PALAEONTOLOGICAL IMPACT ASSESSMENT: DESKTOP STUDY

Graaff-Reinet Emergency / Contingency Water Plan, Camdeboo Local Municipality, Eastern Cape Province

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1. SUMMARY

A proposed upgrading of the water supply at Graaff-Reinet (Camdeboo Local Municipality, Eastern Cape Province) will involve the installation of a 4km new pipeline as well as eight new boreholes to the north of town. The study area is underlain by sediments of the Lower Beaufort Group (Middleton Formation) that have yielded rich continental fossil assemblages of Late Permian age, notably of therapsids ("mammal-like reptiles") and true reptiles. However, this development will probably have a very low impact on local fossil heritage because (a) the greater part of the proposed pipeline route will be underlain by Late Caenozoic superficial sediments (*e.g.* river alluvium, alluvial fans) of low palaeontological sensitivity; (b) potentially fossiliferous bedrocks of the Lower Beaufort Group at the southern end of the pipeline have probably been baked by adjacent igneous intrusions, compromising their fossil heritage; and (c) deep excavations (> 1.5m) are not envisaged. Specialist palaeontological mitigation of this development is therefore not considered necessary.

Should substantial fossil remains, such as vertebrate bones, teeth or petrified wood, be found or exposed at any time during development, these should be recorded (*e.g.* photos, GPS reading) and safeguarded, preferably in situ, by the ECO. SAHRA and / or a professional palaeontologist should be informed at the earliest opportunity so that appropriate palaeontological mitigation can be undertaken at the developer's expense.

2. INTRODUCTION & BRIEF

The proposed upgrading of the water supply for Graaff-Reinet (Camdeboo Local Municipality) will involve the following key components (See Fig. 1 for location):

- construction of ~ 4km of 315 mm diameter pipeline from a well field north of the town along the western side of the N9 to the existing Water Treatment Plant. A section of this pipeline will traverse National Parks land.
- reconstruction of the existing reservoir and upgrading of inlet pipes
- repair and upgrading of all borehole pumps and electrical infrastructure
- repair of the pump house
- the sinking of ~ 8 new boreholes with pumps and pipes

Trenches are anticipated to be between one and one-and-a-half meters deep and will be excavated either by machine or by manual labour over a period of six to twelve months. Deep excavations are not envisaged.

The Graaff-Reinet area is underlain by highly fossil-rich sediments of the Late Permian Beaufort Group. Scientifically valuable fossils might be damaged, disturbed or destroyed during trenching operations for the water supply project. A desktop palaeontological impact assessment for the proposed development has therefore been requested by SAHRA in accordance with the National Heritage Resources Act, 1999. The various categories of heritage resources recognised as part of the National Estate in Section 3 of the Heritage Resources Act include, among others:

- geological sites of scientific or cultural importance
- palaeontological sites
- palaeontological objects and material, meteorites and rare geological specimens

This study has accordingly been commissioned on behalf of the Camdeboo Local Municipality by the CEN IEM Unit, Port Elizabeth.

Fig. 1. Google Earth satellite image of the study area just north of Graaff-Reinet, Eastern Cape (kindly provided by CEN IEM Unit, Port Elizabeth). The proposed pipeline is indicated by the thin white line to the west of the N9 and east of the Vanryneveldpas Dam. The reddish-brown *koppies* in the south, including the reservoir area, are capped by dolerite. Doleritic colluvial deposits impart a reddish coloration to the surrounding vlaktes across which the pipeline will be laid. The different coloration along the northern margin of the image is not of geological origin.

2.1. General approach used for palaeontological impact desktop studies

In preparing a palaeontological desktop study the potentially fossiliferous rock units (groups, formations *etc*) represented within the study area are determined from geological maps. The known fossil heritage within each rock unit is inventoried from the published scientific literature, previous palaeontological impact studies in the same region, and the author's field experience (Consultation with professional colleagues as well as examination of institutional fossil collections may play a role here, or later following scoping during the compilation of the final report). This data is then used to assess the palaeontological sensitivity of each rock unit to development (Provisional tabulations of palaeontological sensitivity of all formations in the Western, Eastern and Northern Cape have already been compiled by J. Almond and colleagues; *e.g.* Almond *et al*. 2008). The likely impact of the proposed development on local fossil heritage is then determined on the basis of (1) the palaeontological sensitivity of the rock units concerned and (2) the nature of the development itself, most notably the extent of fresh bedrock excavation envisaged. When rock units of moderate to high palaeontological sensitivity are present within the development footprint, a field scoping study by a professional palaeontologist is usually warranted.

3. GEOLOGICAL BACKGROUND

As shown on the relevant 1: 250 000 geological map, Sheet 3224 Graaff-Reinet published by the Council for Geoscience (Hill 1993, Fig. 2 herein), the Graaff-Reinet region is largely underlain by Late Permian continental sediments of the Lower Beaufort Group (Adelaide Subgroup, Karoo Supergroup). In particular the Karoo sediments in the lower-lying areas at the foot of the Great Escarpment belong to the mudrock-dominated **Middleton Formation** (**Pm**) (Hill 1993, Cole *et al*. 2004, Rubidge 1995, Johnson *et al*., 2006). In general the Lower Beaufort sediments near Graaff-Reinet are fairly flat-lying so they, and the fossils within them, have not suffered extensively from tectonic deformation.

The Middleton Formation mudrocks are overlain by the sandstone-rich basal portion of the **Balfour Formation** (**Pb**)(Oudeberg Member) which forms the upper slopes of the higher escarpment edge *koppies* surrounding Graaff-Reinet (*e.g.* Spandaukop). Along this stretch of the Great Escarpment the lower Balfour Formation is intruded by a major, sheet-like intrusions of the **Karoo Dolerite Suite** (**Jd**) of Early Jurassic age (*c*. 183 Ma). The Balfour Formation will not be directly impacted by the present development and therefore is not considered further here. At the southern end of the proposed pipeline, near the reservoir, a dolerite sill has transgressed down into the Middleton Formation. South of the Broederstroom an elongate, curved spur of Middleton rocks crosses the pipeline route, but for the most part the latter is blanketed by a mantle of Late Caenozoic "drift" deposits (yellow on geological map) related to the Sundays River drainage system. These drift deposits are probably rather thick (perhaps up to several meters) in much of the study area around the Vanryneveldpas Dam.

3.1. Middleton Formation (Pm)

This formation forms the middle portion of the Adelaide Subgroup east of 24°E, including the Graaff-Reinet sheet area (Hill 1993, Johnson *et al*., 2006). The fluvial Middleton succession comprises greenish-grey to reddish overbank mudrocks with subordinate resistant-weathering, fine-grained channel sandstones deposited by large meandering river systems. Because of the dominance of recessive-weathering mudrocks, the Middleton Formation erodes readily to form low-lying *vlaktes* and hilly terrain at the base of the Escarpment near Graaff-Reinet and extensive exposures of fresh (unweathered) bedrock are rare.

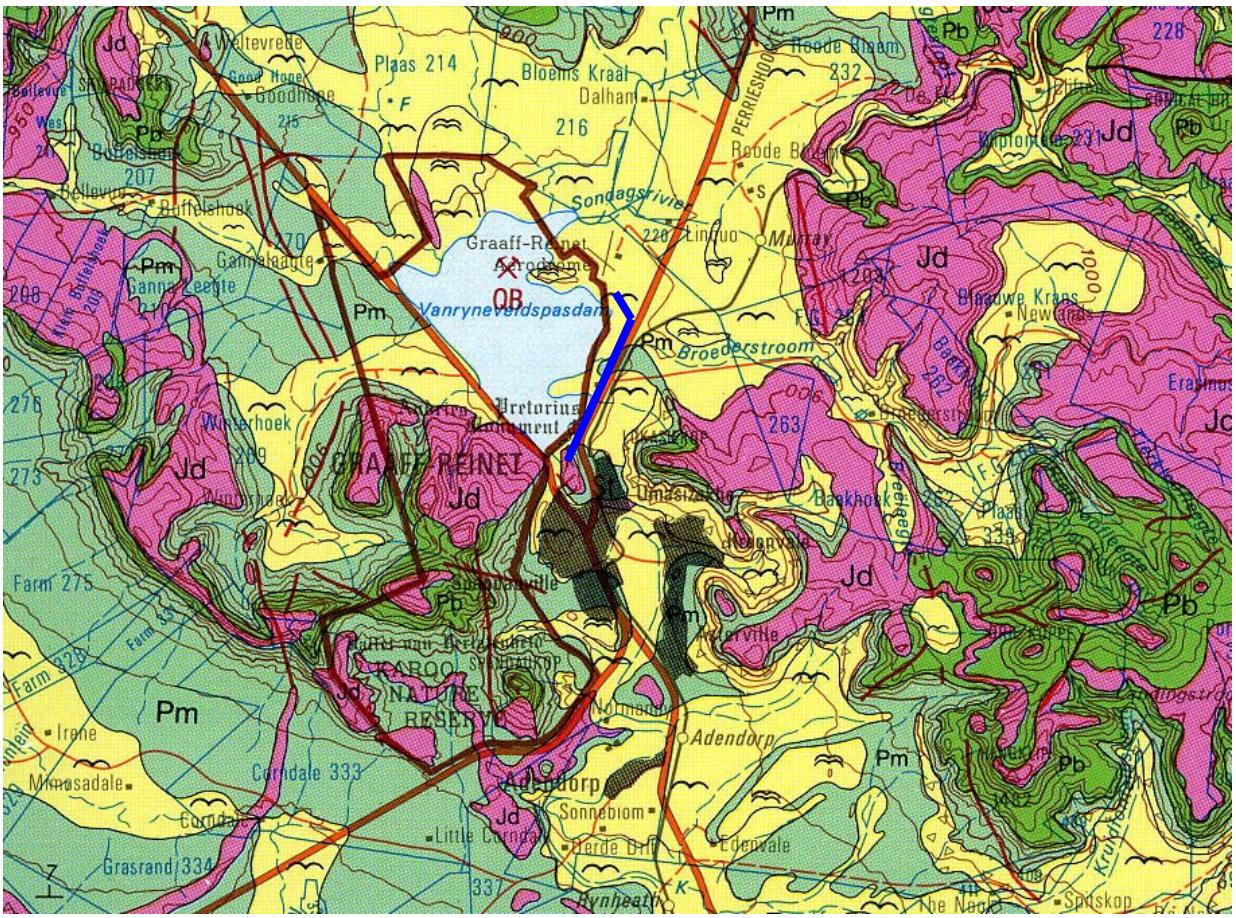

Fig. 2. Extract from 1: 250 000 geological sheet 3224 Graaff-Reinet (Council for Geoscience, Pretoria) showing geology of the study area around Graaff-Reinet, Eastern Cape. The proposed new pipeline route is indicated by the blue line.

Major geological units:

Pm (blue-green) = Middleton Formation Pb (middle green) = Balfour Formation Jd (pink) = Jurassic dolerite intrusions Yellow = Caenozoic alluvium of the Sundays River and its tributaries. The map distinguishes between finer alluvium (single "bird" symbol) and terrace gravels and calcrete (double "bird" symbol). QB in the Vanrhyneveldpas Dam area refers to quarrying for building sand.

3.2. Karoo Dolerite Suite (Jd)

Igneous intrusions intruding the Beaufort Group in the vicinity of the Great Escarpment are referred to the Karoo Dolerite Suite of Early Jurassic age (*c*. 182 Ma; Duncan & Marsh 2006). Concordant dolerite sills typically occur just above the base of the Balfour Formation (Oudeberg Member) in the Graaff-Reinet sheet area (Hill 1993), but also penetrate down into the Middleton Formation. Thermal metamorphism of the Beaufort country rocks resulted in the transformation of mudrock to hornfels and sandstone to quartzite in the vicinity of the larger intrusions. This probably applies to the small area of Middleton Formation sediments in the reservoir area at the southern end of the proposed pipeline route.

3.3. Caenozoic superficial deposits ("drift")

Various types of superficial deposits ("drift") of Late Caenozoic (Miocene / Pliocene to Recent) age occur widely throughout the Great Karoo study region. They include pedocretes (*e.g.*.calcretes),

colluvial slope deposits (dolerite scree *etc*), river alluvium, as well as spring and pan sediments (Hill 1993*,* Partridge *et al*. 2006). As a result, surface exposure of fresh Beaufort Group rocks within the development region is generally poor, apart from stream beds, dongas and steeper hill slopes and artificial exposures in road and railway cuttings. The hill slopes are typically mantled with a thin layer of colluvium or slope deposits (*e.g.* sandstone and / or dolerite scree). Thicker accumulations of sandy, gravelly and bouldery alluvium of Late Caenozoic age (< 5Ma) are found in stream and river beds, notably adjacent to the Sundays River and its various tributaries that converge in the low-lying area surrounding the Vanryneveldspas Dam north of Graaff-Reinet. These colluvial and alluvial deposits may be extensively calcretised (*i.e.* cemented with soil limestone or calcrete), especially in the neighbourhood of dolerite intrusions. Reddish alluvial fans spreading westwards from dolerite-capped koppies northeast of Graaff-Reinet towards the pipeline route should include a high percentage of dolerite clasts and are probably extensively calcretized. Small patches of older terrace gravels - probably Late Neogene to Pleistocene in age - that are probably calcretised in part are mapped just north of the Vanryneveldpas Dam and the Broederstroom, just northwest of the pipeline route, but are not directly affected by the proposed development.

4. PALAEONTOLOGICAL HERITAGE

The known fossil heritage recorded within the main sedimentary rock units within the study area is outlined in this section of the report.

4.1. Fossil heritage within the Lower Beaufort Group

The overall palaeontological sensitivity of the Beaufort Group sediments is high (Rubidge 1995 and 2005, Nicolas 2007, Almond *et al*. 2008). These continental sediments have yielded one of the richest fossil records of land-dwelling plants and animals of Permo-Triassic age anywhere in the world. A chronological series of mappable fossil biozones or assemblage zones (AZ), defined mainly on their characteristic tetrapod faunas, has been established for the Main Karoo Basin of South Africa (Rubidge 1995, Nicolas 2007). Maps showing the distribution of the Beaufort assemblage zones within the Main Karoo Basin have been provided by Kitching (1977), Keyser and Smith (1979), Rubidge (1995), and Nicolas (2007). For the Graaff-Reinet sheet area they are available in Hill (1993).

The Middleton Formation comprises portions of three successive Beaufort Group fossil assemblage zones (AZ) that are largely based on the occurrence of specific genera and species of fossil therapsids. These are, in order of decreasing age, the *Pristerognathus*, *Tropidostoma* and *Cistecephalus* Assemblage Zones (Rubidge 1995). The three biozones have been assigned to the Wuchiapingian Stage of the Late Permian Period, with an approximate age range of 260-254 million years (Rubidge 2005). Recent, but as yet unpublished, radiometric dates from the *Cistecephalus* AZ assign a Wuchiapingian age (256.6 – 255.2Ma) age to this unit (Rubidge *et al.* 2010). According to published maps showing the distribution of the Beaufort assemblage zones within the Main Karoo Basin (Keyser & Smith 1977-78, Hill 1993, Rubidge 1995, Nicolas & Rubidge in press), the uppermost Middleton Formation succession in the Graaff-Reinet area lies within the ***Cistecephalus* Assemblage Zone** (= upper *Cistecephalus* Biozone or *Aulacephalodon-Cistecephalus* Assemblage Zone of earlier authors). Authoritative lists of vertebrate genera and species recorded so far from the *Cistecephalus* Assemblage Zone are given by Smith and Keyser (1995).

The following major categories of fossils might be expected within *Cistecephalus* AZ sediments in the study area (Kitching 1977, Keyser & Smith 1977-78, Anderson & Anderson 1985, Hill 1993, Smith & Keyser *in* Rubidge 1995, MacRae 1999, Cole *et al*., 2004, Almond *et al*. 2008, Nicolas & Rubidge 2010) (See also Fig. 3 herein):

- isolated petrified bones as well as rare articulated skeletons of **terrestrial vertebrates** such as true **reptiles** (notably large herbivorous pareiasaurs, small insectivorous owenettids) and **therapsids** or "mammal-like reptiles" (*e.g.* diverse herbivorous dicynodonts, flesh-eating gorgonopsians, and insectivorous therocephalians)

- aquatic vertebrates such as large **temnospondyl amphibians** (*Rhinesuchus*, usually disarticulated), and **palaeoniscoid bony fish** (*Atherstonia*, *Namaichthys*; these are often represented by scattered scales rather than intact fish)

- freshwater **bivalves** (*Palaeomutela*)

- **trace fossils** such as worm, arthropod and tetrapod burrows and trackways, coprolites (fossil droppings), plant roots

- **vascular plant remains** including leaves, twigs, roots and silicified woods ("*Dadoxylon*") of the *Glossopteris* Flora, especially glossopterid trees and arthrophytes (horsetails). Plant remains are usually sparse and fragmentary.

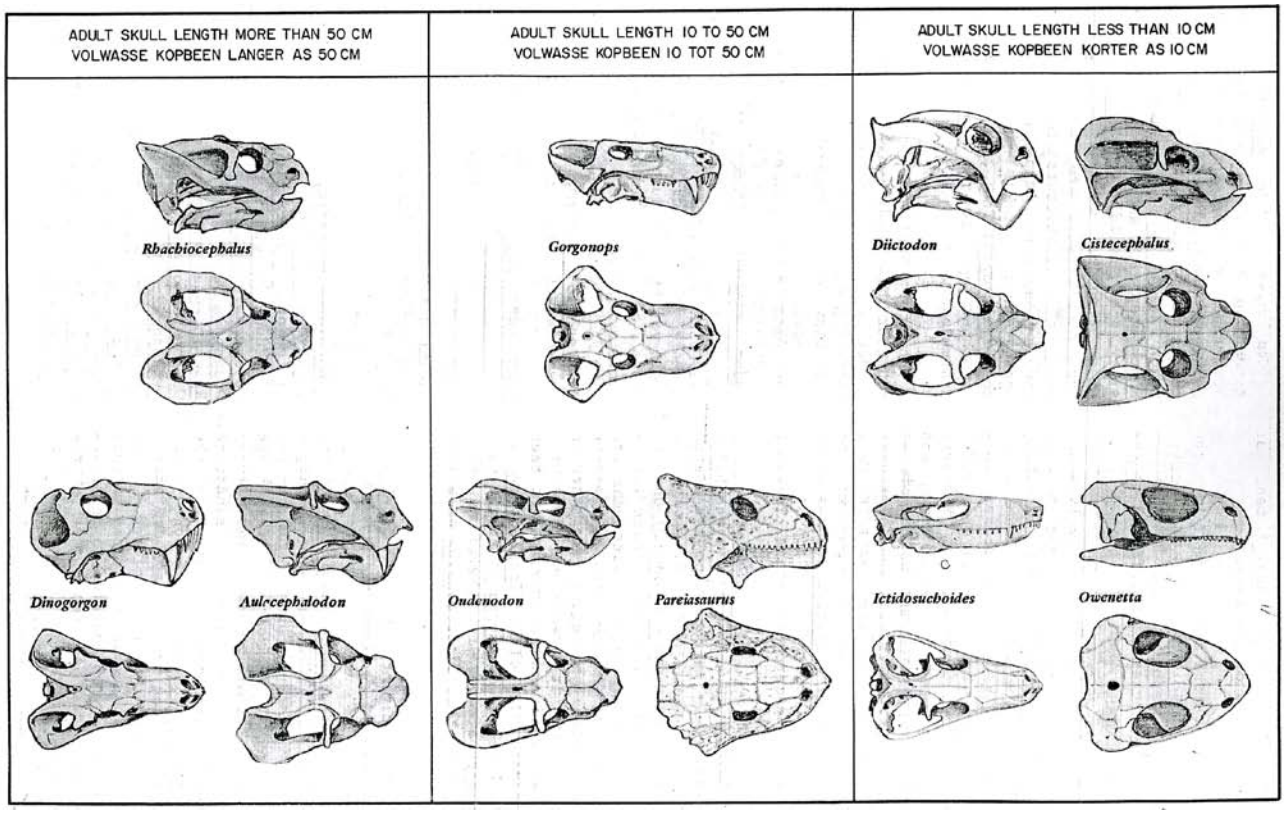

Fig. 3. Skulls of characteristic fossil vertebrates from the *Cistecephalus* Assemblage Zone (From Keyser & Smith 1977-78). *Pareiasaurus,* a large herbivore, and *Owenetta*, a small insectivore, are true reptiles. The remainder are therapsids or "mammal-like reptiles". Of these, *Gorgonops* and *Dinogorgon* are large flesh-eating gorgonopsians, *Ictidosuchoides* is an insectivorous therocephalian, while the remainder are small to large-bodied herbivorous dicynodonts.

As far as the biostratigraphically important tetrapod remains are concerned, the best fossil material is generally found within overbank mudrocks. In contrast, fossils preserved within channel sandstones (*e.g.* channel lag breccio-conglomerates of reworked mudflakes and calcrete nodules) tend to be fragmentary and water-worn (Smith & Keyser 1995, Smith 1993). Many fossils are found in association with ancient soils (palaeosol horizons) that can usually be recognised by

bedding-parallel concentrations of calcrete nodules. The fossil bones are isolated and disarticulated for the most part, and are typically permineralised and encrusted in a mantle of calcrete (often brown-weathering). Fossil bone embedded in mudrocks adjacent to major dolerite intrusions may be modified by thermal metamorphism; for example, bones in the Graaff-Reinet District may acquire a smooth, white "porcellanite" pallor, while bones recorded near Bedford, just east of the study area, may be black (Smith & Keyser 1995). The dolerite intrusions themselves are unfossiliferous.

4.2. Fossil heritage within the superficial deposits ('drift')

Karoo drift deposits have been comparatively neglected in palaeontological terms for the most part. However, they may occasionally contain important fossil biotas, notably the bones, teeth and horn cores of mammals (*e.g.* Skead 1980, Klein 1984, MacRae 1999, Partridge & Scott 2000). Other late Caenozoic fossil biotas from these superficial deposits include non-marine molluscs (bivalves, gastropods, rhizoliths), ostrich egg shells, trace fossils (*e.g.* calcretised termitaria, coprolites), and plant remains such as peats or palynomorphs (pollens) in organic-rich alluvial horizons.

5. CONCLUSIONS & RECOMMENDATIONS

The proposed upgrade of the water supply to Graaff-Reinet will probably have a very low impact on local fossil heritage for the following reasons:

- The greater part of the proposed pipeline route will be underlain by Late Caenozoic superficial sediments (*e.g.* river alluvium) of low palaeontological sensitivity;
- Potentially fossiliferous bedrocks of the Lower Beaufort Group at the southern end of the pipeline have probably been baked by adjacent igneous intrusions, compromising their fossil heritage;
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Specialist palaeontological mitigation of this development is therefore not considered necessary.

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6. ACKNOWLEDGEMENTS

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8. QUALIFICATIONS & EXPERIENCE OF THE AUTHOR

Dr John Almond has an Honours Degree in Natural Sciences (Zoology) as well as a PhD in Palaeontology from the University of Cambridge, UK. He has been awarded post-doctoral research fellowships at Cambridge University and in Germany, and has carried out palaeontological research in Europe, North America, the Middle East as well as North and South Africa. For eight years he was a scientific officer (palaeontologist) for the Geological Survey / Council for Geoscience in the RSA. His current palaeontological research focuses on fossil record of the Precambrian - Cambrian boundary and the Cape Supergroup of South Africa. He has recently written palaeontological reviews for several 1: 250 000 geological maps published by the Council for Geoscience and has contributed educational material on fossils and evolution for new school textbooks in the RSA.

Since 2002 Dr Almond has also carried out palaeontological impact assessments for developments and conservation areas in the Western, Eastern and Northern Cape under the aegis of his Cape Town-based company *Natura Viva* cc. He is a long-standing member of the Archaeology, Palaeontology and Meteorites Committee for Heritage Western Cape (HWC) and an advisor on palaeontological conservation and management issues for the Palaeontological Society of South Africa (PSSA), HWC and SAHRA. He is currently compiling technical reports on the provincial palaeontological heritage of Western, Northern and Eastern Cape for SAHRA and HWC. Dr Almond is an accredited member of PSSA and APHAP (Association of Professional Heritage Assessment Practitioners – Western Cape).

Declaration of Independence

I, John E. Almond, declare that I am an independent consultant and have no business, financial, personal or other interest in the proposed project, application or appeal in respect of which I was appointed other than fair remuneration for work performed in connection with the activity, application or appeal. There are no circumstances that compromise the objectivity of my performing such work.

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