



OCTOPUS: An Open Cosmogenic Isotope and Luminescence Database

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Abstract. We present a new open and global database of cosmogenic radionuclide and luminescence measurements in fluvial sediment. With support from the Australian National Data Service (ANDS) we have built infrastructure for hosting and maintaining the data at the University of Wollongong and making this available to the research community via an Open Geospatial Consortium (OGC) compliant Web Map Service. The cosmogenic radionuclide (CRN) part of the database consists of ¹⁰Be

- 5 and ²⁶Al measurements in fluvial sediment samples along with ancillary geospatial vector and raster layers, including sample site, basin outline, digital elevation model, gradient raster, flow direction and flow accumulation rasters, atmospheric pressure raster, and CRN production scaling and topographic shielding factor rasters. Sample metadata is comprehensive and includes all necessary information for the recalculation of denudation rates using CAIRN, an open source program for calculating basin-wide denudation rates from ¹⁰Be and ²⁶Al data. Further all data have been recalculated and harmonised using the same
- 10 program. The luminescence part of the database consists of thermoluminescence (TL) and optically stimulated luminescence (OSL) measurements in fluvial sediment samples from stratigraphic sections and sediment cores from across the Australian continent, and includes ancillary vector and raster geospatial data. The repository and visualisation system enable easy search and discovery of available data. Use of open standards also ensures that data layers are visible to other OGC compliant data sharing services. Thus, OCTOPUS will turn data that was previously invisible to those not within the CRN and luminescence
- 15 research communities into a findable resource. This aspect is of importance to industry or local government who are yet to discover the value of geochronological data in, amongst others, placing human impacts on the environment into context. The availability of the repository and its associated data curation framework will provide the opportunity for researchers to store, curate, recalculate and re-use previously published but otherwise unusable CRN and luminescence data. This delivers the potential to harness old but valuable data that would otherwise be 'lost' to the research community. The streamlined repository
- 20 and transparent data re-analysis framework will also reduce research time and avoid duplication of effort, which will be highly attractive to other researchers. OCTOPUS can be accessed at https://earth.uow.edu.au. The data collections can also be ac-





cessed via the following DOIs: 10.4225/48/5a8367feac9b2 (*CRN International*), 10.4225/48/5a836cdfac9b5 (*CRN Australia*), and 10.4225/48/5a836db1ac9b6 (*OSL & TL Australia*).

1 Introduction

- Cosmogenic radionuclide (CRN) exposure dating and luminescence dating are suites of geochronological techniques that 5 have become important for the studying of Earth surface processes (e.g., Rhodes, 2011; Granger et al., 2013). Both permit quantifying the timing of geological events by dating individual landforms. In addition, CRNs can also be used to measure the rate at which landforms or landscapes are being denuded by physical and chemical erosion processes. Thus, the two suites of techniques have been extensively used among others to quantify basin-wide denudation rates (von Blanckenburg, 2005; Granger and Schaller, 2014), to reconstruct the extent of Quaternary glaciations (Spencer and Owen, 2004; Balco, 2011;
- 10 Ivy-Ochs and Briner, 2014), to study how rivers have adapted to past climate change via incision and aggradation (Schaller et al., 2004; Lewis et al., 2009; Wallinga et al., 2010), and to study the timing of dune construction (Fitzsimmons et al., 2007; Fujioka et al., 2009; Bristow et al., 2010). Both suites of techniques are costly (both in terms of time and money) and require specialised training, laboratories, and equipment. As such, CRN and luminescence studies are often very focused and involve a relatively small number of samples (n < 100). The research questions being addressed by these studies are very specific and</p>
- 15 study areas are often relatively small. Hence, CRN and luminescence studies will produce small datasets that are unmanaged and that may become 'forgotten' once the study has been completed and results published. Further, despite there being calls for minimum data reporting standards (e.g., Dunai and Stuart, 2009; Frankel et al., 2010), often the published work will not include appropriate levels of metadata to make the raw data reusable with ease. The latter is especially important in the case of cosmogenic nuclides as procedures used to interpret CRN data are regularly revised and updated, requiring denudation rates
- 20 and/or exposure ages to be recalculated using updated measurement standards and calculation protocols. Such recalculations are also necessary when comparing results produced by different Accelerator Mass Spectrometry (AMS) facilities that happen to normalise results to different AMS standards. Therefore, without periodic recalculation and maintenance of the data, CRN-based age and rate estimates, for example, can become out-of-date after a few years. A system and framework for managing CRN and luminescence data and metadata is critical to ensure the longevity and value of such data collections.
- 25 Here we present a new open and global database of cosmogenic radionuclide and luminescence measurements in fluvial sediment. With support from the Australian National Data Service (ANDS) we have built infrastructure for hosting and maintaining the data at the University of Wollongong and making this available to the research community via an Open Geospatial Consortium (OGC) compliant Web Map Service (http://www.opengeospatial.org). The CRN part of the database consists of ¹⁰Be and ²⁶Al measurements in fluvial sediment samples from across the globe. Sample metadata is comprehensive and in-
- 30 cludes all necessary information for the recalculation of denudation rates using CAIRN, an open source program for calculating basin-wide denudation rates from ¹⁰Be and ²⁶Al data (Mudd et al., 2016). To this end, the database also includes a comprehensive suite of geospatial data layers, both vector (e.g., sample site and basin outline) and raster (e.g., elevation, gradient and flow routing rasters, atmospheric pressure, and CRN production scaling and topographic shielding factors). The luminescence





part of the database consists of thermoluminescence (TL) and optically stimulated luminescence (OSL) measurements in fluvial sediment samples from stratigraphic sections and sediment cores from across the Australian continent. Comprehensive metadata and ancillary vector and raster geospatial data are likewise included and available for download. OCTOPUS can be accessed at https://earth.uow.edu.au.

5 2 CRN and Luminescence dating in a nutshell

This section briefly describes the two suites of dating techniques and provides information on CAIRN.

2.1 Inferring denudation rates from cosmogenic ¹⁰Be (and ²⁶Al)

Cosmogenic nuclide exposure dating is based on the study of rare isotopes produced by high-energy cosmic radiation breaking up the atoms that make up the minerals and rocks at the Earth's surface. The term *in situ* is used to distinguish these isotopes

- 10 from those that are produced through the same cosmic-ray induced nuclear reactions in the atmosphere termed *meteoric* (Dunai, 2010; Granger et al., 2013). Several of the in situ cosmogenic nuclides, including the stable ³He and ²¹Ne, and the radioactive ¹⁰Be, ²⁶Al, and ³⁶Cl, are now routinely measured and have been used in geomorphological studies for the last three decades (Bierman and Nichols, 2004; von Blanckenburg, 2005; Dunai, 2010; Granger and Schaller, 2014). Of these nuclides, however, ¹⁰Be produced in quartz is the 'workhorse' for in situ applications, and most in situ cosmogenic nuclide studies have
- 15 used ¹⁰Be, either alone or in conjunction with other cosmogenic nuclides such as ²⁶Al and ²¹Ne. Given the long half-life of ¹⁰Be (T_{1/2}=1.387 Myr, Chmeleff et al., 2010; Korschinek et al., 2010) and the increasingly low analytical backgrounds that can be realised, it is now possible to analyse samples covering a wide range of temporal settings, including historic times (e.g., Schaefer et al., 2009). The rate at which cosmogenic nuclides are produced is extremely low a few atoms per gram of rock per year (Borchers et al., 2015) and the rapid attenuation of cosmic radiation with depth confines the production of cosmogenic
- 20 nuclides to the upper few metres of the crust, production rates decreasing roughly exponentially with depth (Argento et al., 2015a, b). Production rates of cosmogenic nuclides are mainly a function of geomagnetic latitude and altitude above sea level (Balco et al., 2008; Lifton et al., 2014). Site-specific cosmogenic nuclide production rates are also subject to several other factors, the most important of these being the geometry of the surrounding topography, which shields part of the incoming cosmic radiation (Dunne et al., 1999; Codilean, 2006).
- The application of ¹⁰Be (or any other in situ-produced cosmogenic nuclide) to the study of Earth surface processes is based on the principle that its concentration is directly proportional to the exposure time to cosmic radiation. Cosmogenic nuclides will accumulate in surficial deposits over time such that their concentration will be directly related to not only the exposure age but also the rate at which the surface is eroding (Lal, 1991; Granger et al., 2013; von Blanckenburg and Willenbring, 2014). As a parcel of rock or sediment is brought toward the surface by erosion on a hillslope, its ¹⁰Be concentration increases at a
- 30 rate that depends mainly on the rate of erosion, and the ¹⁰Be surface production rate at that locality. When the parcel of rock or sediment reaches the surface, it is transported via hillslope processes to the fluvial system, where it mixes with sediment from other parts of the contributing catchment. Thus, rivers act not only as agents of erosion but also as integrators, collecting





sediment from all parts of the catchment in an amount that is proportional to their denudation rate such that at the outlet of the catchment, the sediment will contain an average concentration of ¹⁰Be (and ²⁶Al) that is a measure of the catchment's mean denudation rate (von Blanckenburg, 2005; Granger and Schaller, 2014). The technique of determining basin-wide denudation rates from CRN concentrations in stream sediments was first introduced in the mid 90s (e.g., Brown et al., 1995; Granger et al.,

5 1996; Bierman and Steig, 1996), and since that time denudation rates have been determined in over 4,000 river basins from a wide range of tectonic and climatic settings.

2.2 Luminescence dating of sediment

Luminescence dating provides an estimate of the amount of time elapsed since mineral grains (quartz or feldspar) were last exposed to intense heat or sunlight. The suite of techniques includes thermoluminescence dating (TL) in which the luminescence
signal is produced by heating mineral grains in the laboratory during measurement (Aitken, 1985; Huntley et al., 1985), and optically stimulated luminescence dating (OSL) in which the luminescence signal is produced by exposing the mineral grains to an intense light source (Aitken, 1998). The suite of techniques can be used to date events as young as a few decades (e.g., Wolfe et al., 1995; Rustomji and Pietsch, 2007; Pietsch et al., 2015; Croke et al., 2016) to as old as nearly 1 Ma (Arnold et al., 2015). The basis of both TL and OSL dating resides in measurements of the trapped charge (e.g., electrons) within mineral

- 15 lattice imperfections which accumulate over time. When electrons are exposed to ionising radiation produced by the decay of radioisotopes contained in the surrounding sediment matrix, and/or via exposure to high-energy cosmic rays, electrons will move from a lower energy level (valence band) to a higher energy level (conduction band). Moving between the two bands, some of the energised electrons will become trapped by defects in the crystal lattice. In a parcel of sediment that is buried and thus shielded from sunlight and/or intense heat, the number of trapped electrons will increase steadily with time in proportion
- 20 to the intensity of the ionising radiation flux (i.e., dose rate) and water saturation of the sediment. When the irradiated mineral grains are exposed to sunlight (or intense heat) the electrons will escape the traps, and the 'luminescence clock' is zeroed. Thus, TL and OSL provide ages that represent the last time the electron traps were emptied or 'bleached' either by exposure of the sediment to sunlight (e.g., during sediment transport) or by heating (e.g., during a bush fire) (Wintle, 2008; Rhodes, 2011). When luminescence dating techniques are applied to sediments, an often used assumption (when analysing multiple grains)
- 25 is that the electron traps were completely emptied prior to deposition and so the luminescence clock has been effectively zeroed. In the case of OSL even short exposure to sunlight (< 1 minute) is sufficient to bleach the sediment grains and thus zero the luminescence clock, however for TL, a longer exposure to sunlight is required to remove the TL signal. Fine mineral grains that are transported by wind or as suspended fluvial sediment should be exposed to sunlight while airborne or in the upper parts of the water column. On the other hand, larger grains that travelled as bedload might only be partially bleached.
- 30 Independent of grain size, when dealing with fluvial sediment, the bleaching characteristics of the sample need to be assessed in order to determine the use of an applicable age model. Possible strategies for determining bleaching characteristics include using geomorphic models that reconstruct mineral grain pathways and thus predict optimal bleaching regimes (e.g., Fuchs and Owen, 2008), analysing recently deposited sediment to assess their residual OSL/TL signals (e.g., Rhodes and Bailey, 1997; Singarayer et al., 2005), pairing with a second independent dating technique such as radiocarbon dating (e.g., Olley et al.,





2004), and analysing different grain size fractions or closely spaced samples with different depositional energies under the assumption that these might have behaved differently during sediment transport (e.g., Richards et al., 2000). Alternatively, various age models can be applied to either single or multi-grain data sets (e.g., minimum age model; Galbraith et al., 1999), which statistically differentiate partially bleached grain populations so as to derive the equivalent dose and subsequent age of

5 the depositional event.

2.3 The CAIRN method for calculating CRN-based basin wide denudation rates

CAIRN is an automated, open-source method for calculating basin averaged denudation rates so that inferred denudation rates are reproducible: the method ingests topographic data, cosmogenic ¹⁰Be and ²⁶Al concentrations and a parameter file and any two users with the same inputs will calculate the same denudation rate (Mudd et al., 2016). CAIRN forward models ¹⁰Be
or ²⁶Al concentrations at every pixel for a given denudation rate, taking into account latitude and altitude scaling of CRN production rates as well as snow, self, and topographic shielding. The obtained concentrations are averaged to predict a basin-averaged ¹⁰Be or ²⁶Al concentration, and Newton's method is then used to find the denudation rate for which the predicted concentration matches the measured concentration and to derive associated uncertainties. CAIRN is also capable of ingesting fixed denudation rates in masked portions of the input raster, allowing users to calculate spatially varying denudation rates in nested basins. In addition, CAIRN outputs spatially averaged CRN production scaling and topographic shielding values

- that can be used with other available CRN calculators that do not provide spatial averaging, including the online calculators formerly known as the CRONUS-Earth online calculators (Balco et al., 2008) and the Microsoft Excel-based COSMOCALC (Vermeesch, 2007). Because there is no graphical interface and because releases of the software are tagged, CAIRN users can simply publish DEM metadata, CRN data files, and CAIRN input files and denudation rates should be reproducible. The open
- 20 source framework means that the code can be modified to include updated methods for production rates and scaling factors. Future users can thus recalculate denudation rates using updated versions of the code. CAIRN includes scripts for producing separate basin rasters for each cosmogenic sample from a regional topographic raster so that the denudation rate calculations can be run on multiple processors, meaning that large regional datasets can be processed simultaneously on compute clusters.

3 The OCTOPUS data storage and sharing setup

25 This section provides a description of the software infrastructure behind OCTOPUS. The latter consists of a combination of off-the-shelf open source packages, bespoke code for handling the upload and download of data, and a web interface.

3.1 Database software setup

The setup of the OCTOPUS data storage and sharing platform is illustrated in Figure 1. The data are stored in two separate locations. First, tabular data and the point and polygon geometries associated with each sample site or study (see Section 4) are

30 stored in a PostGIS database. PostGIS (https://postgis.net) is a spatial database extender for the PostgreSQL object-relational database management system (https://www.postgresql.org), adding support for geographic objects and allowing location-based





queries to be run in SQL. Second, all data (tabular, vector, and raster) and auxiliary information (e.g., CAIRN input and output files) (see Section 4) are also stored in separate zip archives, one zip file for each study. This hybrid setup was chosen over having all tabular, vector, and raster data together in the PostGIS database because (i) it offered more flexibility regarding the list of files and file formats that could be included for download, and (ii) it made the coding of data upload and download

- 5 simpler. The PostGIS database is connected to a GeoServer instance (Figure 1). GeoServer is an open-source server that allows the sharing, processing, and editing of geospatial data (http://geoserver.org), and implements a range of OCG data sharing standards, including the widely used Web Feature Service (WFS) and the Web Map Service (WMS) standards. GeoServer also produces a variety of commonly used geospatial data formats, including KML and ESRI Shapefile, and so can feed data directly to Google Earth, ArcGIS, and QGIS (Figure 1). The OpenLayers (https://openlayers.org) JavaScript library is used to
- 10 display the geospatial data served by the GeoServer instance in a web browser (Figure 1). OpenLayers also allows for the data to be queried and a selection to be made for download.

3.2 Web Interface

The web interface has a simple design and includes the following elements (Figure 2): a message box, that provides the user with step-by-step help on how to navigate the web page (Figure 2, #1); a collapsible panel with a list of all available data layers

- 15 these are grouped by data collection (see Section 4) and can be toggled on or off (Figure 2, #2); navigation buttons allowing zooming and scrolling (Figure 2, #3); and the data download button (Figure 2, #4). The latter opens a dialog panel and switches the cursor from panning mode to selection mode, allowing for data layers to be selected and added to a download list. The OpenLayers map frame uses Google Terrain as the base layer and the point and polygon data are displayed using different colours for each collection (Figure 2, #5).
- Figure 3 illustrates a typical user session. First, the user displays the data collection(s) of interest and navigates to the desired geographical area. This can be achieved by using the navigation buttons or simply by clicking (to zoom) and dragging (to pan) on the map area. To query the data, the user clicks on a point or polygon feature. This action displays an information panel that includes a subset of the records available as part of the attribute table for each point or polygon feature. In case of overlapping features, the information panel displays records for all features (Figure 3, #1). Displayed information includes
- 25 sample ID, publication details, and recalculated ¹⁰Be-based denudation rate with uncertainty for CRN data, or published age with uncertainty for OSL/TL data, respectively. The dialog panel closes automatically once the user clicks anywhere outside of the panel in the map display window. To download data, the user clicks on the download button. This action turns the cursor into a selection tool (the user drags a box around desired points and polygons to select), and displays a dialog panel requesting user information such as name, email address, and the intended use of the data (Figure 3, #2-3). The user has the option to
- 30 fine-tune the list of selected studies by toggling on or off each study from the list generated after the selection box is drawn. It is possible to select multiple studies from multiple collections at the same time. A valid email address is required as links to the data are sent to the user via email. Entered information is stored in a log file permanently.



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4 The OCTOPUS data collections and data structure

The compiled CRN and OSL/TL data are organised in three collections, namely: (i) *CRN International*, including ¹⁰Be (and ²⁶Al) measurements in fluvial sediment samples from across the globe but excluding Australia; (ii) *CRN Australia*, including ¹⁰Be (and ²⁶Al) measurements in fluvial sediment samples from Australia; and (iii) *OSL & TL Australia*, including OSL and TL measurements in fluvial sediment samples from stratigraphic sections and sediment cores from across the Australian continent.

4.1 CRN International and CRN Australia

The *CRN International* and *CRN Australia* collections consist of ¹⁰Be (and where available, also ²⁶Al) basin-wide denudation rates published in the peer-reviewed literature up to 2018. The data are organised in studies – each publication is a 'study' – with files belonging to each study stored in separated zip archives (Figure 4). The mean sample number per study is ~ 20
and the ratio of published ²⁶Al to published ¹⁰Be measurements is approximately 1 to 10. For each ¹⁰Be data point, there is a point geometry file representing the location of the sample site, and a polygon geometry file representing the outline of the drainage basin from where the sampled material is originating from. An attribute table including published and recalculated ¹⁰Be (and ²⁶Al) data and a comprehensive set of metadata is linked to the polygon geometry file. A complete description of all attribute data entries is provided in Table S1, included as part of the supplementary material. For each study, each zip archive also includes seven raster layers: (i) a hydrologically corrected DEM with elevation values in m, (ii) a flow direction raster calculated using the D8 flow routing method (Jenson and Domingue, 1988), (iii) a flow accumulation raster calculated with the same D8 method, (iv) a slope gradient raster calculated using the method described in Horn (1981) with units in

climate reanalysis data (Compo et al., 2011), (vi) a cosmogenic nuclide production scaling raster calculated using the method described in Stone (2000), and (vii) a cosmogenic nuclide production topographic shielding raster calculated using the method described in Codilean (2006). All raster layers were derived using the SRTM 90 m Digital Elevation Database (Farr et al., 2007) and extend 20 km beyond the boundaries of the drainage basins in each study. For two studies, namely Henck et al. (2011) and Reber et al. (2017), due to very large basin areas, all raster layers with the exception of slope gradient were calculated from SRTM data resampled to 500 m resolution. Each zip archive also includes a series of text files representing CAIRN

 $m.km^{-1}$, (v) an atmospheric pressure raster, showing local atmospheric pressure in hPa calculated based on the NCEP2

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known as the CRONUS-Earth online calculators (Balco et al., 2008).

Published ¹⁰Be concentrations (atoms.g⁻¹) were re-normalised to the Nishiizumi 2007 ¹⁰Be AMS standard (Nishiizumi et al., 2007), and basin-wide denudation rates recalculated with CAIRN. Basin averaged nuclide production from neutrons and muons was calculated with the approximation of Braucher et al. (2011) and using a sea-level and high-latitude total

configuration and input data files, and CAIRN output files, including files to be used with the online calculators formerly

¹⁰Be production rate of 4.3 atoms.g⁻¹.yr⁻¹ (Mudd et al., 2016). Production rates for catchment wide denudation rates were calculated at every pixel using the SRTM 90 m DEM, with the time-independent Lal/Stone scaling scheme (Stone, 2000). Atmospheric pressure was calculated via interpolation from the NCEP2 reanalysis data (Compo et al., 2011). Topographic shielding was calculated from the same DEM using the method of Codilean (2006) with θ = 8 degrees and ϕ = 5 degrees. All

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calculations assumed a 10 Be half-life of 1.387 ± 0.012 Myr (Chmeleff et al., 2010; Korschinek et al., 2010). For consistency across the global compilation, no corrections were made for lithological differences in quartz abundance, glacier cover, and snow shielding. However, all CAIRN input and configuration files are provided and these corrections can be readily applied by end users to individual studies. Figure 5 shows a comparison between published and recalculated 10 Be denudation rates. With

5 the exception of a small number of data points ($n \sim 10$), there is good agreement between published and recalculated ¹⁰Be denudation rates, with no trends related to elevation or basin size obvious. Where discrepancies exist, these are due either to differences in drainage basins as published versus drainage basins identified on the SRTM DEM during data recalculation, or due to corrections that were applied to the data in the original publication that were not appropriately described in the latter. Approximately 5% of compiled ¹⁰Be measurements – all of which were published in two highly-regarded journals – could not

10 be incorporated into OCTOPUS due to insufficient information to reproduce drainage basin extents. In terms of geographical extent, the global CRN compilation exhibits considerable bias (Figure 6A). The majority of the ¹⁰Be (and ²⁶Al) measurements are from northern-hemisphere drainage basins, clustering around distinct, mostly tectonically active, topographic regions, such as the Pacific coast of the United States, the Appalachians, the European Alps, and Tibet-Himalaya. Due to some recent studies, there is also good coverage of the South American Cordillera. However, there is considerable

- 15 lack of data from low-gradient and tectonically passive regions, such as large parts of Australia, most of Africa, and most of Asia less the Tibet-Himalaya region. Further, there is no data from latitudes above ~ 55 degrees. The observed geographical bias is a reflection of the intense interest of the geomorphological community in estimating rates of erosion and weathering in tectonically active mountain regions with the aim, among others, to understand the role of surface processes in the global climate system (e.g., Molnar and England, 1990; Raymo and Ruddiman, 1992; Willenbring and von Blanckenburg, 2010;
- 20 Herman et al., 2013). Further, the lack of data from high latitudes is partly due to the desire of staying away from formerly glaciated environments. Although the geographical bias does not make the CRN collection less valuable, it may confound studies aiming to infer global-scale trends from these data (cf. Portenga and Bierman, 2011; Willenbring et al., 2013; Harel et al., 2016). Despite the geographical bias, however, the global CRN data samples basins with a wide range of slope gradients, elevations, and basin areas (Figure 6B-C).

25 4.2 OSL & TL Australia

The OSL & TL Australia collection consists of thermoluminescence (TL) and optically stimulated luminescence (OSL) measurements in fluvial sediment samples from stratigraphic sections and sediment cores from across the Australian continent. The collection includes data published in the peer-reviewed literature up to 2017 and also previously unpublished data compiled from technical reports and various Honours, MSc, and PhD theses. The majority of the TL data is from sources published from

30 1986 up to 2005 whereas the majority of the OSL data is from sources less than 10 years old (Figure 7). In terms of geographical extent both TL and OSL data are concentrated in the south-eastern and eastern parts of the Australian continent, with ~ 500 measurements from Australia's largest river basins – Lake Eyre (LEB) and Murray-Darling (MDB) basins – and with an equal amount from rivers draining the eastern seaboard (Figure 7). The western half of Australia is severely understudied, with one single OSL study for the entire region, namely, Veth et al. (2009). Focused interest on river systems is proximal to high popu-

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lation density areas, where floods are a potential threat (e.g., Brisbane River, after major floods of 2011; Croke et al., 2016), or where rivers are of a great agricultural importance, such as the Murray-Darling basin. This well justified bias however, leaves a gap in knowledge where rivers are now dry or ephemeral, and yet they could hold information on the past climatic regimes now buried under the desert sand. The focus on south-eastern coast river systems draining the Great Dividing Range could

5 be a source of bias in continent-wide interpretations, where the rivers draining the western intra-continental ranges and plains remain underrepresented.

Similar to the CRN collections, the data are organised in studies – each publication is a 'study' – with files belonging to each study stored in separated zip archives (Figure 4). For each OSL or TL data point, there is a point geometry file representing the location of the sample site. An attribute table including published OSL or TL ages and a comprehensive set of metadata

- 10 is linked to the point geometry file (a complete description of all attribute data entries is provided in Table S2, included as part of the supplementary material). The zip archive also includes two separate polygon geometry files: one representing the outline of the drainage basin of the most downstream sample, and one representing the area extending 20 km beyond the boundaries of this drainage basin. For studies with basin areas up to 100,000 km², each zip archive also includes four raster layers: (i) a hydrologically corrected DEM with elevation values in m, (ii) a flow direction raster calculated using the D8 flow
- 15 routing method (Jenson and Domingue, 1988), (iii) a flow accumulation raster calculated with the same D8 method, and (iv) a slope gradient raster calculated using the method described in Horn (1981) with units in m.km⁻¹. All raster layers were derived using the hydrologically enforced SRTM 30 m Digital Elevation Model (DEM-H) obtained from Geoscience Australia (Geoscience Australia, 2011) and were clipped to the extent of the 20 km buffer polygon layer. For studies with basin areas exceeding 100,000 km² (e.g., Callen and Nanson, 1992; Bourman et al., 2010; Jansen et al., 2013) raster layers (i) to (iii) were
- 20 derived using Geoscience Australia's GEODATA 250 m digital elevation model and flow direction grid (Geoscience Australia, 2008), as the SRTM DEM produced files that were too large for transferring online.

4.3 Other collections

In addition to the CRN and OSL/TL collections described above, the current version of OCTOPUS also includes additional CRN data organised under two collections: *CRN XXL* and *CRN In-Prep*. These two collections are not officially supported by the OCTOPUS project, and are included here only for completeness. The first collection consists of five studies with samples from the Yangtse (Chappell et al., 2006), Amazon (Wittmann et al., 2009, 2011), Ganga (Lupker et al., 2012), and Brahmaputra basins (Lupker et al., 2017). These studies focused on very large basins that could only be handled by CAIRN when ran using a 500 m resolution DEM that, however, produced drainage basins that were substantially different to what was published, especially in the case of rivers in the Amazon basin. Further, Chappell et al. (2006) do not report denudation rates – suggesting

30 that calculating these might have little meaning for their samples –, and both Wittmann et al. (2009; 2011) and Lupker et al. (2012; 2017) perform corrections to the data, some of which (e.g., removing floodplain areas from production rate calculations) we do not deem appropriate and so did not wish to replicate. To this end, *CRN XXL* does not include recalculated values nor does it include any raster layers. *CRN In-Prep* is an inventory of samples processed at the University of Wollongong where





¹⁰Be and ²⁶Al have been measured and the data are not yet published. The collection includes sample metadata and point and polygon geometry files.

5 Conclusions

We have produced a new open and global database of cosmogenic radionuclide and luminescence measurements in fluvial sediment and we have built infrastructure for hosting and maintaining the data at the University of Wollongong and making this available to the research community via an OGC compliant Web Map Service. The database consists of ¹⁰Be, ²⁶Al, TL, and OSL measurements in fluvial sediment samples along with ancillary geospatial vector and raster layers. Sample metadata is comprehensive and includes all necessary information for the recalculation of ¹⁰Be and ²⁶Al denudation rates using the CAIRN

program. The repository and visualisation system enable easy search and discovery of available data. Use of open standards

- 10 also ensures that data layers are visible to other OGC compliant data sharing services. Thus, this project will turn data that was previously invisible to those not within the CRN and luminescence research community into a findable resource. This aspect is of particular importance to industry or local government who are yet to discover the value of geochronological data in, for example, evaluating how human-induced land use practices have accelerated soil erosion, and what measures are necessary for restoring these rates to their natural benchmark levels. Our intention is for the Web Map Service to become the default go-to
- 15 place for CRN and luminescence data. The availability of the repository and its associated data curation framework will provide the opportunity for researchers to store, curate, recalculate and re-use previously published but otherwise unusable CRN and luminescence data. This delivers the potential to harness old but valuable data that would otherwise be 'lost' to the research community. OCTOPUS will enable new research and generate new knowledge by converting a multitude of disconnected data sets into one connected and streamlined database. Current data sets allow local-scale analyses. The streamlined database will
- 20 allow for regional-scale and even continental- or global-scale analyses. The transparent data re-analysis framework will also reduce research time and avoid duplication of effort, which will be highly attractive to other researchers. Ultimately, OCTOPUS will ensure that CRN and luminescence data are reusable beyond the scope of the project for which they were initially collected.

6 Data availability

OCTOPUS can be accessed at https://earth.uow.edu.au. The data collections that make up the 2018 release of OCTOPUS
(Version 1 – 'Dooku's Dilemma'), have been assigned the following DOIs: 10.4225/48/5a8367feac9b2 (CRN International), 10.4225/48/5a836cdfac9b5 (CRN Australia), and 10.4225/48/5a836db1ac9b6 (OSL & TL Australia). A copy of OCTOPUS has also been deployed to https://earthtest.uow.edu.au. This copy is not supported and is used for testing modifications to the website and data collections before deployment to the official site. Users should refer to the DOIs provided to ensure that they are accessing the current and supported version of the data.





Author contributions. ATC, HM, TJC, and WMS compiled the CRN and luminescence data; ATC and HM performed the GIS analyses and the data recalculations using CAIRN with input from SMM; AG designed and built the OCTOPUS platform and web interface with input from ATC; All authors contributed to the writing of the manuscript.

Competing interests. The authors declare that they have no conflict of interest.

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Figure 1. The setup of the OCTOPUS data storage and sharing platform. See text for more details.







Figure 2. The OCTOPUS web interface with main elements: (1) message box, that provides the user with step-by-step help on how to navigate the web page, (2) collapsible panel with a list of all available data layers, (3) navigation buttons, (4) data download button, (5) Google Terrain base map and point and polygon data layers. See text for more details.









Figure 3. Screenshots of the OCTOPUS webpage illustrating a typical user session. See text for more details.







Figure 4. Data organisation diagrams for the CRN and OSL/TL collections. See text for details.







Figure 5. Published versus recalculated ¹⁰Be-based denudation rates. Data points are coloured according to average basin elevation and circle sizes are proportional with basin area. Note the good agreement between the two datasets and the lack of obvious trends related to basin elevation and basin area.







Figure 6. The global CRN dataset: (A) geographical extent and latitudinal sample distribution, (B) average basin slope versus recalculated ¹⁰Be denudation rate, and (C) average basin elevation versus recalculated ¹⁰Be denudation rate. Data points in (B) and (C) are coloured according to average basin elevation and circle sizes are proportional with basin area. Contour lines show kernel density estimates for the point clouds (arbitrary units).







Figure 7. The spatial and temporal extent of the OSL & TL Australia dataset. Blue triangles denote TL measurements and yellow circles denote OSL measurements. Grey lines depict major topographic drainage divisions and river regions based on the Australian Hydrological Geospatial Fabric (Geofabric). Box plot whiskers represent the inter quartile range and horizontal lines the median.