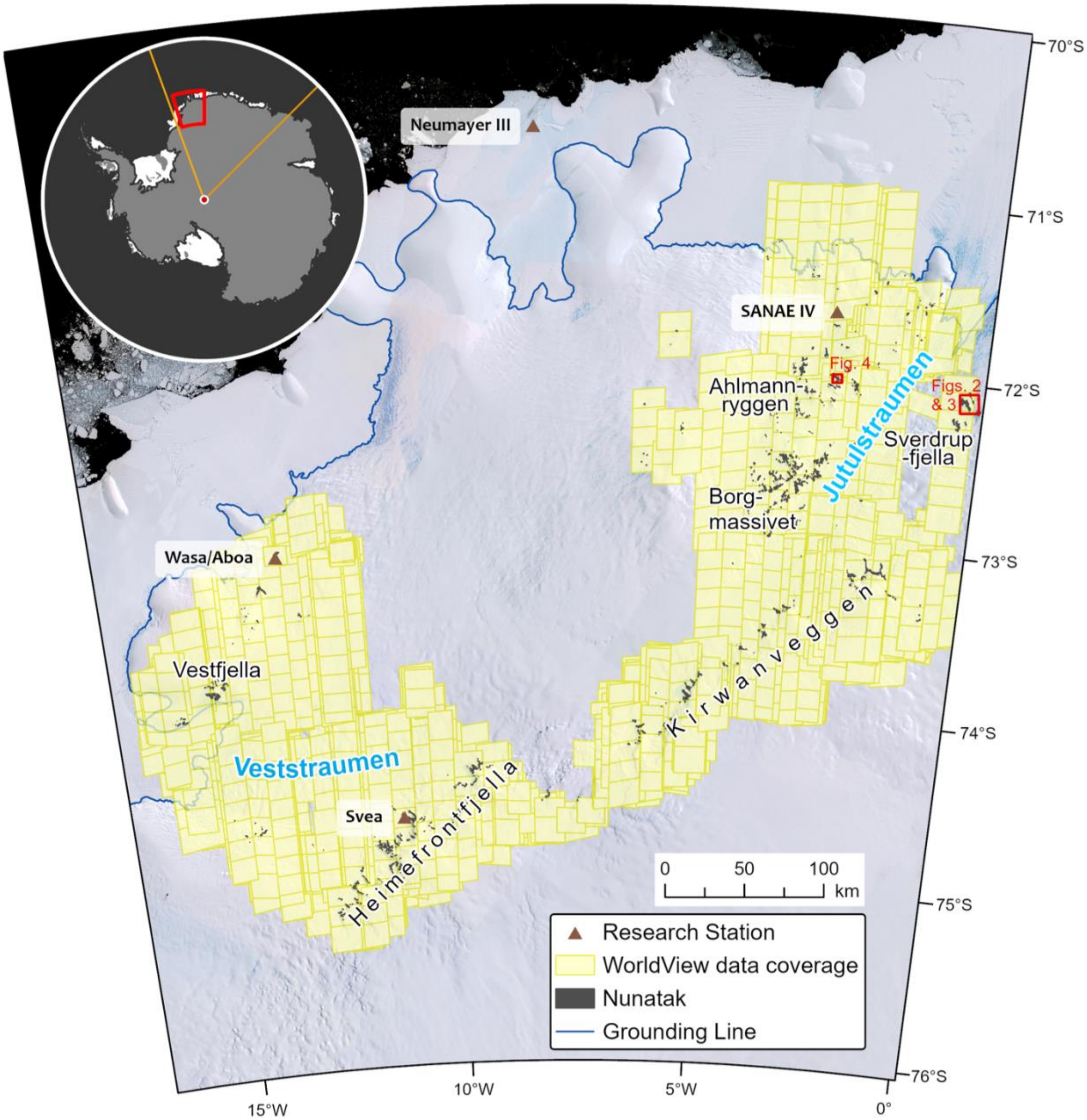

Figure 3.1 Overview of the mapped area in western Dronning Maud Land

The ice sheet grounding line is shown as the solid blue line, and the ice streams and nunatak ranges labelled are referred to in the text. The extent of WorldView satellite imagery obtained for the mapping is shown by the yellow polygons. Locations of Figures 3.2-4 are indicated by red rectangles. Inset map indicates the location of the mapped area within Antarctica (red box), with the red dot representing the South Pole, and the orange lines showing the defined limits of Dronning Maud Land. Basemap is the Landsat Image Mosaic of Antarctica (Bindschadler et al., 2008)

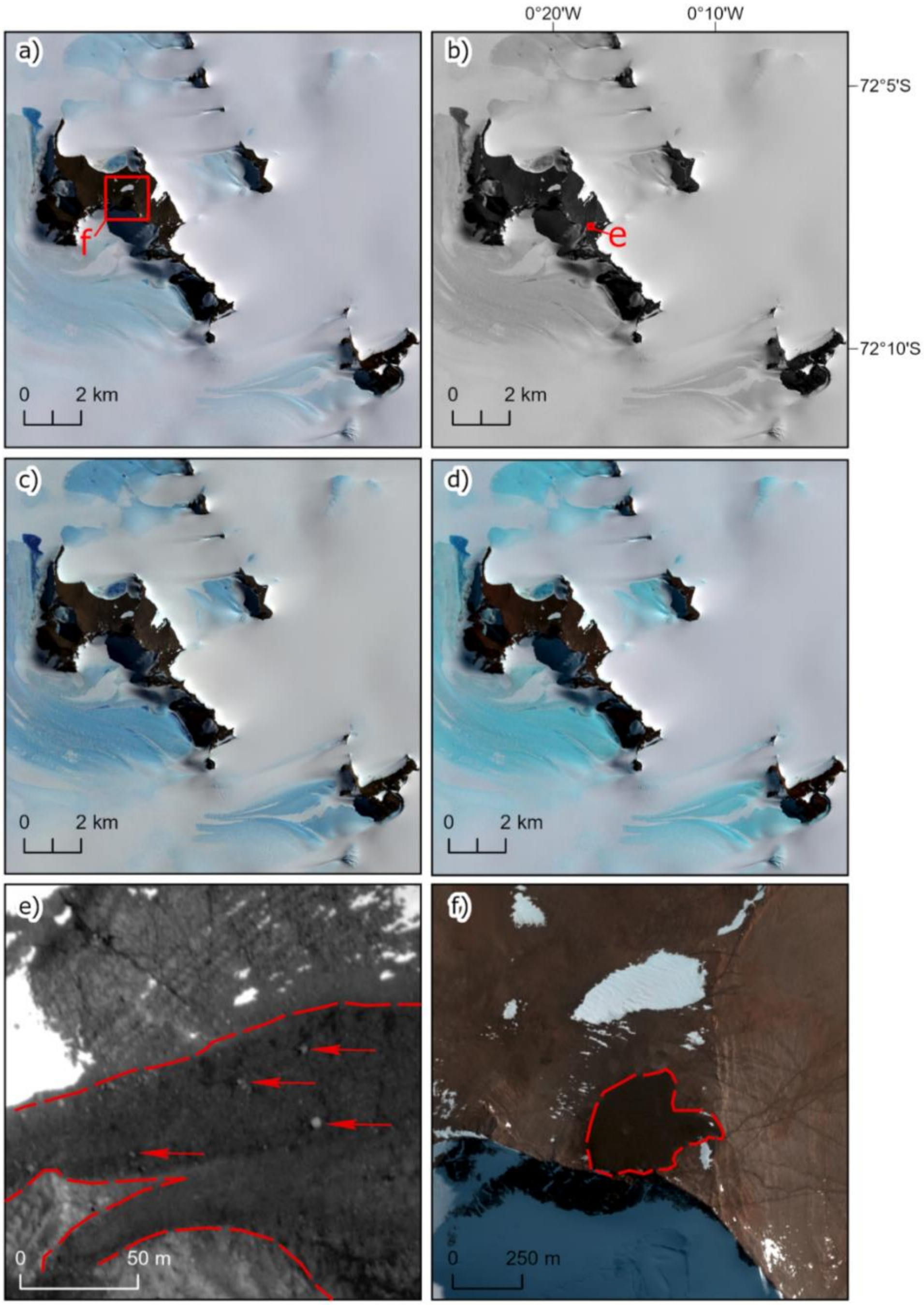

Figure 3.2 WorldView-2 imagery color composites

WorldView-2 imagery (© 2017 DigitalGlobe Inc.) of Sverdrupfjella (cf. Fig. 3.1) demonstrating the different band combinations used in the mapping. The colour composites are: a) natural colour (5,3,2), b) panchromatic, c) standard false colour (7,5,3), and d) modified false colour (7,3,2). The bands utilised for each colour composite are shown in parenthesis - see Table 3.1 for band details. The stronger contrast between snow (white) and ice (blue), and the ability to capture subtle variations in the blue ice, made the standard false colour the optimal base for mapping ice surface features. Locations of panels e and f are indicated by red rectangles in panels b and a, respectively. The best detail is seen in panchromatic imagery, where individual boulders can be observed (e - highlighted by red arrows). The modified false colour composite proved optimal for mapping surficial features, in particular the sediment cover as it exaggerates the subtle colour differences in reds, browns, and greys (f).

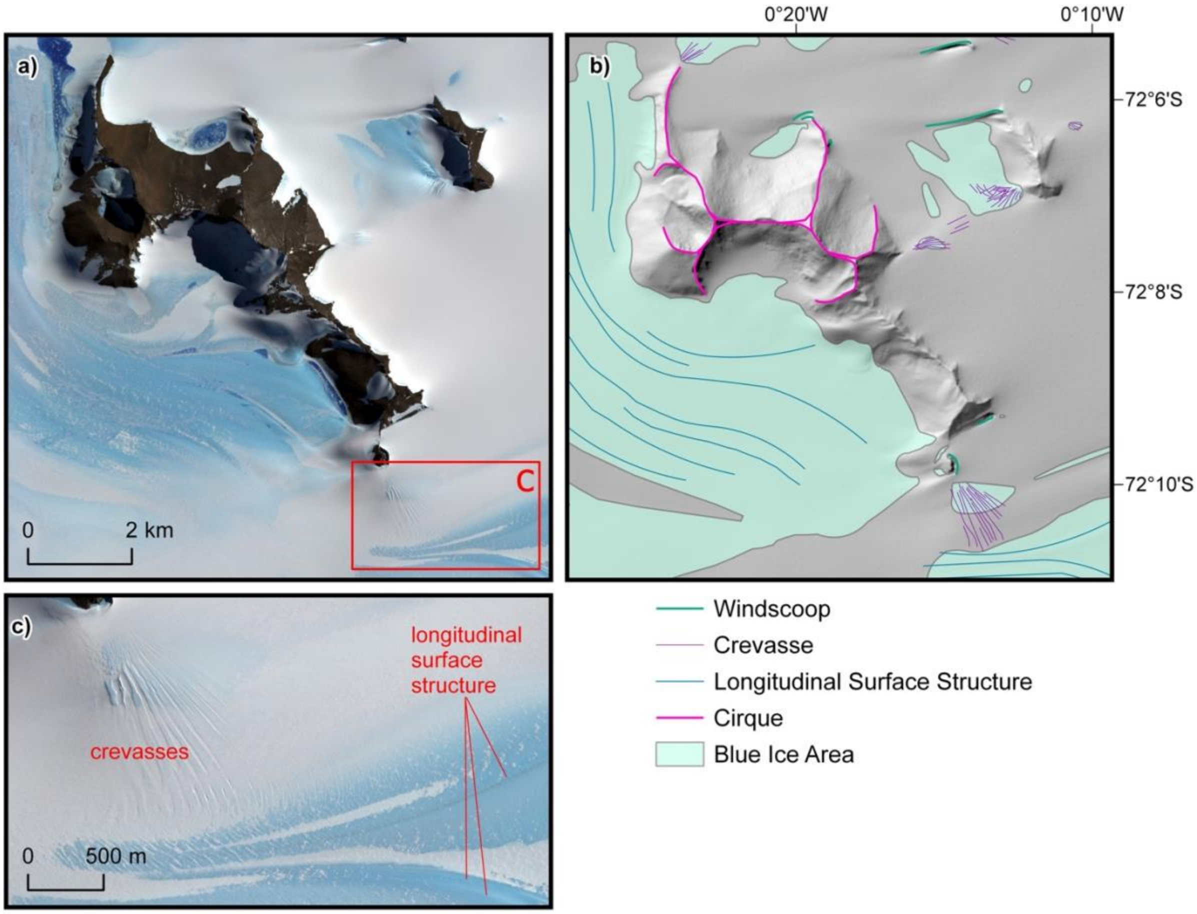

Figure 3.3 Mapping of ice surface features

Mapping of ice surface features and cirques at Sverdrupfjella (cf. Fig. 3.1) from WorldView-2 satellite imagery (© 2017 DigitalGlobe Inc.). (a) Sverdrupfjella in the standard false colour composite. The standard false colour emphasises bare ice, and the difference between snow and ice, and was therefore used in mapping ice features. Location of panel c is indicated by red rectangle. b) Mapped ice features identified from a) with a hillshade derived from the REMA DEM (Howat et al., 2019) used as background. c) Examples of some of the smaller ice surface features, showing the detail that can be mapped from the WorldView imagery. Almost all crevasses observed were snow-filled or had partially collapsed snow bridges.

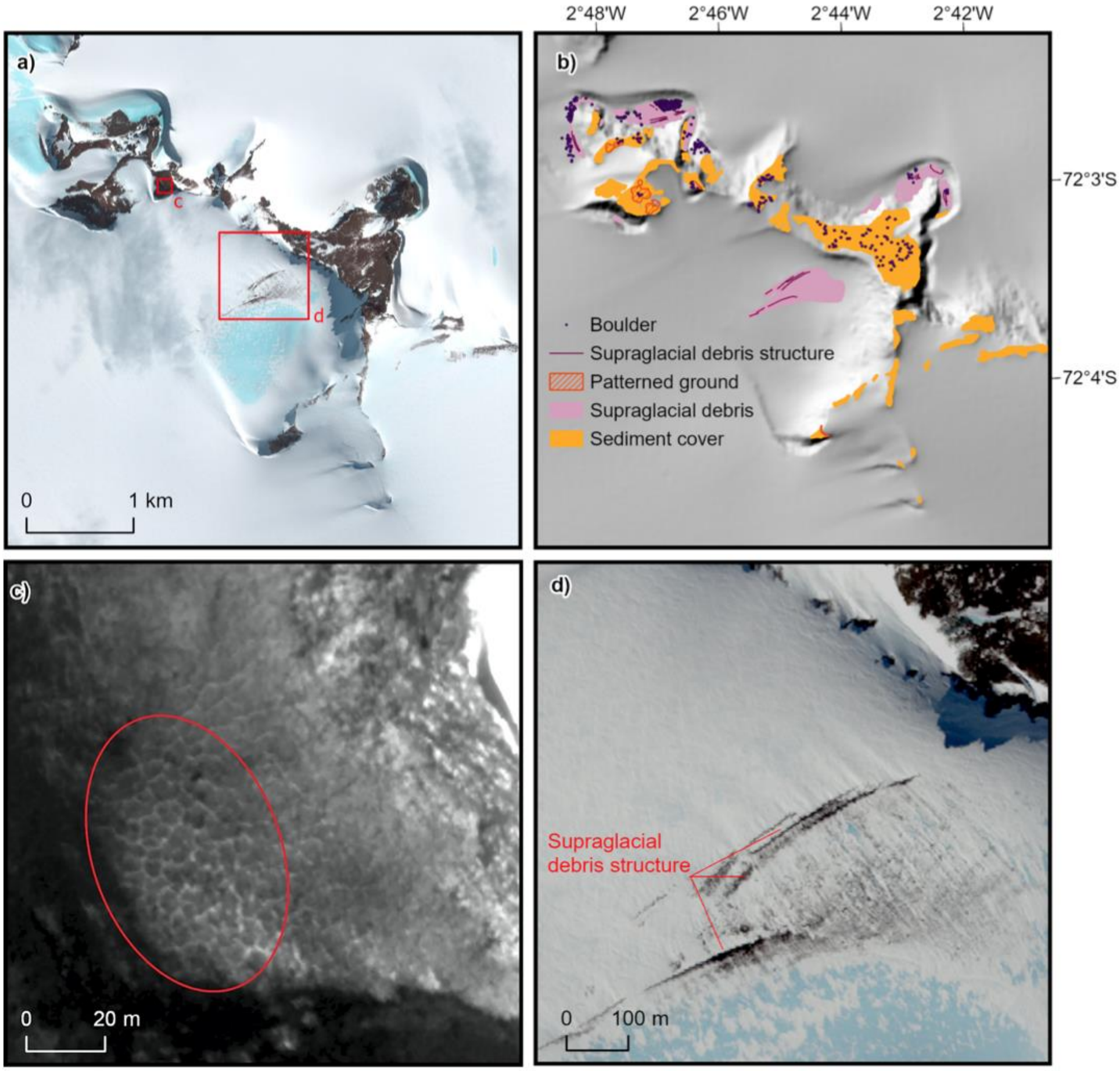

Figure 3.4 Mapping of (nunatak) surficial features

Mapping of surficial features at Grunehogna (in the Ahlmannryggen nunatak region; cf. Fig. 3.1) from WorldView-2 imagery (©2015 DigitalGlobe Inc.). a) Grunehogna in the modified false colour imagery. Locations of panels c and d are indicated by red rectangles. b) The resulting mapping of surficial features from a). Hillshade derived from the REMA DEM (Howat et al., 2019) is used for the background on which the mapping is presented. c) and d) show the high detail achieved in mapping from the very-high-resolution WorldView data. c) shows patterned ground on a nunatak plateau summit area, and d) illustrates how supraglacial debris structures clearly stand out within the general area of supraglacial debris.

CHAPTER 4. OUTLOOK

This chapter presents a recap of the main findings of this thesis and outlines directions for further work that builds on the results presented here. Much of the future work discussed is either underway or planned within the MAGIC-DML (Mapping, Measuring and Modelling Antarctic Geomorphology and Ice Change in Dronning Maud Land) project. Integral to the work of MAGIC-DML is our team-based interdisciplinary approach, thus there is a broad scope for future work. We limit the discussion of future work to that which contributes towards the empirical ice sheet reconstruction as this was the focus of the thesis, and will continue to be the author's focus in her PhD work.

4.1 Findings

Improving our understanding of how the East Antarctic Ice Sheet (EAIS) has responded to climate perturbations in the past can inform and train numerical ice sheet models that predict its future behavior under different climate scenarios. An important societal implication of this research is that such knowledge enables better preparedness and adaption planning for the communities around the world that will be affected by higher global sea levels due EAIS mass loss. In addressing the overall objectives of MAGIC-DML, the author presents the first step towards an empirical-based paleoglaciological reconstruction of the DML margin of the EAIS based from geomorphological mapping which utilized the new WorldView (WV) satellite imagery dataset.

Due to a study area of more than 200,000 km^2 and the fact that < 0.2% of this surface area consists of exposed rock in the form of nunataks, the geomorphological mapping relies on remote sensing, combined with ground validation during field campaigns. Chapter 2 describes how a key challenge of the spatial resolution in the satellite data used in the mapping of nunatak- and smaller-scale features was overcome through this application of the very high-resolution (VHR) WV satellite imagery. The VHR WV satellite imagery we utilized is relatively new and not yet freely available, therefore this study is among the first to use this data in the geomorphological mapping of nunataks. As such, a comparison to Landsat-based mapping was conducted and it illustrated the significant advancements in the detail of mapping that is made possible by the VHR of the WV satellite imagery. Landforms that had previously been too small to be identified from satellite imagery were clearly identifiable; for example, the sub-meter resolution of the WV satellite imagery made it possible to observe individual boulders. This is of particular value to studies such as CN surface exposure dating where boulders are a target landform (as potentially glacial erratic for sampling). Ground truthing enabled us to evaluate the accuracy of the mapping from the WV data. Overall there was good agreement between the remotely sensed mapping and reality. However, we show that from the imagery alone it is not possible to reliably distinguish the type of surficial cover. However, the basic distinction of bedrock from sediment cover is still an improvement over the detail of mapping possible from Landsat imagery.

In Chapter 3 the results of the geomorphological mapping are presented. The mapping revealed geomorphic and stratigraphic evidence of former ice cover at all sites and elevations across the study area, from the present-day ice surface to the highest summits. The implication of this mapping is that at some point in time the ice sheet has covered all of the nunataks. The geomorphological evidence for wet-based ice covering the nunataks was not widespread. Hence, I suggest, based on this and corroborated by field observations, that the nunatak surfaces show a predominantly relict landscape.

The geomorphological mapping presented in Chapters 2 and 3 has provided the first step (the spatial component described in Chapter 1) towards the MAGIC-DML project objectives to produce an empirical dataset on the glacial history of western DML. The conclusion from this mapping is that the EAIS at some point covered all of the nunataks in western DML.

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4.2 Future work

As described in Chapter 1, there are two critical elements to any ice sheet reconstruction; the spatial component and the chronological component. The geomorphological mapping presented in this thesis satisfies the former for our study area of western DML. The next step is to complement this mapping with a chronological dataset which establishes the timing of ice abandonment from nunatak surfaces across western DML. The surface exposure histories of nunataks we collected samples from during the two MAGIC-DML field seasons will be established using measurements of multiple CNs on individual samples. The results from nunataks along the margins of the Jutulstraumen (Fig. 1.1) have been published in Andersen et al., (2020) and show ice sheet thinning of up to 300 m during the last glacial cycle, ~35-120 m of thinning towards the modern ice surface during the Holocene, and long exposure histories (Pliocene) from the highest summits above the ice-stream. CN measurements have also been conducted for samples collected from nunataks in the Heimefrontfjella and Vestfjella ranges (Fig. 1.1), with analysis and interpretation forthcoming.

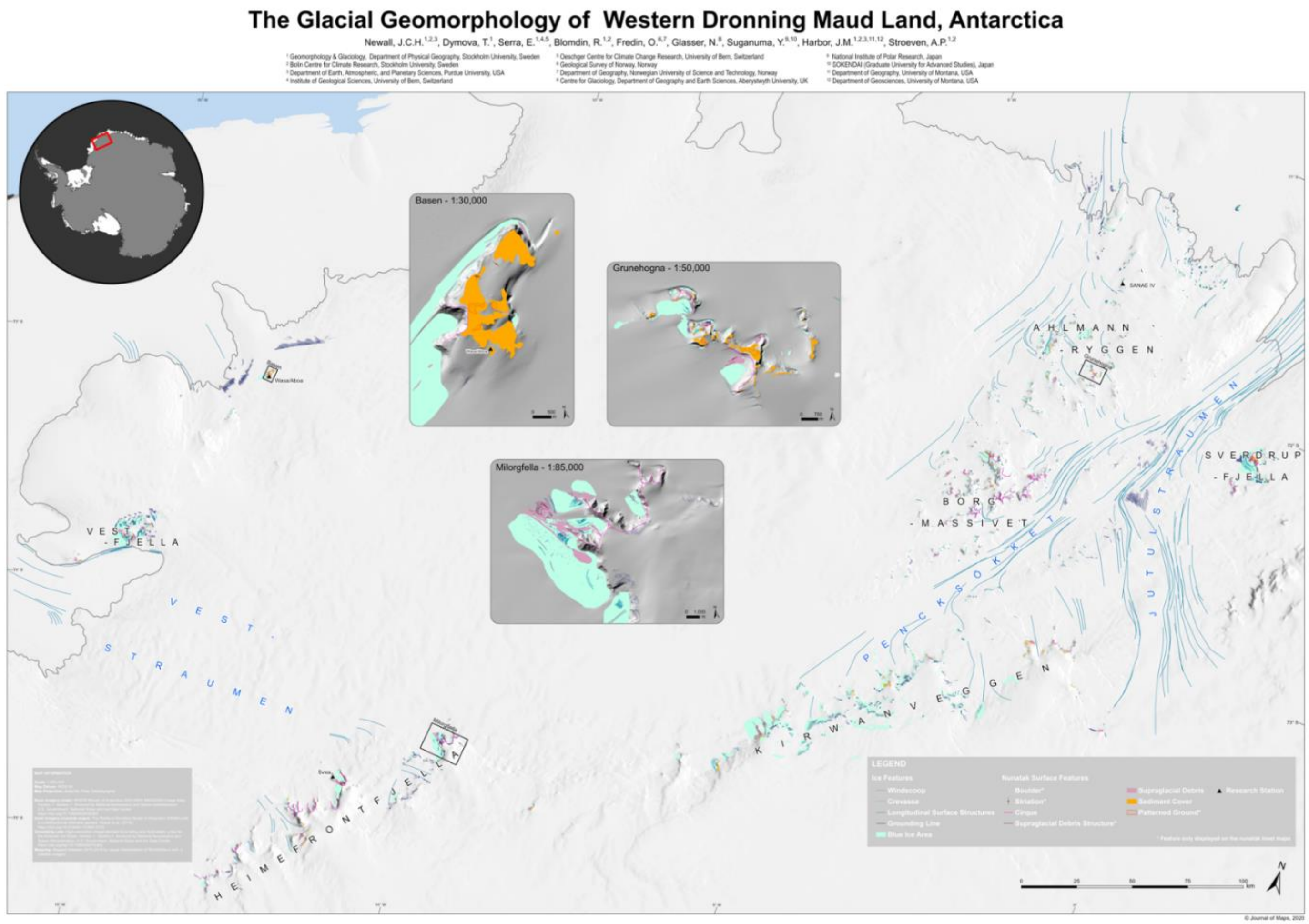
4.3 Summary

This thesis presents the first step towards producing a comprehensive reconstruction of changes in the vertical extent of the EAIS at its margin in western DML. The first phase of this work was a mapping of the glacial geomorphology on nunatak summits. This was completed primarily by remote sensing using very high-resolution World View satellite imagery. I review the merits of this new data for mapping at the scale of individual nunataks, and present a map of the glacial geomorphology of western DML showing evidence that the EAIS once covered all nunatak summits in our study area. This work is presented in Chapters 2 and 3 of this thesis; Chapter 2 is intended to be submitted to a special issue on geomorphological mapping in the journal *Remote Sensing*, and Chapter 3 is published in *Journal of Maps*.

APPENDIX A

PRINT MAP

Overview version of the A0 print map product that compliments Chapter 3 – full version can be downloaded at: https://www.tandfonline.com/doi/full/10.1080/17445647.2020.1761464



APPENDIX B

WORLDVIEW SATELLITE IMAGERY UTILIZED

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WV02	2012-10-19T09:23:41.000000	WV02_103001001B829C00_M1BS_052819618010_02
WV02	2012-10-19T09:23:41.000000	WV02_103001001B829C00_P1BS_052819618010_02
WV02	2012-10-19T09:23:41.000000	WV02_103001001B829C00_P1BS_052819618010_02
WV02	2012-10-19T09:23:41.000000	WV02_103001001B829C00_P1BS_052819618010_02
WV02	2012-10-27T09:27:15.000000	WV02_103001001DD0A400_M1BS_052819617010_01
WV02	2012-10-27T09:27:15.000000	WV02_103001001DD0A400_M1BS_052819617010_01
WV02	2012-10-27T09:27:15.000000	WV02_103001001DD0A400_M1BS_052819617010_01
WV02	2012-10-27T09:27:15.000000	WV02_103001001DD0A400_P1BS_052819617010_01
WV02	2012-10-27T09:27:15.000000	WV02_103001001DD0A400_P1BS_052819617010_01
WV02	2012-10-27T09:27:15.000000	WV02_103001001DD0A400_P1BS_052819617010_01
WV02	2012-10-27T09:28:28.000000	WV02_103001001D574800_M1BS_052819618010_03
WV02	2012-10-27T09:28:28.000000	WV02_103001001D574800_M1BS_052819618010_03
WV02	2012-10-27T09:28:28.000000	WV02_103001001D574800_M1BS_052819618010_03
WV02	2012-10-27T09:28:28.000000	WV02_103001001D574800_P1BS_052819618010_03
WV02	2012-10-27T09:28:28.000000	WV02_103001001D574800_P1BS_052819618010_03
WV02	2012-10-27T09:28:28.000000	WV02_103001001D574800_P1BS_052819618010_03
WV02	2012-11-12T09:38:49.000000	WV02_103001001C36CD00_P1BS_500067111090_01
WV02	2012-11-12T09:38:50.000000	WV02_103001001C36CD00_P1BS_500067111090_01
WV02	2012-11-12T09:38:52.000000	WV02_103001001C36CD00_P1BS_500067111090_01
WV02	2012-11-12T09:38:53.000000	WV02_103001001C36CD00_P1BS_500067111090_01
WV02	2012-11-12T09:38:54.000000	WV02_103001001C36CD00_P1BS_500067111090_01
WV02	2012-11-15T09:28:24.000000	WV02_103001001D40F900_M1BS_500057779090_01
WV02	2012-11-15T09:28:25.000000	WV02_103001001D40F900_M1BS_500057779090_01
WV02	2012-11-15T09:28:26.000000	WV02_103001001D40F900_M1BS_500057779090_01
WV02	2012-11-15T09:28:27.000000	WV02_103001001D40F900_M1BS_500057779090_01
WV02	2012-11-15T09:28:28.000000	WV02_103001001D40F900_M1BS_500057779090_01
WV02	2012-11-15T09:28:29.000000	WV02_103001001D40F900_M1BS_500057779090_01
WV02	2012-11-16T08:50:17.000000	WV02_103001001D513000_M1BS_052819617010_02
WV02	2012-11-16T08:50:17.000000	WV02_103001001D513000_P1BS_052819617010_02
WV02	2012-11-16T08:51:36.000000	WV02_103001001C612D00_M1BS_052819616010_02
WV02	2012-11-16T08:51:36.000000	WV02_103001001C612D00_M1BS_052819616010_02
WV02	2012-11-16T08:51:36.000000	WV02_103001001C612D00_P1BS_052819616010_02

WV02	2012-11-16T08:51:36.000000	WV02_103001001C612D00_P1BS_052819616010_02
WV02	2012-11-16T08:51:54.000000	WV02_103001001DA22400_M1BS_500058299170_01
WV02	2012-11-16T08:51:55.000000	WV02_103001001DA22400_M1BS_500058299170_01
WV02	2012-11-16T08:51:56.000000	WV02_103001001DA22400_M1BS_500058299170_01
WV02	2012-11-16T08:51:57.000000	WV02_103001001DA22400_M1BS_500058299170_01
WV02	2012-11-16T08:51:58.000000	WV02_103001001DA22400_M1BS_500058299170_01
WV02	2012-11-16T08:51:59.000000	WV02_103001001DA22400_M1BS_500058299170_01
WV02	2012-11-18T09:16:31.000000	WV02_103001001C505600_M1BS_500058416070_01
WV02	2012-11-18T09:16:32.000000	WV02_103001001C505600_M1BS_500058416070_01
WV02	2012-11-18T09:16:33.000000	WV02_103001001C505600_M1BS_500058416070_01
WV02	2012-11-18T09:16:34.000000	WV02_103001001C505600_M1BS_500058416070_01
WV02	2012-11-18T09:16:36.000000	WV02_103001001C505600_M1BS_500058416070_01
WV02	2012-11-18T09:16:37.000000	WV02_103001001C505600_M1BS_500058416070_01
WV02	2012-11-18T09:18:03.000000	WV02_103001001C442100_M1BS_500058234120_01
WV02	2012-11-18T09:18:04.000000	WV02_103001001C442100_M1BS_500058234120_01
WV02	2012-11-18T09:18:05.000000	WV02_103001001C442100_M1BS_500058234120_01
WV02	2012-11-21T09:06:02.000000	WV02_103001001D726C00_M1BS_052819617010_03
WV02	2012-11-21T09:06:02.000000	WV02_103001001D726C00_M1BS_052819617010_03
WV02	2012-11-21T09:06:02.000000	WV02_103001001D726C00_M1BS_052819617010_03
WV02	2012-11-21T09:06:02.000000	WV02_103001001D726C00_P1BS_052819617010_03
WV02	2012-11-21T09:06:02.000000	WV02_103001001D726C00_P1BS_052819617010_03
WV02	2012-11-21T09:06:02.000000	WV02_103001001D726C00_P1BS_052819617010_03
WV02	2012-11-21T09:07:33.000000	WV02_103001001C3DA200_M1BS_500060945160_01
WV02	2012-11-21T09:07:33.000000	WV02_103001001C3DA200_P1BS_500060945160_01
WV02	2012-11-21T09:07:34.000000	WV02_103001001C3DA200_M1BS_500060945160_01
WV02	2012-11-21T09:07:34.000000	WV02_103001001C3DA200_P1BS_500060945160_01
WV02	2012-11-21T09:07:35.000000	WV02_103001001C3DA200_M1BS_500060945160_01
WV02	2012-11-21T09:07:35.000000	WV02_103001001C3DA200_P1BS_500060945160_01
WV02	2012-11-21T09:07:36.000000	WV02_103001001C3DA200_M1BS_500060945160_01
WV02	2012-11-21T09:07:36.000000	WV02_103001001C3DA200_P1BS_500060945160_01
WV02	2012-11-21T09:07:37.000000	WV02_103001001C3DA200_M1BS_500060945160_01
WV02	2012-11-21T09:07:37.000000	WV02_103001001C3DA200_P1BS_500060945160_01
WV02	2012-11-21T09:07:38.000000	WV02_103001001C3DA200_M1BS_500060945160_01
WV02	2012-11-21T09:07:38.000000	WV02_103001001C3DA200_P1BS_500060945160_01
WV02	2012-11-28T08:08:54.000000	WV02_103001001C683D00_M1BS_052890469070_01
WV02	2012-11-28T08:08:54.000000	WV02_103001001C683D00_P1BS_052890469070_01
WV02	2012-12-30T08:28:38.000000	WV02_103001001EBC3200_M1BS_052819661010_02
WV02	2012-12-30T08:28:38.000000	WV02_103001001EBC3200_P1BS_052819661010_02
WV02	2012-12-30T08:28:56.000000	WV02_103001001E8BEF00_M1BS_052819661010_02
WV02	2012-12-30T08:28:56.000000	WV02_103001001E8BEF00_P1BS_052819661010_02
WV02	2012-12-30T08:29:43.000000	WV02_103001001EC16700_M1BS_052819658010_01
WV02	2012-12-30T08:29:43.000000	WV02_103001001EC16700_P1BS_052819658010_01
WV02	2012-12-30T08:30:00.000000	WV02_103001001EB3AD00_M1BS_052819664010_03

WV02	2012-12-30T08:30:00.000000	WV02_103001001EB3AD00_P1BS_052819664010_03
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WV02	2013-01-28T08:59:26.000000	WV02_103001001E185000_P1BS_500076339060_01
WV02	2013-01-28T08:59:27.000000	WV02_103001001E185000_M1BS_500076339060_01
WV02	2013-01-28T08:59:27.000000	WV02_103001001E185000_P1BS_500076339060_01
WV02	2013-01-28T08:59:29.000000	WV02_103001001E185000_M1BS_500076339060_01
WV02	2013-01-28T08:59:29.000000	WV02_103001001E185000_P1BS_500076339060_01
WV02	2013-01-28T08:59:30.000000	WV02_103001001E185000_M1BS_500076339060_01
WV02	2013-01-28T08:59:30.000000	WV02_103001001E185000_P1BS_500076339060_01
WV02	2013-01-28T08:59:31.000000	WV02_103001001E185000_M1BS_500076339060_01
WV02	2013-01-28T08:59:31.000000	WV02_103001001E185000_P1BS_500076339060_01
WV02	2013-01-28T08:59:32.000000	WV02_103001001E185000_M1BS_500076339060_01
WV02	2013-01-28T08:59:32.000000	WV02_103001001E185000_P1BS_500076339060_01
WV02	2013-01-28T08:59:47.000000	WV02_103001001F569300_M1BS_500076332140_01
WV02	2013-01-28T08:59:47.000000	WV02_103001001F569300_P1BS_500076332140_01
WV02	2013-01-28T08:59:49.000000	WV02_103001001F569300_M1BS_500076332140_01
WV02	2013-01-28T08:59:49.000000	WV02_103001001F569300_P1BS_500076332140_01
WV02	2013-01-28T08:59:50.000000	WV02_103001001F569300_M1BS_500076332140_01
WV02	2013-01-28T08:59:50.000000	WV02_103001001F569300_P1BS_500076332140_01
WV02	2013-01-28T08:59:51.000000	WV02_103001001F569300_M1BS_500076332140_01
WV02	2013-01-28T08:59:51.000000	WV02_103001001F569300_P1BS_500076332140_01
WV02	2013-01-28T08:59:52.000000	WV02_103001001F569300_M1BS_500076332140_01
WV02	2013-01-28T08:59:52.000000	WV02_103001001F569300_P1BS_500076332140_01
WV02	2013-01-28T08:59:54.000000	WV02_103001001F569300_M1BS_500076332140_01
WV02	2013-01-28T08:59:54.000000	WV02_103001001F569300_P1BS_500076332140_01
WV02	2013-01-29T08:23:45.000000	WV02_103001001E83B700_M1BS_500076339180_01
WV02	2013-01-29T08:23:45.000000	WV02_103001001E83B700_P1BS_500076339180_01
WV02	2013-01-29T08:23:46.000000	WV02_103001001E83B700_M1BS_500076339180_01
WV02	2013-01-29T08:23:46.000000	WV02_103001001E83B700_P1BS_500076339180_01
WV02	2013-01-29T08:23:47.000000	WV02_103001001E83B700_M1BS_500076339180_01
WV02	2013-01-29T08:23:47.000000	WV02_103001001E83B700_P1BS_500076339180_01
WV02	2013-01-29T08:23:49.000000	WV02_103001001E83B700_M1BS_500076339180_01
WV02	2013-01-29T08:23:49.000000	WV02_103001001E83B700_P1BS_500076339180_01
WV02	2013-01-29T08:23:50.000000	WV02_103001001E83B700_M1BS_500076339180_01
WV02	2013-01-29T08:23:50.000000	WV02_103001001E83B700_P1BS_500076339180_01
WV02	2013-01-29T08:23:51.000000	WV02_103001001E83B700_M1BS_500076339180_01
WV02	2013-01-29T08:23:51.000000	WV02_103001001E83B700_P1BS_500076339180_01
WV02	2013-01-29T08:24:01.000000	WV02_103001001E400100_M1BS_500196592010_01
WV02	2013-01-29T08:24:01.000000	WV02_103001001E400100_P1BS_500196592010_01
WV02	2013-01-29T08:24:03.000000	WV02_103001001E400100_M1BS_500196592010_01
WV02	2013-01-29T08:24:03.000000	WV02_103001001E400100_P1BS_500196592010_01
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WV02	2013-01-31T08:50:05.000000	WV02_103001001F5D0600_P1BS_500130373080_01

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WV02	2013-01-31T08:50:06.000000	WV02_103001001F5D0600_P1BS_500130373080_01
WV02	2013-01-31T08:50:07.000000	WV02_103001001F5D0600_M1BS_500130373080_01
WV02	2013-01-31T08:50:07.000000	WV02_103001001F5D0600_P1BS_500130373080_01
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WV02	2013-01-31T08:50:08.000000	WV02_103001001F5D0600_P1BS_500130373080_01
WV02	2013-01-31T08:50:09.000000	WV02_103001001F5D0600_M1BS_500130373080_01
WV02	2013-01-31T08:50:09.000000	WV02_103001001F5D0600_P1BS_500130373080_01
WV02	2013-01-31T08:50:10.000000	WV02_103001001F5D0600_M1BS_500130373080_01
WV02	2013-01-31T08:50:10.000000	WV02_103001001F5D0600_P1BS_500130373080_01
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WV02	2013-02-01T09:51:49.000000	WV02_103001001F0C8600_P1BS_500142216100_01
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WV02	2013-10-04T09:25:17.000000	WV02_1030010027CAB600_P1BS_500095324180_01
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WV02	2013-10-04T09:25:18.000000	WV02_1030010027CAB600_P1BS_500095324180_01
WV02	2013-10-04T09:25:19.000000	WV02_1030010027CAB600_M1BS_500095324180_01
WV02	2013-10-04T09:25:19.000000	WV02_1030010027CAB600_P1BS_500095324180_01
WV02	2013-10-04T09:25:20.000000	WV02_1030010027CAB600_M1BS_500095324180_01
WV02	2013-10-04T09:25:20.000000	WV02_1030010027CAB600_P1BS_500095324180_01
WV02	2013-10-04T09:25:21.000000	WV02_1030010027CAB600_M1BS_500095324180_01
WV02	2013-10-04T09:25:21.000000	WV02_1030010027CAB600_P1BS_500095324180_01
WV02	2013-10-04T09:26:42.000000	WV02_1030010028809800_M1BS_500095283020_01
WV02	2013-10-04T09:26:42.000000	WV02_1030010028809800_P1BS_500095283020_01
WV02	2013-10-04T09:26:43.000000	WV02_1030010028809800_M1BS_500095283020_01
WV02	2013-10-04T09:26:43.000000	WV02_1030010028809800_P1BS_500095283020_01
WV02	2013-10-04T09:26:44.000000	WV02_1030010028809800_M1BS_500095283020_01
WV02	2013-10-04T09:26:44.000000	WV02_1030010028809800_P1BS_500095283020_01
WV02	2013-10-04T09:26:45.000000	WV02_1030010028809800_M1BS_500095283020_01
WV02	2013-10-04T09:26:45.000000	WV02_1030010028809800_P1BS_500095283020_01
WV02	2013-10-04T09:26:46.000000	WV02_1030010028809800_M1BS_500095283020_01
WV02	2013-10-04T09:26:46.000000	WV02_1030010028809800_P1BS_500095283020_01
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WV02	2013-10-05T08:48:49.000000	WV02_1030010028C3BF00_P1BS_500095318130_01
WV02	2013-10-05T08:48:50.000000	WV02_1030010028C3BF00_M1BS_500095318130_01
WV02	2013-10-05T08:48:50.000000	WV02_1030010028C3BF00_P1BS_500095318130_01
WV02	2013-10-05T08:48:52.000000	WV02_1030010028C3BF00_M1BS_500095318130_01
WV02	2013-10-05T08:48:52.000000	WV02_1030010028C3BF00_P1BS_500095318130_01
WV02	2013-10-05T08:48:53.000000	WV02_1030010028C3BF00_M1BS_500095318130_01
WV02	2013-10-05T08:48:53.000000	WV02_1030010028C3BF00_P1BS_500095318130_01
WV02	2013-10-05T08:48:54.000000	WV02_1030010028C3BF00_M1BS_500095318130_01
WV02	2013-10-05T08:48:54.000000	WV02_1030010028C3BF00_P1BS_500095318130_01
WV02	2013-10-05T08:50:24.000000	WV02_10300100262BAB00_M1BS_500099264200_01

WV02	2013-10-05T08:50:24.000000	WV02_10300100262BAB00_P1BS_500099264200_01
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WV02	2013-10-05T08:50:25.000000	WV02_10300100262BAB00_P1BS_500099264200_01
WV02	2013-10-05T08:50:26.000000	WV02_10300100262BAB00_M1BS_500099264200_01
WV02	2013-10-05T08:50:26.000000	WV02_10300100262BAB00_P1BS_500099264200_01
WV02	2013-10-05T08:50:27.000000	WV02_10300100262BAB00_M1BS_500099264200_01
WV02	2013-10-05T08:50:27.000000	WV02_10300100262BAB00_P1BS_500099264200_01
WV02	2013-10-05T08:50:28.000000	WV02_10300100262BAB00_M1BS_500099264200_01
WV02	2013-10-05T08:50:28.000000	WV02_10300100262BAB00_P1BS_500099264200_01
WV02	2014-02-12T09:02:48.000000	WV02_103001002C47B600_M1BS_500143379050_01
WV02	2014-02-12T09:02:48.000000	WV02_103001002C47B600_P1BS_500143379050_01
WV02	2014-02-12T09:02:49.000000	WV02_103001002C47B600_M1BS_500143379050_01
WV02	2014-02-12T09:02:49.000000	WV02_103001002C47B600_M1BS_500143379050_01
WV02	2014-02-12T09:02:49.000000	WV02_103001002C47B600_P1BS_500143379050_01
WV02	2014-02-12T09:02:49.000000	WV02_103001002C47B600_P1BS_500143379050_01
WV02	2014-02-12T09:04:14.000000	WV02_103001002C9CDE00_M1BS_500143382190_01
WV02	2014-02-12T09:04:14.000000	WV02_103001002C9CDE00_P1BS_500143382190_01
WV02	2014-02-12T09:04:15.000000	WV02_103001002C9CDE00_M1BS_500143382190_01
WV02	2014-02-12T09:04:15.000000	WV02_103001002C9CDE00_P1BS_500143382190_01
WV02	2014-02-12T09:04:16.000000	WV02_103001002C9CDE00_M1BS_500143382190_01
WV02	2014-02-12T09:04:16.000000	WV02_103001002C9CDE00_P1BS_500143382190_01
WV02	2014-02-22T09:34:29.000000	WV02_103001002D46A500_M1BS_500130044120_01
WV02	2014-02-22T09:34:29.000000	WV02_103001002D46A500_P1BS_500130044120_01
WV02	2014-02-22T09:34:30.000000	WV02_103001002D46A500_M1BS_500130044120_01
WV02	2014-02-22T09:34:30.000000	WV02_103001002D46A500_P1BS_500130044120_01
WV02	2014-02-22T09:34:40.000000	WV02_103001002E0E6000_M1BS_500130372200_01
WV02	2014-02-22T09:34:40.000000	WV02_103001002E0E6000_P1BS_500130372200_01
WV02	2014-02-22T09:34:41.000000	WV02_103001002E0E6000_M1BS_500130372200_01
WV02	2014-02-22T09:34:41.000000	WV02_103001002E0E6000_P1BS_500130372200_01
WV02	2014-02-22T09:35:41.000000	WV02_103001002B26E200_M1BS_500130370030_01
WV02	2014-02-22T09:35:41.000000	WV02_103001002B26E200_P1BS_500130370030_01
WV02	2014-02-22T09:35:42.000000	WV02_103001002B26E200_M1BS_500130370030_01
WV02	2014-02-22T09:35:42.000000	WV02_103001002B26E200_P1BS_500130370030_01
WV02	2014-02-22T09:35:43.000000	WV02_103001002B26E200_M1BS_500130370030_01
WV02	2014-02-22T09:35:43.000000	WV02_103001002B26E200_P1BS_500130370030_01
WV02	2014-02-22T09:35:55.000000	WV02_103001002D60D800_M1BS_500145741020_01
WV02	2014-02-22T09:35:55.000000	WV02_103001002D60D800_P1BS_500145741020_01
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WV02	2014-02-22T09:35:57.000000	WV02_103001002D60D800_P1BS_500145741020_01
WV02	2014-02-22T09:35:58.000000	WV02_103001002D60D800_M1BS_500145741020_01
WV02	2014-02-22T09:35:58.000000	WV02_103001002D60D800_P1BS_500145741020_01

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WV02	2014-02-22T09:35:59.000000	WV02_103001002D60D800_P1BS_500145741020_01
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WV02	2014-10-03T09:10:58.000000	WV02_1030010037A8D200_P1BS_500147804100_01
WV02	2014-10-03T09:10:58.000000	WV02_1030010037A8D200_P1BS_500147804100_01
WV02	2014-10-03T09:10:58.000000	WV02_1030010037A8D200_P1BS_500147804100_01
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WV02	2014-10-03T09:12:28.000000	WV02_10300100382C4B00_M1BS_500147804100_01
WV02	2014-10-03T09:12:28.000000	WV02_10300100382C4B00_M1BS_500147804100_01
WV02	2014-10-03T09:12:28.000000	WV02_10300100382C4B00_P1BS_500147804100_01
WV02	2014-10-03T09:12:28.000000	WV02_10300100382C4B00_P1BS_500147804100_01
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WV02	2014-10-06T09:00:27.000000	WV02_1030010037C41B00_M1BS_500147804100_02
WV02	2014-10-06T09:00:27.000000	WV02_1030010037C41B00_M1BS_500147804100_02
WV02	2014-10-06T09:00:27.000000	WV02_1030010037C41B00_P1BS_500147804100_02
WV02	2014-10-06T09:00:27.000000	WV02_1030010037C41B00_P1BS_500147804100_02
WV02	2014-10-06T09:00:27.000000	WV02_1030010037C41B00_P1BS_500147804100_02
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WV02	2014-10-06T09:01:36.000000	WV02_103001003882DE00_P1BS_500147804100_02
WV02	2014-10-06T09:01:36.000000	WV02_103001003882DE00_P1BS_500147804100_02
WV02	2014-10-06T09:01:36.000000	WV02_103001003882DE00_P1BS_500147804100_02
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WV02	2014-11-04T09:30:15.000000	WV02_10300100393A4C00_P1BS_500319411030_01
WV02	2014-11-04T09:30:16.000000	WV02_10300100393A4C00_M1BS_500319411030_01
WV02	2014-11-04T09:30:16.000000	WV02_10300100393A4C00_P1BS_500319411030_01
WV02	2014-11-04T09:30:17.000000	WV02_10300100393A4C00_M1BS_500319411030_01
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WV02	2014-11-04T09:30:18.000000	WV02_10300100393A4C00_P1BS_500319411030_01
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WV02	2014-11-14T08:20:15.000000	WV02_1030010039783C00_M1BS_500339937130_01
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WV02	2014-11-14T08:20:16.000000	WV02_1030010039783C00_M1BS_500339937130_01

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WV02	2014-11-14T08:21:23.000000	WV02_10300100399DAC00_M1BS_500319430120_01
WV02	2014-11-14T08:21:23.000000	WV02_10300100399DAC00_P1BS_500319430120_01
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WV02	2015-09-22T08:03:45.000000	WV02_1030010048558500_P1BS_500597089080_01
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WV02	2015-12-01T08:24:09.000000	WV02_103001004E55DE00_P1BS_500621428010_01
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WV02	2015-12-01T08:24:27.000000	WV02_103001004DB50300_P1BS_500621460060_01
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WV02	2015-12-02T09:27:11.000000	WV02_103001004C6B3800_P1BS_500621472060_01
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WV02	2015-12-02T09:27:12.000000	WV02_103001004C6B3800_P1BS_500621472060_01
WV02	2015-12-02T09:27:13.000000	WV02_103001004C6B3800_M1BS_500621472060_01
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WV02	2015-12-09T08:30:27.000000	WV02_103001004D874C00_P1BS_500593066080_01
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WV02	2015-12-09T08:30:28.000000	WV02_103001004D874C00_P1BS_500593066080_01
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WV02	2015-12-14T08:45:49.000000	WV02_103001004C997700_P1BS_500578106040_01
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WV02	2015-12-16T09:11:50.000000	WV02_103001004F5E8300_P1BS_500578178010_01
WV02	2015-12-16T09:11:51.000000	WV02_103001004F5E8300_M1BS_500578178010_01
WV02	2015-12-16T09:11:51.000000	WV02_103001004F5E8300_P1BS_500578178010_01
WV02	2015-12-16T09:11:52.000000	WV02_103001004F5E8300_M1BS_500578178010_01
WV02	2015-12-16T09:11:52.000000	WV02_103001004F5E8300_P1BS_500578178010_01
WV02	2016-01-01T09:20:51.000000	WV02_1030010050C3F500_M1BS_500579544030_01
WV02	2016-01-01T09:20:51.000000	WV02_1030010050C3F500_M1BS_500579544030_01
WV02	2016-01-01T09:20:51.000000	WV02_1030010050C3F500_P1BS_500579544030_01
WV02	2016-01-01T09:20:51.000000	WV02_1030010050C3F500_P1BS_500579544030_01
WV02	2016-01-13T08:39:12.000000	WV02_103001004F53B800_M1BS_500718518090_01
WV02	2016-01-13T08:39:12.000000	WV02_103001004F53B800_P1BS_500718518090_01
WV02	2016-01-13T08:39:13.000000	WV02_103001004F53B800_M1BS_500718518090_01
WV02	2016-01-13T08:39:13.000000	WV02_103001004F53B800_P1BS_500718518090_01
WV02	2016-01-13T08:39:40.000000	WV02_103001004EC2D500_M1BS_500718519010_01
WV02	2016-01-13T08:39:40.000000	WV02_103001004EC2D500_M1BS_500718519010_01
WV02	2016-01-13T08:39:40.000000	WV02_103001004EC2D500_P1BS_500718519010_01
WV02	2016-01-13T08:39:40.000000	WV02_103001004EC2D500_P1BS_500718519010_01
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WV02	2016-02-16T07:46:07.000000	WV02_1030010052CC6200_P1BS_500717397070_01
WV02	2016-02-16T07:46:08.000000	WV02_1030010052CC6200_M1BS_500717397070_01
WV02	2016-02-16T07:46:08.000000	WV02_1030010052CC6200_P1BS_500717397070_01
WV02	2016-02-16T07:46:09.000000	WV02_1030010052CC6200_M1BS_500717397070_01
WV02	2016-02-16T07:46:09.000000	WV02_1030010052CC6200_P1BS_500717397070_01
WV02	2016-02-20T08:37:01.000000	WV02_1030010052AAF700_M1BS_500717388050_01
WV02	2016-02-20T08:37:01.000000	WV02_1030010052AAF700_P1BS_500717388050_01
WV02	2016-02-20T08:37:02.000000	WV02_1030010052AAF700_M1BS_500717388050_01

WV02	2016-02-20T08:37:02.000000	WV02_1030010052AAF700_P1BS_500717388050_01
WV02	2016-02-20T08:37:03.000000	WV02_1030010052AAF700_M1BS_500717388050_01
WV02	2016-02-20T08:37:03.000000	WV02_1030010052AAF700_P1BS_500717388050_01
WV02	2016-02-20T08:37:04.000000	WV02_1030010052AAF700_M1BS_500717388050_01
WV02	2016-02-20T08:37:04.000000	WV02_1030010052AAF700_P1BS_500717388050_01
WV02	2016-02-20T08:37:05.000000	WV02_1030010052AAF700_M1BS_500717388050_01
WV02	2016-02-20T08:37:05.000000	WV02_1030010052AAF700_P1BS_500717388050_01
WV02	2016-02-20T08:37:07.000000	WV02_1030010052AAF700_M1BS_500717388050_01
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WV02	2016-02-20T08:37:08.000000	WV02_1030010052AAF700_P1BS_500717388050_01
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WV02	2016-02-20T08:37:16.000000	WV02_1030010052A62D00_P1BS_500717416060_01
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WV02	2016-02-20T08:37:18.000000	WV02_1030010052A62D00_P1BS_500717416060_01
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WV02	2016-02-20T08:37:20.000000	WV02_1030010052A62D00_P1BS_500717416060_01
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WV02	2016-02-20T08:37:21.000000	WV02_1030010052A62D00_P1BS_500717416060_01
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WV02	2016-02-20T08:37:40.000000	WV02_1030010050020900_M1BS_500717416050_01
WV02	2016-02-20T08:37:40.000000	WV02_1030010050020900_P1BS_500717416050_01
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WV02	2016-02-20T08:37:42.000000	WV02_1030010050020900_P1BS_500717416050_01
WV02	2016-02-20T08:37:44.000000	WV02_1030010050020900_M1BS_500717416050_01
WV02	2016-02-20T08:37:44.000000	WV02_1030010050020900_P1BS_500717416050_01
WV02	2016-02-20T08:37:45.000000	WV02_1030010050020900_M1BS_500717416050_01
WV02	2016-02-20T08:37:45.000000	WV02_1030010050020900_P1BS_500717416050_01
WV02	2016-02-20T08:37:54.000000	WV02_10300100530E9400_M1BS_500717390100_01
WV02	2016-02-20T08:37:54.000000	WV02_10300100530E9400_P1BS_500717390100_01
WV02	2016-02-20T08:37:55.000000	WV02_10300100530E9400_M1BS_500717390100_01
WV02	2016-02-20T08:37:55.000000	WV02_10300100530E9400_P1BS_500717390100_01
WV02	2016-02-20T08:37:56.000000	WV02_10300100530E9400_M1BS_500717390100_01
WV02	2016-02-20T08:37:56.000000	WV02_10300100530E9400_P1BS_500717390100_01
WV02	2016-02-20T08:37:57.000000	WV02_10300100530E9400_M1BS_500717390100_01
WV02	2016-02-20T08:37:57.000000	WV02_10300100530E9400_P1BS_500717390100_01

WV02	2016-02-20T08:37:59.000000	WV02_10300100530E9400_M1BS_500717390100_01
WV02	2016-02-20T08:37:59.000000	WV02_10300100530E9400_P1BS_500717390100_01
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WV02	2016-02-20T08:38:15.000000	WV02_10300100516F0800_P1BS_500717391020_01
WV02	2016-02-20T08:38:16.000000	WV02_10300100516F0800_M1BS_500717391020_01
WV02	2016-02-20T08:38:16.000000	WV02_10300100516F0800_P1BS_500717391020_01
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WV02	2016-02-20T08:38:19.000000	WV02_10300100516F0800_M1BS_500717391020_01
WV02	2016-02-20T08:38:19.000000	WV02_10300100516F0800_P1BS_500717391020_01
WV02	2016-02-20T08:38:20.000000	WV02_10300100516F0800_M1BS_500717391020_01
WV02	2016-02-20T08:38:20.000000	WV02_10300100516F0800_P1BS_500717391020_01
WV02	2016-02-20T08:38:21.000000	WV02_10300100516F0800_M1BS_500717391020_01
WV02	2016-02-20T08:38:21.000000	WV02_10300100516F0800_P1BS_500717391020_01
WV02	2016-02-20T08:38:30.000000	WV02_1030010051C6EC00_M1BS_500717388070_01
WV02	2016-02-20T08:38:30.000000	WV02_1030010051C6EC00_P1BS_500717388070_01
WV02	2016-02-20T08:38:31.000000	WV02_1030010051C6EC00_M1BS_500717388070_01
WV02	2016-02-20T08:38:31.000000	WV02_1030010051C6EC00_P1BS_500717388070_01
WV02	2016-02-20T08:38:32.000000	WV02_1030010051C6EC00_M1BS_500717388070_01
WV02	2016-02-20T08:38:32.000000	WV02_1030010051C6EC00_P1BS_500717388070_01
WV02	2016-02-20T08:38:33.000000	WV02_1030010051C6EC00_M1BS_500717388070_01
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WV02	2016-09-15T09:02:26.000000	WV02_103001005E982000_P1BS_500909065060_01
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WV02	2016-09-15T09:02:27.000000	WV02_103001005E982000_P1BS_500909065060_01
WV02	2016-09-15T09:04:18.000000	WV02_103001005C253D00_M1BS_500909064060_01
WV02	2016-09-15T09:04:18.000000	WV02_103001005C253D00_P1BS_500909064060_01
WV02	2016-09-15T09:04:19.000000	WV02_103001005C253D00_M1BS_500909064060_01
WV02	2016-09-15T09:04:19.000000	WV02_103001005C253D00_P1BS_500909064060_01
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WV02	2016-09-21T08:41:31.000000	WV02_103001005D3B9300_P1BS_501212004050_01
WV02	2016-09-21T08:41:32.000000	WV02_103001005D3B9300_M1BS_501212004050_01
WV02	2016-09-21T08:41:32.000000	WV02_103001005D3B9300_P1BS_501212004050_01
WV02	2016-09-21T08:41:56.000000	WV02_103001005DC82500_M1BS_500963537020_01
WV02	2016-09-21T08:41:56.000000	WV02_103001005DC82500_M1BS_500963537020_01
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WV02	2016-10-18T08:45:41.000000	WV02_103001005E007200_P1BS_501017491090_01
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WV02	2016-10-18T08:47:10.000000	WV02_1030010060814900_P1BS_501012769040_01
WV02	2016-10-18T08:47:11.000000	WV02_1030010060814900_M1BS_501012769040_01
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WV02	2016-10-18T08:47:12.000000	WV02_1030010060814900_P1BS_501012769040_01
WV02	2016-10-18T08:47:13.000000	WV02_1030010060814900_M1BS_501012769040_01
WV02	2016-10-18T08:47:13.000000	WV02_1030010060814900_P1BS_501012769040_01
WV02	2016-10-18T08:47:14.000000	WV02_1030010060814900_M1BS_501012769040_01
WV02	2016-10-18T08:47:14.000000	WV02_1030010060814900_P1BS_501012769040_01
WV02	2016-10-18T08:47:16.000000	WV02_1030010060814900_M1BS_501012769040_01
WV02	2016-10-18T08:47:16.000000	WV02_1030010060814900_P1BS_501012769040_01
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WV02	2010-12-25T08:54:04.000000	WV02_1030010008552700_P1BS_052883758020_01
WV02	2010-12-25T08:54:06.000000	WV02_1030010008552700_M1BS_052883758020_01
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WV02	2010-12-25T08:54:06.000000	WV02_1030010008552700_P1BS_052883758020_01
WV02	2010-12-25T08:54:06.000000	WV02_1030010008552700_P1BS_052883758020_01
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WV02	2010-12-30T09:10:55.000000	WV02_1030010008841D00_P1BS_052883905040_01
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WV02	2011-11-28T09:29:49.000000	WV02_103001000F669900_M1BS_052888092040_01
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WV02	2012-01-02T09:43:08.000000	WV02_1030010010311B00_P1BS_052639217010_02
WV02	2012-01-02T09:43:09.000000	WV02_1030010010311B00_P1BS_052639217010_02
WV02	2012-01-02T09:43:10.000000	WV02_1030010010311B00_P1BS_052639217010_02
WV02	2012-01-02T09:43:32.000000	WV02_1030010010A3B200_P1BS_052639217010_01
WV02	2012-01-02T09:43:33.000000	WV02_1030010010A3B200_P1BS_052639217010_01
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WV02	2012-01-02T09:44:09.000000	WV02_103001000F3AE800_P1BS_052639123010_01
WV02	2012-01-02T09:44:10.000000	WV02_103001000F3AE800_P1BS_052639123010_01
WV02	2012-01-02T09:44:12.000000	WV02_103001000F3AE800_P1BS_052639123010_01
WV02	2012-01-18T09:54:38.000000	WV02_1030010010642E00_P1BS_052639123010_02
WV02	2012-01-18T09:54:39.000000	WV02_1030010010642E00_P1BS_052639123010_02
WV02	2012-01-18T09:54:40.000000	WV02_1030010010642E00_P1BS_052639123010_02
WV02	2012-09-29T10:00:01.000000	WV02_103001001C1D2400_M1BS_052789983010_02
WV02	2012-09-29T10:00:01.000000	WV02_103001001C1D2400_P1BS_052789983010_02
WV02	2012-09-29T10:00:02.000000	WV02_103001001C1D2400_M1BS_052789983010_02
WV02	2012-09-29T10:00:02.000000	WV02_103001001C1D2400_P1BS_052789983010_02
WV02	2012-09-29T10:00:03.000000	WV02_103001001C1D2400_M1BS_052789983010_02
WV02	2012-09-29T10:00:03.000000	WV02_103001001C1D2400_M1BS_052789983010_02
WV02	2012-09-29T10:00:03.000000	WV02_103001001C1D2400_P1BS_052789983010_02
WV02	2012-09-29T10:00:03.000000	WV02_103001001C1D2400_P1BS_052789983010_02
WV02	2012-09-29T10:00:25.000000	WV02_103001001BC07E00_M1BS_052789983010_01
WV02	2012-09-29T10:00:25.000000	WV02_103001001BC07E00_P1BS_052789983010_01
WV02	2012-09-29T10:00:26.000000	WV02_103001001BC07E00_M1BS_052789983010_01
WV02	2012-09-29T10:00:26.000000	WV02_103001001BC07E00_P1BS_052789983010_01
WV02	2012-09-29T10:00:27.000000	WV02_103001001BC07E00_M1BS_052789983010_01
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WV02	2012-09-29T10:00:27.000000	WV02_103001001BC07E00_P1BS_052789983010_01

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WV02	2012-09-29T10:00:36.000000	WV02_103001001B38BD00_P1BS_052789893010_02
WV02	2012-09-29T10:00:37.000000	WV02_103001001B38BD00_M1BS_052789893010_02
WV02	2012-09-29T10:00:37.000000	WV02_103001001B38BD00_P1BS_052789893010_02
WV02	2012-09-29T10:00:38.000000	WV02_103001001B38BD00_M1BS_052789893010_02
WV02	2012-09-29T10:00:38.000000	WV02_103001001B38BD00_P1BS_052789893010_02
WV02	2012-09-29T10:00:39.000000	WV02_103001001B38BD00_M1BS_052789893010_02
WV02	2012-09-29T10:00:39.000000	WV02_103001001B38BD00_P1BS_052789893010_02
WV02	2012-09-29T10:01:00.000000	WV02_103001001C950A00_M1BS_052789893010_01
WV02	2012-09-29T10:01:00.000000	WV02_103001001C950A00_P1BS_052789893010_01
WV02	2012-09-29T10:01:01.000000	WV02_103001001C950A00_M1BS_052789893010_01
WV02	2012-09-29T10:01:01.000000	WV02_103001001C950A00_P1BS_052789893010_01
WV02	2012-09-29T10:01:02.000000	WV02_103001001C950A00_M1BS_052789893010_01
WV02	2012-09-29T10:01:02.000000	WV02_103001001C950A00_P1BS_052789893010_01
WV02	2012-10-02T09:49:20.000000	WV02_103001001C83F500_M1BS_052819615010_01
WV02	2012-10-02T09:49:20.000000	WV02_103001001C83F500_P1BS_052819615010_01
WV02	2012-10-02T09:50:36.000000	WV02_103001001C1D7900_M1BS_052819615010_01
WV02	2012-10-02T09:50:36.000000	WV02_103001001C1D7900_P1BS_052819615010_01
WV02	2013-01-21T09:57:52.000000	WV02_103001001EAEF100_M1BS_500076333180_01
WV02	2013-01-21T09:57:52.000000	WV02_103001001EAEF100_P1BS_500076333180_01
WV02	2013-01-21T09:57:53.000000	WV02_103001001EAEF100_M1BS_500076333180_01
WV02	2013-01-21T09:57:53.000000	WV02_103001001EAEF100_P1BS_500076333180_01
WV02	2013-01-21T09:57:54.000000	WV02_103001001EAEF100_M1BS_500076333180_01
WV02	2013-01-21T09:57:54.000000	WV02_103001001EAEF100_P1BS_500076333180_01
WV02	2013-01-21T09:57:56.000000	WV02_103001001EAEF100_M1BS_500076333180_01
WV02	2013-01-21T09:57:56.000000	WV02_103001001EAEF100_P1BS_500076333180_01
WV02	2013-01-21T09:57:57.000000	WV02_103001001EAEF100_M1BS_500076333180_01
WV02	2013-01-21T09:57:57.000000	WV02_103001001EAEF100_P1BS_500076333180_01
WV02	2013-01-27T07:57:48.000000	WV02_103001001EC40400_M1BS_500076316180_01
WV02	2013-01-27T07:57:48.000000	WV02_103001001EC40400_P1BS_500076316180_01
WV02	2013-01-27T07:57:49.000000	WV02_103001001EC40400_M1BS_500076316180_01
WV02	2013-01-27T07:57:49.000000	WV02_103001001EC40400_P1BS_500076316180_01
WV02	2013-01-27T07:57:50.000000	WV02_103001001EC40400_M1BS_500076316180_01
WV02	2013-01-27T07:57:50.000000	WV02_103001001EC40400_P1BS_500076316180_01
WV02	2013-01-27T07:57:51.000000	WV02_103001001EC40400_M1BS_500076316180_01
WV02	2013-01-27T07:57:51.000000	WV02_103001001EC40400_P1BS_500076316180_01
WV02	2013-01-27T07:57:52.000000	WV02_103001001EC40400_M1BS_500076316180_01
WV02	2013-01-27T07:57:52.000000	WV02_103001001EC40400_P1BS_500076316180_01
WV02	2013-01-27T07:58:00.000000	WV02_103001001F49D600_M1BS_500076340060_01
WV02	2013-01-27T07:58:00.000000	WV02_103001001F49D600_P1BS_500076340060_01
WV02	2013-01-27T07:58:02.000000	WV02_103001001F49D600_M1BS_500076340060_01
WV02	2013-01-27T07:58:02.000000	WV02_103001001F49D600_P1BS_500076340060_01

WV02	2013-01-27T07:58:03.000000	WV02_103001001F49D600_M1BS_500076340060_01
WV02	2013-01-27T07:58:03.000000	WV02_103001001F49D600_P1BS_500076340060_01
WV02	2013-01-27T07:58:04.000000	WV02_103001001F49D600_M1BS_500076340060_01
WV02	2013-01-27T07:58:04.000000	WV02_103001001F49D600_P1BS_500076340060_01
WV02	2013-01-27T07:58:23.000000	WV02_103001001F13BC00_M1BS_500146123050_01
WV02	2013-01-27T07:58:23.000000	WV02_103001001F13BC00_P1BS_500146123050_01
WV02	2013-01-27T07:58:24.000000	WV02_103001001F13BC00_M1BS_500146123050_01
WV02	2013-01-27T07:58:24.000000	WV02_103001001F13BC00_P1BS_500146123050_01
WV02	2013-01-27T07:58:25.000000	WV02_103001001F13BC00_M1BS_500146123050_01
WV02	2013-01-27T07:58:25.000000	WV02_103001001F13BC00_P1BS_500146123050_01
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WV02	2013-03-31T09:13:48.000000	WV02_10300100206C8F00_P1BS_500067099070_01
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WV02	2013-10-29T09:06:05.000000	WV02_1030010028634F00_M1BS_500095284070_01
WV02	2013-10-29T09:06:05.000000	WV02_1030010028634F00_P1BS_500095284070_01
WV02	2013-10-29T09:06:07.000000	WV02_1030010028634F00_M1BS_500095284070_01
WV02	2013-10-29T09:06:07.000000	WV02_1030010028634F00_M1BS_500095284070_01
WV02	2013-10-29T09:06:07.000000	WV02_1030010028634F00_P1BS_500095284070_01
WV02	2013-10-29T09:06:07.000000	WV02_1030010028634F00_P1BS_500095284070_01
WV02	2013-10-29T09:07:31.000000	WV02_1030010028BEFC00_M1BS_500095293040_01
WV02	2013-10-29T09:07:31.000000	WV02_1030010028BEFC00_P1BS_500095293040_01
WV02	2013-10-29T09:07:32.000000	WV02_1030010028BEFC00_M1BS_500095293040_01
WV02	2013-10-29T09:07:32.000000	WV02_1030010028BEFC00_P1BS_500095293040_01
WV02	2014-02-01T09:08:00.000000	WV02_103001002BAF5000_M1BS_500110271060_01
WV02	2014-02-01T09:08:00.000000	WV02_103001002BAF5000_P1BS_500110271060_01
WV02	2014-02-01T09:08:02.000000	WV02_103001002BAF5000_M1BS_500110271060_01
WV02	2014-02-01T09:08:02.000000	WV02_103001002BAF5000_P1BS_500110271060_01
WV02	2014-02-01T09:09:31.000000	WV02_103001002C2F2400_M1BS_500106858120_01
WV02	2014-02-01T09:09:31.000000	WV02_103001002C2F2400_P1BS_500106858120_01
WV02	2014-02-01T09:09:32.000000	WV02_103001002C2F2400_M1BS_500106858120_01
WV02	2014-02-01T09:09:32.000000	WV02_103001002C2F2400_P1BS_500106858120_01
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WV02	2014-02-07T08:47:15.000000	WV02_103001002CCDA200_P1BS_500143401180_01
WV02	2014-02-07T08:47:16.000000	WV02_103001002CCDA200_M1BS_500143401180_01
WV02	2014-02-07T08:47:16.000000	WV02_103001002CCDA200_P1BS_500143401180_01
WV02	2014-02-07T08:47:17.000000	WV02_103001002CCDA200_M1BS_500143401180_01
WV02	2014-02-07T08:47:17.000000	WV02_103001002CCDA200_M1BS_500143401180_01
WV02	2014-02-07T08:47:17.000000	WV02_103001002CCDA200_P1BS_500143401180_01
WV02	2014-02-07T08:47:17.000000	WV02_103001002CCDA200_P1BS_500143401180_01
WV02	2014-02-07T08:48:44.000000	WV02_103001002BA65600_M1BS_500130361080_01
WV02	2014-02-07T08:48:44.000000	WV02_103001002BA65600_P1BS_500130361080_01
WV02	2014-02-07T08:48:45.000000	WV02_103001002BA65600_M1BS_500130361080_01
WV02	2014-02-07T08:48:45.000000	WV02_103001002BA65600_P1BS_500130361080_01

WV02	2014-02-07T08:48:46.000000	WV02_103001002BA65600_M1BS_500130361080_01
WV02	2014-02-07T08:48:46.000000	WV02_103001002BA65600_P1BS_500130361080_01
WV02	2014-02-07T08:48:47.000000	WV02_103001002BA65600_M1BS_500130361080_01
WV02	2014-02-07T08:48:47.000000	WV02_103001002BA65600_P1BS_500130361080_01
WV02	2014-02-15T08:54:11.000000	WV02_103001002B8C8700_M1BS_500130026060_01
WV02	2014-02-15T08:54:11.000000	WV02_103001002B8C8700_P1BS_500130026060_01
WV02	2014-02-15T08:54:13.000000	WV02_103001002B8C8700_M1BS_500130026060_01
WV02	2014-02-15T08:54:13.000000	WV02_103001002B8C8700_P1BS_500130026060_01
WV02	2014-02-15T08:54:14.000000	WV02_103001002B8C8700_M1BS_500130026060_01
WV02	2014-02-15T08:54:14.000000	WV02_103001002B8C8700_P1BS_500130026060_01
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WV02	2014-11-30T08:28:44.000000	WV02_103001003B6FD900_P1BS_500319439050_01
WV02	2014-11-30T08:28:46.000000	WV02_103001003B6FD900_M1BS_500319439050_01
WV02	2014-11-30T08:28:46.000000	WV02_103001003B6FD900_P1BS_500319439050_01
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WV02	2014-11-30T08:28:48.000000	WV02_103001003B6FD900_P1BS_500319439050_01
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WV02	2014-11-30T08:29:50.000000	WV02_103001003A157F00_P1BS_500340639050_01
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WV02	2014-11-30T08:29:51.000000	WV02_103001003A157F00_P1BS_500340639050_01
WV02	2014-11-30T08:29:52.000000	WV02_103001003A157F00_M1BS_500340639050_01
WV02	2014-11-30T08:29:52.000000	WV02_103001003A157F00_P1BS_500340639050_01
WV02	2014-12-02T08:55:13.000000	WV02_103001003A75F200_M1BS_500319435200_01
WV02	2014-12-02T08:55:13.000000	WV02_103001003A75F200_P1BS_500319435200_01
WV02	2014-12-02T08:55:15.000000	WV02_103001003A75F200_M1BS_500319435200_01
WV02	2014-12-02T08:55:15.000000	WV02_103001003A75F200_P1BS_500319435200_01
WV02	2014-12-02T08:55:16.000000	WV02_103001003A75F200_M1BS_500319435200_01
WV02	2014-12-02T08:55:16.000000	WV02_103001003A75F200_P1BS_500319435200_01
WV02	2014-12-02T08:55:17.000000	WV02_103001003A75F200_M1BS_500319435200_01
WV02	2014-12-02T08:55:17.000000	WV02_103001003A75F200_P1BS_500319435200_01
WV02	2014-12-02T08:56:16.000000	WV02_103001003B420F00_M1BS_500340585020_01
WV02	2014-12-02T08:56:16.000000	WV02_103001003B420F00_P1BS_500340585020_01
WV02	2014-12-02T08:56:17.000000	WV02_103001003B420F00_M1BS_500340585020_01
WV02	2014-12-02T08:56:17.000000	WV02_103001003B420F00_P1BS_500340585020_01
WV02	2014-12-02T08:56:18.000000	WV02_103001003B420F00_M1BS_500340585020_01
WV02	2014-12-02T08:56:18.000000	WV02_103001003B420F00_P1BS_500340585020_01
WV02	2014-12-02T08:56:19.000000	WV02_103001003B420F00_M1BS_500340585020_01
WV02	2014-12-02T08:56:19.000000	WV02_103001003B420F00_P1BS_500340585020_01
WV02	2014-12-12T09:24:56.000000	WV02_103001003B6A3700_M1BS_500319473140_01
WV02	2014-12-12T09:24:56.000000	WV02_103001003B6A3700_P1BS_500319473140_01
WV02	2014-12-12T09:24:57.000000	WV02_103001003B6A3700_M1BS_500319473140_01

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WV02	2014-12-12T09:24:58.000000	WV02_103001003B6A3700_P1BS_500319473140_01
WV02	2014-12-12T09:24:59.000000	WV02_103001003B6A3700_M1BS_500319473140_01
WV02	2014-12-12T09:24:59.000000	WV02_103001003B6A3700_P1BS_500319473140_01
WV02	2014-12-12T09:25:01.000000	WV02_103001003B6A3700_M1BS_500319473140_01
WV02	2014-12-12T09:25:01.000000	WV02_103001003B6A3700_P1BS_500319473140_01
WV02	2014-12-12T09:26:01.000000	WV02_103001003A1A5400_M1BS_500340670170_01
WV02	2014-12-12T09:26:01.000000	WV02_103001003A1A5400_P1BS_500340670170_01
WV02	2014-12-12T09:26:03.000000	WV02_103001003A1A5400_M1BS_500340670170_01
WV02	2014-12-12T09:26:03.000000	WV02_103001003A1A5400_P1BS_500340670170_01
WV02	2014-12-12T09:26:04.000000	WV02_103001003A1A5400_M1BS_500340670170_01
WV02	2014-12-12T09:26:04.000000	WV02_103001003A1A5400_P1BS_500340670170_01
WV02	2014-12-12T09:26:05.000000	WV02_103001003A1A5400_M1BS_500340670170_01
WV02	2014-12-12T09:26:05.000000	WV02_103001003A1A5400_P1BS_500340670170_01
WV02	2014-12-12T09:26:06.000000	WV02_103001003A1A5400_M1BS_500340670170_01
WV02	2014-12-12T09:26:06.000000	WV02_103001003A1A5400_P1BS_500340670170_01
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WV02	2015-02-07T09:20:22.000000	WV02_103001003E4BD900_P1BS_500320705040_01
WV02	2015-02-07T09:20:23.000000	WV02_103001003E4BD900_M1BS_500320705040_01
WV02	2015-02-07T09:20:23.000000	WV02_103001003E4BD900_P1BS_500320705040_01
WV02	2015-02-07T09:20:24.000000	WV02_103001003E4BD900_M1BS_500320705040_01
WV02	2015-02-07T09:20:24.000000	WV02_103001003E4BD900_P1BS_500320705040_01
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WV02	2015-02-07T09:21:27.000000	WV02_103001003DB13700_P1BS_500318588200_01
WV02	2015-02-07T09:21:28.000000	WV02_103001003DB13700_M1BS_500318588200_01
WV02	2015-02-07T09:21:28.000000	WV02_103001003DB13700_M1BS_500318588200_01
WV02	2015-02-07T09:21:28.000000	WV02_103001003DB13700_P1BS_500318588200_01
WV02	2015-02-07T09:21:28.000000	WV02_103001003DB13700_P1BS_500318588200_01
WV02	2015-09-24T08:29:17.000000	WV02_103001004A200400_M1BS_500597105080_01
WV02	2015-09-24T08:29:17.000000	WV02_103001004A200400_P1BS_500597105080_01
WV02	2015-09-24T08:29:18.000000	WV02_103001004A200400_M1BS_500597105080_01
WV02	2015-09-24T08:29:18.000000	WV02_103001004A200400_P1BS_500597105080_01
WV02	2015-09-24T08:29:19.000000	WV02_103001004A200400_M1BS_500597105080_01
WV02	2015-09-24T08:29:19.000000	WV02_103001004A200400_P1BS_500597105080_01
WV02	2015-09-24T08:29:20.000000	WV02_103001004A200400_M1BS_500597105080_01
WV02	2015-09-24T08:29:20.000000	WV02_103001004A200400_P1BS_500597105080_01
WV02	2015-09-24T08:29:21.000000	WV02_103001004A200400_M1BS_500597105080_01
WV02	2015-09-24T08:29:21.000000	WV02_103001004A200400_P1BS_500597105080_01
WV02	2015-09-24T08:29:49.000000	WV02_103001004865C100_M1BS_500597112070_01
WV02	2015-09-24T08:29:49.000000	WV02_103001004865C100_P1BS_500597112070_01
WV02	2015-09-24T08:29:50.000000	WV02_103001004865C100_M1BS_500597112070_01
WV02	2015-09-24T08:29:50.000000	WV02_103001004865C100_P1BS_500597112070_01

WV02	2015-09-24T08:29:51.000000	WV02_103001004865C100_M1BS_500597112070_01
WV02	2015-09-24T08:29:51.000000	WV02_103001004865C100_P1BS_500597112070_01
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WV02	2015-09-24T08:31:19.000000	WV02_1030010049C3E400_P1BS_500597105020_01
WV02	2015-09-24T08:31:20.000000	WV02_1030010049C3E400_M1BS_500597105020_01
WV02	2015-09-24T08:31:20.000000	WV02_1030010049C3E400_P1BS_500597105020_01
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WV02	2015-10-06T07:48:18.000000	WV02_10300100496C8B00_P1BS_500606189100_01
WV02	2015-10-13T08:29:11.000000	WV02_103001004B998100_M1BS_500606289050_01
WV02	2015-10-13T08:29:11.000000	WV02_103001004B998100_P1BS_500606289050_01
WV02	2015-10-13T08:29:12.000000	WV02_103001004B998100_M1BS_500606289050_01
WV02	2015-10-13T08:29:12.000000	WV02_103001004B998100_P1BS_500606289050_01
WV02	2015-10-13T08:29:13.000000	WV02_103001004B998100_M1BS_500606289050_01
WV02	2015-10-13T08:29:13.000000	WV02_103001004B998100_P1BS_500606289050_01
WV02	2015-10-13T08:29:14.000000	WV02_103001004B998100_M1BS_500606289050_01
WV02	2015-10-13T08:29:14.000000	WV02_103001004B998100_P1BS_500606289050_01
WV02	2015-10-13T08:31:05.000000	WV02_103001004A318700_M1BS_500606142010_01
WV02	2015-10-13T08:31:05.000000	WV02_103001004A318700_P1BS_500606142010_01
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WV02	2015-10-13T08:31:07.000000	WV02_103001004A318700_M1BS_500606142010_01
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WV02	2015-10-13T08:31:08.000000	WV02_103001004A318700_P1BS_500606142010_01
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WV02	2015-10-27T08:13:38.000000	WV02_103001004BCE4900_M1BS_500609603030_01
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WV02	2015-10-27T08:13:39.000000	WV02_103001004BCE4900_P1BS_500609603030_01
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WV02	2015-10-28T09:16:10.000000	WV02_103001004C060200_P1BS_500609636060_01
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WV02	2015-11-02T09:32:05.000000	WV02_103001004B8E4500_P1BS_500612336010_01
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WV02	2015-11-02T09:34:03.000000	WV02_103001004B4DF000_P1BS_500612342040_01
WV02	2015-11-02T09:34:04.000000	WV02_103001004B4DF000_M1BS_500612342040_01
WV02	2015-11-02T09:34:04.000000	WV02_103001004B4DF000_M1BS_500612342040_01
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WV02	2015-11-02T09:34:04.000000	WV02_103001004B4DF000_P1BS_500612342040_01
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WV02	2015-12-04T08:14:58.000000	WV02_103001004D40CF00_P1BS_500621597070_01
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WV02	2016-12-02T09:26:38.000000	WV02_1030010060B18700_P1BS_501046573010_01
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WV02	2016-12-04T08:10:28.000000	WV02_1030010061A1A200_P1BS_501046736100_01
WV02	2016-12-04T08:12:35.000000	WV02_1030010060D25900_M1BS_501046583010_01
WV02	2016-12-04T08:12:35.000000	WV02_1030010060D25900_P1BS_501046583010_01
WV02	2016-12-04T08:12:36.000000	WV02_1030010060D25900_M1BS_501046583010_01
WV02	2016-12-04T08:12:36.000000	WV02_1030010060D25900_P1BS_501046583010_01
WV02	2016-12-04T08:12:37.000000	WV02_1030010060D25900_M1BS_501046583010_01
WV02	2016-12-04T08:12:37.000000	WV02_1030010060D25900_P1BS_501046583010_01
WV02	2016-12-07T08:00:28.000000	WV02_10300100616DE000_M1BS_501084199070_01
WV02	2016-12-07T08:00:28.000000	WV02_10300100616DE000_P1BS_501084199070_01
WV02	2016-12-07T08:00:29.000000	WV02_10300100616DE000_M1BS_501084199070_01
WV02	2016-12-07T08:00:29.000000	WV02_10300100616DE000_P1BS_501084199070_01
WV02	2016-12-07T08:00:30.000000	WV02_10300100616DE000_M1BS_501084199070_01
WV02	2016-12-07T08:00:30.000000	WV02_10300100616DE000_P1BS_501084199070_01
WV02	2016-12-07T08:00:31.000000	WV02_10300100616DE000_M1BS_501084199070_01
WV02	2016-12-07T08:00:31.000000	WV02_10300100616DE000_P1BS_501084199070_01
WV02	2016-12-07T08:02:21.000000	WV02_1030010062014A00_M1BS_501084325100_01
WV02	2016-12-07T08:02:21.000000	WV02_1030010062014A00_P1BS_501084325100_01
WV02	2016-12-07T08:02:22.000000	WV02_1030010062014A00_M1BS_501084325100_01
WV02	2016-12-07T08:02:22.000000	WV02_1030010062014A00_P1BS_501084325100_01
WV02	2016-12-07T08:02:23.000000	WV02_1030010062014A00_M1BS_501084325100_01
WV02	2016-12-07T08:02:23.000000	WV02_1030010062014A00_M1BS_501084325100_01
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WV02	2016-12-07T08:02:23.000000	WV02_1030010062014A00_P1BS_501084325100_01
WV02	2016-12-08T09:03:17.000000	WV02_1030010060753500_M1BS_501078784030_01
WV02	2016-12-08T09:03:17.000000	WV02_1030010060753500_P1BS_501078784030_01
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WV02	2016-12-08T09:04:52.000000	WV02_103001005FBDF000_P1BS_501082935050_01
WV02	2017-03-12T07:53:38.000000	WV02_103001006672A600_M1BS_501213882100_01
WV02	2017-03-12T07:53:38.000000	WV02_103001006672A600_P1BS_501213882100_01
WV02	2017-03-12T07:53:39.000000	WV02_103001006672A600_M1BS_501213882100_01
WV02	2017-03-12T07:53:39.000000	WV02_103001006672A600_P1BS_501213882100_01
WV02	2017-03-12T07:53:40.000000	WV02_103001006672A600_M1BS_501213882100_01
WV02	2017-03-12T07:53:40.000000	WV02_103001006672A600_P1BS_501213882100_01

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WV02	2017-03-12T07:55:02.000000	WV02_1030010065891400_P1BS_501212134020_01
WV02	2017-03-12T07:55:03.000000	WV02_1030010065891400_M1BS_501212134020_01
WV02	2017-03-12T07:55:03.000000	WV02_1030010065891400_M1BS_501212134020_01
WV02	2017-03-12T07:55:03.000000	WV02_1030010065891400_P1BS_501212134020_01
WV02	2017-03-12T07:55:03.000000	WV02_1030010065891400_P1BS_501212134020_01
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WV02	2011-11-03T09:47:37.000000	WV02_103001000F925800_P1BS_052590586010_02
WV02	2011-11-03T09:47:38.000000	WV02_103001000F925800_P1BS_052590586010_02
WV02	2011-11-03T09:47:38.000000	WV02_103001000F925800_P1BS_052590586010_02
WV02	2011-11-11T08:14:16.000000	WV02_103001000EBA7100_M1BS_052886629040_01
WV02	2011-11-11T08:14:16.000000	WV02_103001000EBA7100_P1BS_052886629040_01
WV02	2011-11-11T08:14:17.000000	WV02_103001000EBA7100_M1BS_052886629040_01
WV02	2011-11-11T08:14:17.000000	WV02_103001000EBA7100_P1BS_052886629040_01
WV02	2011-11-11T09:53:53.000000	WV02_103001000ED70000_M1BS_052886634060_01
WV02	2011-11-11T09:53:53.000000	WV02_103001000ED70000_P1BS_052886634060_01
WV02	2012-11-12T09:36:46.000000	WV02_103001001B66AB00_M1BS_052819745010_02
WV02	2012-11-12T09:36:46.000000	WV02_103001001B66AB00_M1BS_052819745010_02
WV02	2012-11-12T09:36:46.000000	WV02_103001001B66AB00_P1BS_052819745010_02
WV02	2012-11-12T09:36:46.000000	WV02_103001001B66AB00_P1BS_052819745010_02
WV02	2012-11-12T09:37:02.000000	WV02_103001001D454600_M1BS_052819744010_01
WV02	2012-11-12T09:37:02.000000	WV02_103001001D454600_M1BS_052819744010_01
WV02	2012-11-12T09:37:02.000000	WV02_103001001D454600_P1BS_052819744010_01
WV02	2012-11-12T09:37:02.000000	WV02_103001001D454600_P1BS_052819744010_01
WV02	2012-11-12T09:38:00.000000	WV02_103001001DCE4600_M1BS_052819744010_02
WV02	2012-11-12T09:38:00.000000	WV02_103001001DCE4600_M1BS_052819744010_02
WV02	2012-11-12T09:38:00.000000	WV02_103001001DCE4600_P1BS_052819744010_02
WV02	2012-11-12T09:38:00.000000	WV02_103001001DCE4600_P1BS_052819744010_02
WV02	2012-11-12T09:38:17.000000	WV02_103001001DB05000_M1BS_052819744010_01
WV02	2012-11-12T09:38:17.000000	WV02_103001001DB05000_M1BS_052819744010_01
WV02	2012-11-12T09:38:17.000000	WV02_103001001DB05000_P1BS_052819744010_01
WV02	2012-11-12T09:38:17.000000	WV02_103001001DB05000_P1BS_052819744010_01
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WV02	2012-11-17T09:52:49.000000	WV02_103001001D523300_M1BS_500057964200_01
WV02	2012-11-17T09:52:50.000000	WV02_103001001D523300_M1BS_500057964200_01
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WV02	2012-11-29T09:12:07.000000	WV02_103001001D5D3300_P1BS_052819746010_01
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WV02	2012-12-04T09:26:27.000000	WV02_103001001DD3D100_P1BS_052858828010_01
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WV02	2012-12-04T09:27:47.000000	WV02_103001001D7C1D00_P1BS_052858828010_01
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WV02	2012-12-30T08:28:38.000000	WV02_103001001EBC3200_P1BS_052819661010_02

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WV02	2013-01-09T08:59:47.000000	WV02_103001001E25FB00_P1BS_052858830010_01
WV02	2013-01-09T09:01:01.000000	WV02_103001001E438300_M1BS_052858830010_01
WV02	2013-01-09T09:01:01.000000	WV02_103001001E438300_P1BS_052858830010_01
WV02	2013-01-27T09:35:21.000000	WV02_103001001F4F2400_M1BS_500143327170_01
WV02	2013-01-27T09:35:21.000000	WV02_103001001F4F2400_P1BS_500143327170_01
WV02	2013-01-27T09:35:22.000000	WV02_103001001F4F2400_M1BS_500143327170_01
WV02	2013-01-27T09:35:22.000000	WV02_103001001F4F2400_P1BS_500143327170_01
WV02	2013-01-27T09:35:23.000000	WV02_103001001F4F2400_M1BS_500143327170_01
WV02	2013-01-27T09:35:23.000000	WV02_103001001F4F2400_M1BS_500143327170_01
WV02	2013-01-27T09:35:23.000000	WV02_103001001F4F2400_P1BS_500143327170_01
WV02	2013-01-27T09:35:23.000000	WV02_103001001F4F2400_P1BS_500143327170_01
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WV02	2013-01-27T09:35:31.000000	WV02_103001001D3BD400_P1BS_500076315110_01
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WV02	2013-01-27T09:35:32.000000	WV02_103001001D3BD400_P1BS_500076315110_01
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WV02	2013-02-16T07:20:36.000000	WV02_103001001F8D0000_P1BS_500057469100_01
WV02	2013-02-19T07:08:36.000000	WV02_103001001FB98E00_P1BS_500057468190_01
WV02	2013-08-28T08:46:23.000000	WV02_103001002795AB00_M1BS_500095293060_01
WV02	2013-08-28T08:46:23.000000	WV02_103001002795AB00_P1BS_500095293060_01
WV02	2013-08-28T08:46:25.000000	WV02_103001002795AB00_M1BS_500095293060_01
WV02	2013-08-28T08:46:25.000000	WV02_103001002795AB00_M1BS_500095293060_01
WV02	2013-08-28T08:46:25.000000	WV02_103001002795AB00_P1BS_500095293060_01
WV02	2013-08-28T08:46:25.000000	WV02_103001002795AB00_P1BS_500095293060_01
WV02	2013-09-20T09:39:35.000000	WV02_1030010025D47000_M1BS_500095318040_01
WV02	2013-09-20T09:39:35.000000	WV02_1030010025D47000_P1BS_500095318040_01
WV02	2013-09-20T09:39:36.000000	WV02_1030010025D47000_M1BS_500095318040_01
WV02	2013-09-20T09:39:36.000000	WV02_1030010025D47000_P1BS_500095318040_01
WV02	2013-09-20T09:39:37.000000	WV02_1030010025D47000_M1BS_500095318040_01
WV02	2013-09-20T09:39:37.000000	WV02_1030010025D47000_P1BS_500095318040_01
WV02	2013-09-20T09:39:38.000000	WV02_1030010025D47000_M1BS_500095318040_01
WV02	2013-09-20T09:39:38.000000	WV02_1030010025D47000_M1BS_500095318040_01
WV02	2013-09-20T09:39:38.000000	WV02_1030010025D47000_P1BS_500095318040_01
WV02	2013-09-20T09:39:38.000000	WV02_1030010025D47000_P1BS_500095318040_01
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WV02	2013-09-23T09:29:41.000000	WV02_1030010026242700_P1BS_500095318120_01
WV02	2013-09-23T09:29:42.000000	WV02_1030010026242700_M1BS_500095318120_01
WV02	2013-09-23T09:29:42.000000	WV02_1030010026242700_P1BS_500095318120_01
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WV02	2013-09-23T09:31:02.000000	WV02_10300100276FD500_P1BS_500095316010_01
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WV02	2013-09-23T09:31:03.000000	WV02_10300100276FD500_P1BS_500095316010_01
WV02	2013-09-23T09:31:04.000000	WV02_10300100276FD500_M1BS_500095316010_01
WV02	2013-09-23T09:31:04.000000	WV02_10300100276FD500_P1BS_500095316010_01
WV02	2013-09-23T09:31:05.000000	WV02_10300100276FD500_M1BS_500095316010_01
WV02	2013-09-23T09:31:05.000000	WV02_10300100276FD500_M1BS_500095316010_01
WV02	2013-09-23T09:31:05.000000	WV02_10300100276FD500_P1BS_500095316010_01
WV02	2013-09-23T09:31:05.000000	WV02_10300100276FD500_P1BS_500095316010_01
WV02	2013-10-02T08:58:32.000000	WV02_10300100275D2B00_M1BS_500099270110_01
WV02	2013-10-02T08:58:32.000000	WV02_10300100275D2B00_P1BS_500099270110_01
WV02	2013-10-02T08:59:52.000000	WV02_1030010027622E00_M1BS_500095284170_01
WV02	2013-10-02T08:59:52.000000	WV02_1030010027622E00_P1BS_500095284170_01
WV02	2014-02-22T09:34:21.000000	WV02_103001002D46A500_M1BS_500130044120_01
WV02	2014-02-22T09:34:21.000000	WV02_103001002D46A500_P1BS_500130044120_01
WV02	2014-02-22T09:34:22.000000	WV02_103001002D46A500_M1BS_500130044120_01
WV02	2014-02-22T09:34:22.000000	WV02_103001002D46A500_P1BS_500130044120_01
WV02	2014-02-22T09:34:23.000000	WV02_103001002D46A500_M1BS_500130044120_01
WV02	2014-02-22T09:34:23.000000	WV02_103001002D46A500_P1BS_500130044120_01
WV02	2014-02-22T09:35:33.000000	WV02_103001002B26E200_M1BS_500130370030_01
WV02	2014-02-22T09:35:33.000000	WV02_103001002B26E200_P1BS_500130370030_01
WV02	2014-02-22T09:35:35.000000	WV02_103001002B26E200_M1BS_500130370030_01
WV02	2014-02-22T09:35:35.000000	WV02_103001002B26E200_P1BS_500130370030_01
WV02	2014-02-22T09:35:36.000000	WV02_103001002B26E200_M1BS_500130370030_01
WV02	2014-02-22T09:35:36.000000	WV02_103001002B26E200_P1BS_500130370030_01
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WV02	2015-01-01T08:46:00.000000	WV02_103001003C6C1A00_P1BS_500316124150_01
WV02	2015-01-01T08:47:17.000000	WV02_103001003C714700_M1BS_500320700150_01
WV02	2015-01-01T08:47:17.000000	WV02_103001003C714700_P1BS_500320700150_01
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WV02	2015-04-02T09:25:26.000000	WV02_1030010040124B00_P1BS_500318649030_01
WV02	2015-04-02T09:25:27.000000	WV02_1030010040124B00_M1BS_500318649030_01
WV02	2015-04-02T09:25:27.000000	WV02_1030010040124B00_P1BS_500318649030_01
WV02	2015-04-02T09:25:28.000000	WV02_1030010040124B00_M1BS_500318649030_01
WV02	2015-04-02T09:25:28.000000	WV02_1030010040124B00_M1BS_500318649030_01
WV02	2015-04-02T09:25:28.000000	WV02_1030010040124B00_P1BS_500318649030_01
WV02	2015-04-02T09:25:28.000000	WV02_1030010040124B00_P1BS_500318649030_01
WV02	2015-04-02T09:26:37.000000	WV02_103001003F01B300_M1BS_500337464150_01

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WV02	2015-04-02T09:26:38.000000	WV02_103001003F01B300_P1BS_500337464150_01
WV02	2015-04-02T09:26:39.000000	WV02_103001003F01B300_M1BS_500337464150_01
WV02	2015-04-02T09:26:39.000000	WV02_103001003F01B300_P1BS_500337464150_01
WV02	2015-04-02T09:26:40.000000	WV02_103001003F01B300_M1BS_500337464150_01
WV02	2015-04-02T09:26:40.000000	WV02_103001003F01B300_P1BS_500337464150_01
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WV02	2015-09-22T08:02:51.000000	WV02_10300100497B6E00_P1BS_500597088030_01
WV02	2015-09-22T08:02:52.000000	WV02_10300100497B6E00_M1BS_500597088030_01
WV02	2015-09-22T08:02:52.000000	WV02_10300100497B6E00_P1BS_500597088030_01
WV02	2015-09-22T08:02:53.000000	WV02_10300100497B6E00_M1BS_500597088030_01
WV02	2015-09-22T08:02:53.000000	WV02_10300100497B6E00_P1BS_500597088030_01
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WV02	2015-09-22T08:04:48.000000	WV02_103001004A9AB000_P1BS_500597110070_01
WV02	2015-09-22T08:04:49.000000	WV02_103001004A9AB000_M1BS_500597110070_01
WV02	2015-09-22T08:04:49.000000	WV02_103001004A9AB000_P1BS_500597110070_01
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WV02	2015-09-23T09:04:58.000000	WV02_1030010048035500_M1BS_500597107080_01
WV02	2015-09-23T09:04:58.000000	WV02_1030010048035500_P1BS_500597107080_01
WV02	2015-09-23T09:04:58.000000	WV02_1030010048035500_P1BS_500597107080_01
WV02	2015-09-23T09:04:59.000000	WV02_1030010048035500_M1BS_500597107080_01
WV02	2015-09-23T09:04:59.000000	WV02_1030010048035500_P1BS_500597107080_01
WV02	2015-09-23T09:05:00.000000	WV02_1030010048035500_M1BS_500597107080_01
WV02	2015-09-23T09:05:00.000000	WV02_1030010048035500_P1BS_500597107080_01
WV02	2015-09-23T09:06:49.000000	WV02_103001004A25F000_M1BS_500597115060_01
WV02	2015-09-23T09:06:49.000000	WV02_103001004A25F000_P1BS_500597115060_01
WV02	2015-09-23T09:06:50.000000	WV02_103001004A25F000_M1BS_500597115060_01
WV02	2015-09-23T09:06:50.000000	WV02_103001004A25F000_P1BS_500597115060_01
WV02	2015-09-23T09:06:51.000000	WV02_103001004A25F000_M1BS_500597115060_01
WV02	2015-09-23T09:06:51.000000	WV02_103001004A25F000_P1BS_500597115060_01
WV02	2015-09-23T09:06:52.000000	WV02_103001004A25F000_M1BS_500597115060_01
WV02	2015-09-23T09:06:52.000000	WV02_103001004A25F000_P1BS_500597115060_01
WV02	2015-12-09T00:17:11.000000	WV02_103001004EBBFD00_M1BS_500593060100_01
WV02	2015-12-09T00:17:11.000000	WV02_103001004EBBFD00_P1BS_500593060100_01
WV02	2015-12-11T08:54:13.000000	WV02_103001004E936C00_M1BS_500578031090_01
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WV02	2015-12-11T08:54:15.000000	WV02_103001004E936C00_M1BS_500578031090_01
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WV02	2015-12-11T08:54:22.000000	WV02_103001004DBBDE00_P1BS_500546680060_01

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WV02	2015-12-11T08:54:23.000000	WV02_103001004DBBDE00_P1BS_500546680060_01
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WV02	2015-12-11T08:54:24.000000	WV02_103001004DBBDE00_P1BS_500546680060_01
WV02	2015-12-11T08:54:25.000000	WV02_103001004DBBDE00_M1BS_500546680060_01
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WV02	2015-12-11T08:54:50.000000	WV02_103001004E7A8D00_P1BS_500546680040_01
WV02	2015-12-11T08:54:51.000000	WV02_103001004E7A8D00_M1BS_500546680040_01
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WV02	2015-12-14T08:44:53.000000	WV02_103001004DADAF00_P1BS_500578105100_01
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WV02	2014-02-12T09:02:46.000000	WV02_103001002C47B600_M1BS_500143379050_01
WV02	2014-02-12T09:02:47.000000	WV02_103001002C47B600_M1BS_500143379050_01
WV02	2014-02-12T09:02:48.000000	WV02_103001002C47B600_M1BS_500143379050_01
WV02	2014-02-12T09:02:49.000000	WV02_103001002C47B600_M1BS_500143379050_01
WV02	2014-02-12T09:02:49.000000	WV02_103001002C47B600_M1BS_500143379050_01
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WV02	2014-02-12T09:04:08.000000	WV02_103001002C9CDE00_M1BS_500143382190_01
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WV02	2014-02-12T09:04:14.000000	WV02_103001002C9CDE00_M1BS_500143382190_01
WV02	2014-02-12T09:04:15.000000	WV02_103001002C9CDE00_M1BS_500143382190_01
WV02	2014-02-12T09:04:16.000000	WV02_103001002C9CDE00_M1BS_500143382190_01
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WV02	2014-02-19T09:44:45.000000	WV02_103001002D5B6900_M1BS_500143384170_01
WV02	2014-02-19T09:44:46.000000	WV02_103001002D5B6900_M1BS_500143384170_01
WV02	2014-02-19T09:44:47.000000	WV02_103001002D5B6900_M1BS_500143384170_01
WV02	2014-02-19T09:44:48.000000	WV02_103001002D5B6900_M1BS_500143384170_01
WV02	2014-02-19T09:44:49.000000	WV02_103001002D5B6900_M1BS_500143384170_01

WV02	2014-02-19T09:44:50.000000	WV02_103001002D5B6900_M1BS_500143384170_01
WV02	2014-02-19T09:44:50.000000	WV02_103001002D5B6900_M1BS_500143384170_01
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WV02	2014-02-19T09:46:10.000000	WV02_103001002D081700_M1BS_500130406030_01
WV02	2014-02-19T09:46:11.000000	WV02_103001002D081700_M1BS_500130406030_01
WV02	2014-02-19T09:46:12.000000	WV02_103001002D081700_M1BS_500130406030_01
WV02	2014-02-19T09:46:13.000000	WV02_103001002D081700_M1BS_500130406030_01
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WV02	2014-02-19T09:46:15.000000	WV02_103001002D081700_M1BS_500130406030_01
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WV02	2014-02-22T09:34:03.000000	WV02_103001002E06C400_M1BS_500196589110_01
WV02	2014-02-22T09:34:04.000000	WV02_103001002E06C400_M1BS_500196589110_01
WV02	2014-02-22T09:34:05.000000	WV02_103001002E06C400_M1BS_500196589110_01
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WV02	2014-02-22T09:34:22.000000	WV02_103001002D46A500_M1BS_500130044120_01
WV02	2014-02-22T09:34:23.000000	WV02_103001002D46A500_M1BS_500130044120_01
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WV02	2014-02-22T09:34:25.000000	WV02_103001002D46A500_M1BS_500130044120_01
WV02	2014-02-22T09:34:26.000000	WV02_103001002D46A500_M1BS_500130044120_01
WV02	2014-02-22T09:34:27.000000	WV02_103001002D46A500_M1BS_500130044120_01
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WV02	2014-02-22T09:34:29.000000	WV02_103001002D46A500_M1BS_500130044120_01
WV02	2014-02-22T09:34:30.000000	WV02_103001002D46A500_M1BS_500130044120_01
WV02	2014-02-22T09:34:40.000000	WV02_103001002E0E6000_M1BS_500130372200_01
WV02	2014-02-22T09:34:41.000000	WV02_103001002E0E6000_M1BS_500130372200_01
WV02	2014-02-22T09:34:42.000000	WV02_103001002E0E6000_M1BS_500130372200_01
WV02	2014-02-22T09:34:44.000000	WV02_103001002E0E6000_M1BS_500130372200_01
WV02	2014-02-22T09:34:45.000000	WV02_103001002E0E6000_M1BS_500130372200_01
WV02	2014-02-22T09:34:46.000000	WV02_103001002E0E6000_M1BS_500130372200_01
WV02	2014-02-22T09:34:47.000000	WV02_103001002E0E6000_M1BS_500130372200_01
WV02	2014-02-22T09:34:48.000000	WV02_103001002E0E6000_M1BS_500130372200_01
WV02	2014-02-22T09:34:49.000000	WV02_103001002E0E6000_M1BS_500130372200_01
WV02	2014-02-22T09:34:49.000000	WV02_103001002E0E6000_M1BS_500130372200_01
WV02	2014-02-22T09:35:16.000000	WV02_103001002C59F100_M1BS_500145765060_01
WV02	2014-02-22T09:35:17.000000	WV02_103001002C59F100_M1BS_500145765060_01
WV02	2014-02-22T09:35:19.000000	WV02_103001002C59F100_M1BS_500145765060_01
WV02	2014-02-22T09:35:19.000000	WV02_103001002C59F100_M1BS_500145765060_01
WV02	2014-02-22T09:35:33.000000	WV02_103001002B26E200_M1BS_500130370030_01
WV02	2014-02-22T09:35:35.000000	WV02_103001002B26E200_M1BS_500130370030_01
WV02	2014-02-22T09:35:36.000000	WV02_103001002B26E200_M1BS_500130370030_01
WV02	2014-02-22T09:35:37.000000	WV02_103001002B26E200_M1BS_500130370030_01
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WV02	2014-02-22T09:36:01.000000	WV02_103001002D60D800_M1BS_500145741020_01
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WV02	2014-02-22T09:36:03.000000	WV02_103001002D60D800_M1BS_500145741020_01
WV02	2014-02-22T09:36:04.000000	WV02_103001002D60D800_M1BS_500145741020_01
WV02	2014-02-25T09:23:47.000000	WV02_103001002D401900_M1BS_500146136190_01
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WV02	2014-02-25T09:25:07.000000	WV02_103001002D1BC400_M1BS_500129763090_01
WV02	2014-02-25T09:25:09.000000	WV02_103001002D1BC400_M1BS_500129763090_01
WV02	2014-02-25T09:25:10.000000	WV02_103001002D1BC400_M1BS_500129763090_01
WV02	2014-02-25T09:25:11.000000	WV02_103001002D1BC400_M1BS_500129763090_01
WV02	2014-02-25T09:25:12.000000	WV02_103001002D1BC400_M1BS_500129763090_01
WV02	2014-02-25T09:25:13.000000	WV02_103001002D1BC400_M1BS_500129763090_01
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WV02	2014-02-27T09:50:04.000000	WV02_103001002D12F500_M1BS_500130024120_01
WV02	2014-02-27T09:50:05.000000	WV02_103001002D12F500_M1BS_500130024120_01
WV02	2014-02-27T09:50:06.000000	WV02_103001002D12F500_M1BS_500130024120_01
WV02	2014-02-27T09:50:07.000000	WV02_103001002D12F500_M1BS_500130024120_01
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WV02	2014-09-13T09:49:21.000000	WV02_1030010037480E00_M1BS_500182092170_01
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WV02	2014-09-13T09:50:24.000000	WV02_103001003763A000_M1BS_500182094010_01
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WV02	2014-11-26T09:17:15.000000	WV02_103001003A586500_M1BS_500340648170_01
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WV02	2014-12-01T09:30:56.000000	WV02_103001003B317A00_M1BS_500340579020_01
WV02	2014-12-01T09:30:57.000000	WV02_103001003B317A00_M1BS_500340579020_01
WV02	2014-12-01T09:30:58.000000	WV02_103001003B317A00_M1BS_500340579020_01
WV02	2014-12-01T09:30:59.000000	WV02_103001003B317A00_M1BS_500340579020_01
WV02	2014-12-01T09:31:01.000000	WV02_103001003B317A00_M1BS_500340579020_01
WV02	2014-12-01T09:31:02.000000	WV02_103001003B317A00_M1BS_500340579020_01
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WV02	2014-12-01T09:32:03.000000	WV02_103001003BB8A800_M1BS_500319444140_01
WV02	2014-12-01T09:32:04.000000	WV02_103001003BB8A800_M1BS_500319444140_01
WV02	2014-12-01T09:32:05.000000	WV02_103001003BB8A800_M1BS_500319444140_01
WV02	2014-12-01T09:32:06.000000	WV02_103001003BB8A800_M1BS_500319444140_01
WV02	2014-12-01T09:32:07.000000	WV02_103001003BB8A800_M1BS_500319444140_01
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WV02	2014-12-12T09:24:24.000000	WV02_10300100396AC300_M1BS_500340676090_01
WV02	2014-12-12T09:24:25.000000	WV02_10300100396AC300_M1BS_500340676090_01
WV02	2014-12-12T09:24:26.000000	WV02_10300100396AC300_M1BS_500340676090_01
WV02	2014-12-12T09:25:23.000000	WV02_103001003B8AE900_M1BS_500319474180_01
WV02	2014-12-12T09:25:24.000000	WV02_103001003B8AE900_M1BS_500319474180_01
WV02	2014-12-12T09:25:25.000000	WV02_103001003B8AE900_M1BS_500319474180_01
WV02	2014-12-12T09:25:26.000000	WV02_103001003B8AE900_M1BS_500319474180_01
WV02	2014-12-12T09:25:27.000000	WV02_103001003B8AE900_M1BS_500319474180_01
WV02	2014-12-12T09:25:28.000000	WV02_103001003B8AE900_M1BS_500319474180_01
WV02	2014-12-12T09:25:29.000000	WV02_103001003B8AE900_M1BS_500319474180_01
WV02	2014-12-12T09:25:30.000000	WV02_103001003B8AE900_M1BS_500319474180_01
WV02	2014-12-12T09:25:32.000000	WV02_103001003B8AE900_M1BS_500319474180_01
WV02	2014-12-12T09:25:33.000000	WV02_103001003B8AE900_M1BS_500319474180_01
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WV02	2014-12-15T09:13:25.000000	WV02_103001003B753200_M1BS_500319484030_01
WV02	2014-12-15T09:13:26.000000	WV02_103001003B753200_M1BS_500319484030_01
WV02	2014-12-15T09:13:27.000000	WV02_103001003B753200_M1BS_500319484030_01
WV02	2014-12-15T09:13:28.000000	WV02_103001003B753200_M1BS_500319484030_01
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WV02	2014-12-15T09:14:32.000000	WV02_103001003A0E6600_M1BS_500315366090_01
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WV02	2014-12-15T09:14:35.000000	WV02_103001003A0E6600_M1BS_500315366090_01
WV02	2014-12-15T09:14:36.000000	WV02_103001003A0E6600_M1BS_500315366090_01
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WV02	2014-12-18T09:02:52.000000	WV02_103001003B3E4300_M1BS_500315363180_01
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WV02	2015-10-02T08:34:35.000000	WV02_103001004B559F00_M1BS_500597315040_01
WV02	2015-10-02T08:34:36.000000	WV02_103001004B559F00_M1BS_500597315040_01
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WV02	2015-12-08T09:04:36.000000	WV02_103001004B187500_M1BS_500593062020_01
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WV02	2015-12-08T09:04:41.000000	WV02_103001004B187500_M1BS_500593062020_01

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WV02	2015-12-08T09:06:51.000000	WV02_103001004D5CF500_M1BS_500593064020_01
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WV02	2015-12-14T08:45:42.000000	WV02_103001004C997700_M1BS_500578106040_01
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WV02	2012-10-12T10:20:44.000000	WV02_103001001D209500_M1BS_500058147080_01
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WV02	2012-10-12T10:20:47.000000	WV02_103001001D209500_M1BS_500058147080_01
WV02	2012-10-12T10:22:06.000000	WV02_103001001C31E700_M1BS_500058172120_01
WV02	2012-10-12T10:22:07.000000	WV02_103001001C31E700_M1BS_500058172120_01
WV02	2012-10-12T10:22:08.000000	WV02_103001001C31E700_M1BS_500058172120_01
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WV02	2012-12-16T10:26:06.000000	WV02_103001001E9F8300_M1BS_500076332070_01
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WV02	2013-01-25T09:12:06.000000	WV02_103001001E1F7300_M1BS_500142220150_01
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WV02	2013-03-14T09:41:44.000000	WV02_103001001F93B800_M1BS_500067201040_01
WV02	2013-03-17T09:30:00.000000	WV02_103001001FBD7700_M1BS_500318620130_01
WV02	2013-03-17T09:30:02.000000	WV02_103001001FBD7700_M1BS_500318620130_01
WV02	2013-03-17T09:30:07.000000	WV02_103001001FBD7700_M1BS_500318620130_01
WV02	2013-03-17T09:30:07.000000	WV02_103001001FBD7700_M1BS_500318620130_01
WV02	2013-03-17T09:31:24.000000	WV02_103001002000C000_M1BS_500067195190_01
WV02	2013-03-17T09:31:28.000000	WV02_103001002000C000_M1BS_500067195190_01
WV02	2013-03-17T09:31:28.000000	WV02_103001002000C000_M1BS_500067195190_01
WV02	2013-03-21T08:42:53.000000	WV02_1030010021764300_M1BS_500067207120_01
WV02	2013-03-21T08:42:54.000000	WV02_1030010021764300_M1BS_500067207120_01
WV02	2013-03-21T08:42:56.000000	WV02_1030010021764300_M1BS_500067207120_01
WV02	2013-03-21T08:42:57.000000	WV02_1030010021764300_M1BS_500067207120_01
WV02	2013-03-21T08:42:58.000000	WV02_1030010021764300_M1BS_500067207120_01
WV02	2013-03-21T08:42:59.000000	WV02_1030010021764300_M1BS_500067207120_01
WV02	2013-03-21T08:43:00.000000	WV02_1030010021764300_M1BS_500067207120_01
WV02	2013-03-21T08:43:01.000000	WV02_1030010021764300_M1BS_500067207120_01
WV02	2013-03-21T08:43:03.000000	WV02_1030010021764300_M1BS_500067207120_01
WV02	2013-03-21T08:43:03.000000	WV02_1030010021764300_M1BS_500067207120_01
WV02	2013-03-21T08:44:12.000000	WV02_10300100212ABD00_M1BS_500067200100_01
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WV02	2013-03-21T08:44:14.000000	WV02_10300100212ABD00_M1BS_500067200100_01
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WV02	2013-03-21T08:44:17.000000	WV02_10300100212ABD00_M1BS_500067200100_01
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WV02	2013-03-21T08:44:20.000000	WV02_10300100212ABD00_M1BS_500067200100_01
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WV02	2013-03-24T10:11:46.000000	WV02_1030010020C5F100_M1BS_500067196040_01
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WV02	2013-03-24T10:13:03.000000	WV02_103001002063E800_M1BS_500067202100_01
WV02	2013-03-24T10:13:04.000000	WV02_103001002063E800_M1BS_500067202100_01
WV02	2013-03-24T10:13:05.000000	WV02_103001002063E800_M1BS_500067202100_01
WV02	2013-03-24T10:13:06.000000	WV02_103001002063E800_M1BS_500067202100_01
WV02	2013-03-24T10:13:07.000000	WV02_103001002063E800_M1BS_500067202100_01
WV02	2013-03-24T10:13:08.000000	WV02_103001002063E800_M1BS_500067202100_01
WV02	2013-03-24T10:13:09.000000	WV02_103001002063E800_M1BS_500067202100_01
WV02	2013-03-24T10:13:10.000000	WV02_103001002063E800_M1BS_500067202100_01
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WV02	2013-10-05T10:28:57.000000	WV02_1030010027D3A000_M1BS_500099269090_01
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WV02	2013-10-13T08:56:24.000000	WV02_1030010027C8C500_M1BS_500099263070_01
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WV02	2013-10-13T08:56:46.000000	WV02_1030010028510D00_M1BS_500099275070_01
WV02	2013-10-13T08:56:47.000000	WV02_1030010028510D00_M1BS_500099275070_01
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WV02	2013-11-03T09:22:07.000000	WV02_1030010029719000_M1BS_500099258020_01
WV02	2013-11-03T09:22:08.000000	WV02_1030010029719000_M1BS_500099258020_01
WV02	2013-11-03T09:22:09.000000	WV02_1030010029719000_M1BS_500099258020_01
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WV02	2013-11-03T09:22:13.000000	WV02_1030010029719000_M1BS_500099258020_01
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WV02	2013-11-03T09:23:14.000000	WV02_10300100294F4F00_M1BS_500110072120_01
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WV02	2013-11-13T09:54:15.000000	WV02_1030010028037C00_M1BS_500095296080_01
WV02	2013-11-13T09:54:16.000000	WV02_1030010028037C00_M1BS_500095296080_01
WV02	2013-11-13T09:54:17.000000	WV02_1030010028037C00_M1BS_500095296080_01
WV02	2013-11-13T09:54:19.000000	WV02_1030010028037C00_M1BS_500095296080_01
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WV02	2013-11-13T09:55:31.000000	WV02_1030010029371E00_M1BS_500095324200_01
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WV02	2013-11-14T09:18:58.000000	WV02_1030010029B8E300_M1BS_500095299150_01
WV02	2013-11-14T09:18:59.000000	WV02_1030010029B8E300_M1BS_500095299150_01
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WV02	2013-11-14T09:19:03.000000	WV02_1030010029B8E300_M1BS_500095299150_01
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WV02	2013-11-15T10:20:06.000000	WV02_103001002903A200_M1BS_500095287180_01
WV02	2013-11-15T10:20:07.000000	WV02_103001002903A200_M1BS_500095287180_01
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WV02	2013-11-15T10:21:35.000000	WV02_103001002980CC00_M1BS_500106162060_01
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WV02	2013-11-15T10:21:37.000000	WV02_103001002980CC00_M1BS_500106162060_01
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WV02	2013-12-13T09:51:18.000000	WV02_103001002ABBC700_M1BS_500106257160_01
WV02	2013-12-21T01:41:59.000000	WV02_103001002BCB5F00_M1BS_500110267030_01
WV02	2013-12-21T01:42:00.000000	WV02_103001002BCB5F00_M1BS_500110267030_01
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WV02	2013-12-21T01:43:36.000000	WV02_103001002BAC4400_M1BS_500106208060_01
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WV02	2013-12-22T09:18:33.000000	WV02_103001002942CB00_M1BS_500106282190_01
WV02	2013-12-22T09:18:34.000000	WV02_103001002942CB00_M1BS_500106282190_01
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WV02	2013-12-23T08:42:19.000000	WV02_103001002B227400_M1BS_500216151030_01
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WV02	2013-12-23T08:43:38.000000	WV02_103001002A76D100_M1BS_500106159090_01
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WV02	2013-12-30T09:24:29.000000	WV02_103001002B1C3B00_M1BS_500145781160_01
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WV02	2013-12-31T10:27:51.000000	WV02_103001002B178F00_M1BS_500146143130_01
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WV02	2013-12-31T10:28:14.000000	WV02_103001002B6E2B00_M1BS_500145766090_01
WV02	2013-12-31T10:28:15.000000	WV02_103001002B6E2B00_M1BS_500145766090_01
WV02	2013-12-31T10:28:17.000000	WV02_103001002B6E2B00_M1BS_500145766090_01
WV02	2013-12-31T10:28:18.000000	WV02_103001002B6E2B00_M1BS_500145766090_01
WV02	2013-12-31T10:28:18.000000	WV02_103001002B6E2B00_M1BS_500145766090_01

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WV02	2014-01-20T09:50:26.000000	WV02_103001002B147E00_M1BS_500219111160_01
WV02	2014-01-20T09:50:27.000000	WV02_103001002B147E00_M1BS_500219111160_01
WV02	2014-01-20T09:50:28.000000	WV02_103001002B147E00_M1BS_500219111160_01
WV02	2014-01-20T09:50:29.000000	WV02_103001002B147E00_M1BS_500219111160_01
WV02	2014-01-20T09:50:30.000000	WV02_103001002B147E00_M1BS_500219111160_01
WV02	2014-01-20T09:50:32.000000	WV02_103001002B147E00_M1BS_500219111160_01
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WV02	2014-01-20T09:50:34.000000	WV02_103001002B147E00_M1BS_500219111160_01
WV02	2014-01-20T09:50:35.000000	WV02_103001002B147E00_M1BS_500219111160_01
WV02	2014-01-20T09:51:41.000000	WV02_103001002B51DD00_M1BS_500106793080_01
WV02	2014-01-20T09:51:42.000000	WV02_103001002B51DD00_M1BS_500106793080_01
WV02	2014-01-20T09:51:43.000000	WV02_103001002B51DD00_M1BS_500106793080_01
WV02	2014-01-20T09:51:44.000000	WV02_103001002B51DD00_M1BS_500106793080_01
WV02	2014-01-20T09:51:45.000000	WV02_103001002B51DD00_M1BS_500106793080_01
WV02	2014-01-20T09:51:46.000000	WV02_103001002B51DD00_M1BS_500106793080_01
WV02	2014-01-20T09:51:47.000000	WV02_103001002B51DD00_M1BS_500106793080_01
WV02	2014-01-20T09:51:49.000000	WV02_103001002B51DD00_M1BS_500106793080_01
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WV02	2014-01-25T10:06:17.000000	WV02_103001002C3A6000_M1BS_500216173140_01
WV02	2014-01-25T10:06:19.000000	WV02_103001002C3A6000_M1BS_500216173140_01
WV02	2014-01-25T10:06:20.000000	WV02_103001002C3A6000_M1BS_500216173140_01
WV02	2014-01-25T10:06:21.000000	WV02_103001002C3A6000_M1BS_500216173140_01
WV02	2014-01-25T10:06:22.000000	WV02_103001002C3A6000_M1BS_500216173140_01
WV02	2014-01-25T10:06:23.000000	WV02_103001002C3A6000_M1BS_500216173140_01
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WV02	2014-01-25T10:06:25.000000	WV02_103001002C3A6000_M1BS_500216173140_01
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WV02	2014-01-25T10:07:31.000000	WV02_103001002B109800_M1BS_500106862160_01
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WV02	2014-01-25T10:07:37.000000	WV02_103001002B109800_M1BS_500106862160_01
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WV02	2014-01-25T10:07:39.000000	WV02_103001002B109800_M1BS_500106862160_01
WV02	2014-01-26T09:29:14.000000	WV02_103001002C0DD800_M1BS_500110302110_01
WV02	2014-01-26T09:29:15.000000	WV02_103001002C0DD800_M1BS_500110302110_01

WV02	2014-01-26T09:29:16.000000	WV02_103001002C0DD800_M1BS_500110302110_01
WV02	2014-01-26T09:29:17.000000	WV02_103001002C0DD800_M1BS_500110302110_01
WV02	2014-01-26T09:29:18.000000	WV02_103001002C0DD800_M1BS_500110302110_01
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WV02	2014-01-26T09:29:20.000000	WV02_103001002C0DD800_M1BS_500110302110_01
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WV02	2014-01-26T09:30:51.000000	WV02_103001002C844100_M1BS_500106793180_01
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WV02	2014-01-26T09:30:53.000000	WV02_103001002C844100_M1BS_500106793180_01
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WV02	2014-01-26T09:30:58.000000	WV02_103001002C844100_M1BS_500106793180_01
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WV02	2014-01-31T09:44:52.000000	WV02_103001002C6A9F00_M1BS_500106281180_01
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WV02	2014-01-31T09:45:24.000000	WV02_103001002C1ABA00_M1BS_500219108150_01
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WV02	2014-01-31T09:45:26.000000	WV02_103001002C1ABA00_M1BS_500219108150_01
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WV02	2014-01-31T09:46:14.000000	WV02_103001002CD1C400_M1BS_500110225030_01
WV02	2014-01-31T09:46:15.000000	WV02_103001002CD1C400_M1BS_500110225030_01
WV02	2014-01-31T09:46:17.000000	WV02_103001002CD1C400_M1BS_500110225030_01
WV02	2014-01-31T09:46:18.000000	WV02_103001002CD1C400_M1BS_500110225030_01
WV02	2014-01-31T09:46:19.000000	WV02_103001002CD1C400_M1BS_500110225030_01
WV02	2014-01-31T09:46:20.000000	WV02_103001002CD1C400_M1BS_500110225030_01
WV02	2014-01-31T09:46:21.000000	WV02_103001002CD1C400_M1BS_500110225030_01
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WV02	2014-01-31T09:46:41.000000	WV02_103001002C540500_M1BS_500106803100_01
WV02	2014-01-31T09:46:42.000000	WV02_103001002C540500_M1BS_500106803100_01
WV02	2014-01-31T09:46:43.000000	WV02_103001002C540500_M1BS_500106803100_01
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WV02	2014-01-31T09:46:45.000000	WV02_103001002C540500_M1BS_500106803100_01
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WV02	2014-02-02T10:11:27.000000	WV02_103001002D10D900_M1BS_500106862030_01
WV02	2014-02-02T10:11:28.000000	WV02_103001002D10D900_M1BS_500106862030_01
WV02	2014-02-02T10:11:29.000000	WV02_103001002D10D900_M1BS_500106862030_01
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WV02	2014-02-02T10:12:50.000000	WV02_103001002D5A9B00_M1BS_500106255170_01
WV02	2014-02-02T10:12:51.000000	WV02_103001002D5A9B00_M1BS_500106255170_01
WV02	2014-02-02T10:12:52.000000	WV02_103001002D5A9B00_M1BS_500106255170_01
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WV02	2014-02-14T09:29:30.000000	WV02_103001002DA9C600_M1BS_500130403040_01
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WV02	2014-02-14T09:30:48.000000	WV02_103001002C023900_M1BS_500145768090_01
WV02	2014-02-19T09:45:30.000000	WV02_103001002D1F0800_M1BS_500129972030_01
WV02	2014-02-19T09:45:31.000000	WV02_103001002D1F0800_M1BS_500129972030_01
WV02	2014-02-19T09:45:32.000000	WV02_103001002D1F0800_M1BS_500129972030_01
WV02	2014-02-19T09:46:41.000000	WV02_103001002E1AA000_M1BS_500145769190_01
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WV02	2014-02-21T10:11:25.000000	WV02_103001002E832800_M1BS_500130007140_01
WV02	2014-02-21T10:11:26.000000	WV02_103001002E832800_M1BS_500130007140_01
WV02	2014-02-21T10:11:27.000000	WV02_103001002E832800_M1BS_500130007140_01
WV02	2014-02-21T10:11:28.000000	WV02_103001002E832800_M1BS_500130007140_01
WV02	2014-02-21T10:11:29.000000	WV02_103001002E832800_M1BS_500130007140_01
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WV02	2014-02-21T10:11:31.000000	WV02_103001002E832800_M1BS_500130007140_01
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WV02	2014-02-21T10:11:32.000000	WV02_103001002E832800_M1BS_500130007140_01

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WV02	2014-02-21T10:12:48.000000	WV02_103001002D730B00_M1BS_500130536150_01
WV02	2014-02-21T10:12:49.000000	WV02_103001002D730B00_M1BS_500130536150_01
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WV02	2014-02-21T10:12:51.000000	WV02_103001002D730B00_M1BS_500130536150_01
WV02	2014-02-21T10:12:52.000000	WV02_103001002D730B00_M1BS_500130536150_01
WV02	2014-02-21T10:12:53.000000	WV02_103001002D730B00_M1BS_500130536150_01
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WV02	2014-02-24T10:01:38.000000	WV02_103001002D1E6400_M1BS_500196567060_01
WV02	2014-02-24T10:01:39.000000	WV02_103001002D1E6400_M1BS_500196567060_01
WV02	2014-02-24T10:01:40.000000	WV02_103001002D1E6400_M1BS_500196567060_01
WV02	2014-02-24T10:01:42.000000	WV02_103001002D1E6400_M1BS_500196567060_01
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WV02	2014-02-24T10:02:49.000000	WV02_103001002D01D100_M1BS_500145597030_01
WV02	2014-02-24T10:02:50.000000	WV02_103001002D01D100_M1BS_500145597030_01
WV02	2014-02-24T10:02:51.000000	WV02_103001002D01D100_M1BS_500145597030_01
WV02	2014-02-24T10:02:52.000000	WV02_103001002D01D100_M1BS_500145597030_01
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WV02	2014-09-18T10:05:20.000000	WV02_10300100357C1000_M1BS_500182079200_01
WV02	2014-09-18T10:06:30.000000	WV02_10300100371B9100_M1BS_500182069190_01
WV02	2014-09-18T10:06:30.000000	WV02_10300100371B9100_M1BS_500182069190_01
WV02	2014-09-27T09:33:48.000000	WV02_10300100370E8600_M1BS_500182093120_01
WV02	2014-09-27T09:33:48.000000	WV02_10300100370E8600_M1BS_500182093120_01
WV02	2014-09-27T09:34:51.000000	WV02_1030010037853600_M1BS_500182084100_01
WV02	2014-09-27T09:34:51.000000	WV02_1030010037853600_M1BS_500182084100_01
WV02	2014-10-17T08:54:22.000000	WV02_1030010039319100_M1BS_500147792200_01
WV02	2014-10-17T08:55:30.000000	WV02_10300100372B0000_M1BS_500147792200_01
WV02	2014-10-18T09:57:12.000000	WV02_10300100391A7500_M1BS_500316191070_01
WV02	2014-10-18T09:57:13.000000	WV02_10300100391A7500_M1BS_500316191070_01
WV02	2014-10-18T09:57:14.000000	WV02_10300100391A7500_M1BS_500316191070_01
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WV02	2014-10-18T09:57:26.000000	WV02_1030010039074500_M1BS_500147803180_02
WV02	2014-10-18T09:57:26.000000	WV02_1030010039074500_M1BS_500147803180_02
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WV02	2014-10-18T09:58:29.000000	WV02_10300100378AE200_M1BS_500340704010_01
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WV02	2014-10-18T09:58:38.000000	WV02_10300100382F0000_M1BS_500147803180_02
WV02	2014-10-18T09:58:38.000000	WV02_10300100382F0000_M1BS_500147803180_02
WV02	2014-10-18T09:58:38.000000	WV02_10300100382F0000_M1BS_500147803180_02
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WV02	2014-10-26T10:03:09.000000	WV02_10300100385D9600_M1BS_500340707090_01
WV02	2014-10-26T10:03:10.000000	WV02_10300100385D9600_M1BS_500340707090_01
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WV02	2014-10-26T10:03:12.000000	WV02_10300100385D9600_M1BS_500340707090_01
WV02	2014-10-26T10:03:13.000000	WV02_10300100385D9600_M1BS_500340707090_01
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WV02	2014-11-13T08:57:41.000000	WV02_103001003AA2C600_M1BS_500339935050_01
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WV02	2014-11-13T08:58:23.000000	WV02_103001003B93E400_M1BS_500319431050_01
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WV02	2014-11-13T08:58:46.000000	WV02_103001003A952D00_M1BS_500319423180_01
WV02	2014-11-13T08:58:47.000000	WV02_103001003A952D00_M1BS_500319423180_01
WV02	2014-11-13T08:58:48.000000	WV02_103001003A952D00_M1BS_500319423180_01
WV02	2014-11-13T08:58:49.000000	WV02_103001003A952D00_M1BS_500319423180_01
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WV02	2014-11-14T10:01:10.000000	WV02_103001003965C000_M1BS_500339932190_01
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WV02	2014-11-14T10:01:12.000000	WV02_103001003965C000_M1BS_500339932190_01
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WV02	2014-11-14T10:01:15.000000	WV02_103001003965C000_M1BS_500339932190_01
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WV02	2014-11-26T09:17:59.000000	WV02_103001003B639600_M1BS_500340647120_01
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WV02	2014-11-26T09:18:07.000000	WV02_103001003B639600_M1BS_500340647120_01
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WV02	2014-11-29T09:05:22.000000	WV02_1030010039507600_M1BS_500319459140_01
WV02	2014-11-29T09:05:23.000000	WV02_1030010039507600_M1BS_500319459140_01
WV02	2014-11-29T09:05:24.000000	WV02_1030010039507600_M1BS_500319459140_01
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WV02	2014-11-30T08:29:18.000000	WV02_103001003BB46800_M1BS_500319463040_01
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WV02	2014-11-30T08:30:26.000000	WV02_103001003A344900_M1BS_500340647140_01
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WV02	2014-11-30T08:30:28.000000	WV02_103001003A344900_M1BS_500340647140_01
WV02	2014-11-30T08:30:29.000000	WV02_103001003A344900_M1BS_500340647140_01
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WV02	2014-12-03T09:57:33.000000	WV02_103001003A8A0F00_M1BS_500340641140_01
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WV02	2014-12-07T09:09:59.000000	WV02_103001003A2C9500_M1BS_500340676150_01
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WV02	2014-12-14T09:50:23.000000	WV02_103001003BBB5700_M1BS_500340669170_01
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WV02	2014-12-14T09:51:29.000000	WV02_103001003B54E500_M1BS_500319489200_01
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WV02	2014-12-16T10:18:25.000000	WV02_103001003A960300_M1BS_500315365190_01
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