Google Earth, GIS, and the Great Divide: a new and simple method for sharing paleontological data.

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Abstract:

Introduction

The ease, efficiency, and speed of data communication and analyses are paramount to, and characteristic of, any mature science. GIS is an extraordinarily powerful tool for many aspects of (geo)spatial analyses (Longley et al., 2001), but while used routinely to solve complex spatial analyses problems in many disciplines, its adoption within paleontology has been lagging (Conroy, 2006). Part of the problem is that (a) GIS software is expensive (usually prohibitively so to the individual paleontological researcher) and (b) very few paleontologists are trained in its use. Here we show how paleontological data can be easily displayed and communicated in ways never before possible by combining Google Earth and Geographic Information Systems (GIS). Using paleontological field data, we demonstrate several examples that go far beyond the novelty of simply "find my house" that many Google Earth users are currently familiar with. Specifically, we show how GIS map layers of paleontological interest, including their associated attribute tables (e.g., field catalog data), can be freely and easily transmitted to anyone with Internet access and familiarity with Google Earth. Data organized in GIS layers can be exported to the keyhole mark-up language native to Google Earth (KML/KMZ), transmitted to colleagues (who may have no knowledge of or access to GIS) as an email attachment, and then simply "dragged and dropped" by the recipient onto their own desktop Google Earth display, where the map layers appear "draped" over the Google Earth landscape. The recipient has access to all the graphics and attributes of each map layer that has been exported from GIS as well as to all Google Earth tools [e.g., ability to adjust map layer transparencies, labeling, longitude/latitude (or UTM determinations), spatial measurements, and "tilting" of landscapes for enhanced 3D views]. These tools are often sufficient to allow the non-GIS user to obtain specific information of interest from the data.

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The Great Divide Basin

We have chosen to illustrate the power and ease of this process by using data derived from The Great Divide Basin Project currently underway by R.L. Anemone and colleagues (Anemone et al., 2007). The Great Divide Basin is a large (ca. 4,000 square miles) sedimentary basin in southwestern Wyoming that forms the northeastern part of a much larger high altitude desert basin known as the Greater Green River Basin (Fig. 1). Structurally, the Great Divide Basin is a syncline with well over a thousand meters of mostly flat-lying sedimentary rocks of the Paleocene Fort Union Formation and the Eocene Wasatch, Green River, and Bridger formations overlying Cretaceous rocks of the Mesa Verde Group. The Great Divide Basin is bounded on the north by the Wind River Mountains, on the east by the Rawlins Uplift, on the south by Interstate 80 and the Wamsutter Arch, and on the west by the Rock Springs Uplift. The basin's name derives from the fact that it is encircled by the Continental Divide. The Great Divide is, thus, an

internal drainage basin, unlike some of the better-known sedimentary basins of Wyoming (e.g., Bighorn, Wind River, and Powder River basins), which are drained by rivers and streams and which, as a result, tend to have a greater proportion of water-eroded badlands. Average elevation is well over 6,000 ft, with some buttes reaching above 9,000 ft. Badland deposits of fossiliferous sedimentary rocks of Paleocene and Eocene age are scattered throughout the basin where the proper combination of relief and erosion have exposed them today. Geological and paleontological work in the Great Divide Basin has been intermittent and less extensive than in other Tertiary basins of the Rocky Mountain interior. Although first mentioned in the late nineteenth century western explorations of the Hayden and King surveys (King, 1877, Endlich, 1879 and Hayden, 1883), significant geological work in the Great Divide Basin did not commence until the beginning of the twentieth century. The most significant recent contributions to stratigraphic and sedimentological analyses of Paleocene and Eocene sediments in the Greater Green River Basin (including important studies within the Great Divide Basin) have been those of USGS geologist H.W. Roehler, who has documented and mapped the complex intertonguing relationships of the Green River and Wasatch formations throughout the Greater Green River Basin, in the process mapping more than 60% of the basin and describing more than half a million feet of Eocene deposits (Roehler, 1992a and Roehler, 1992b).
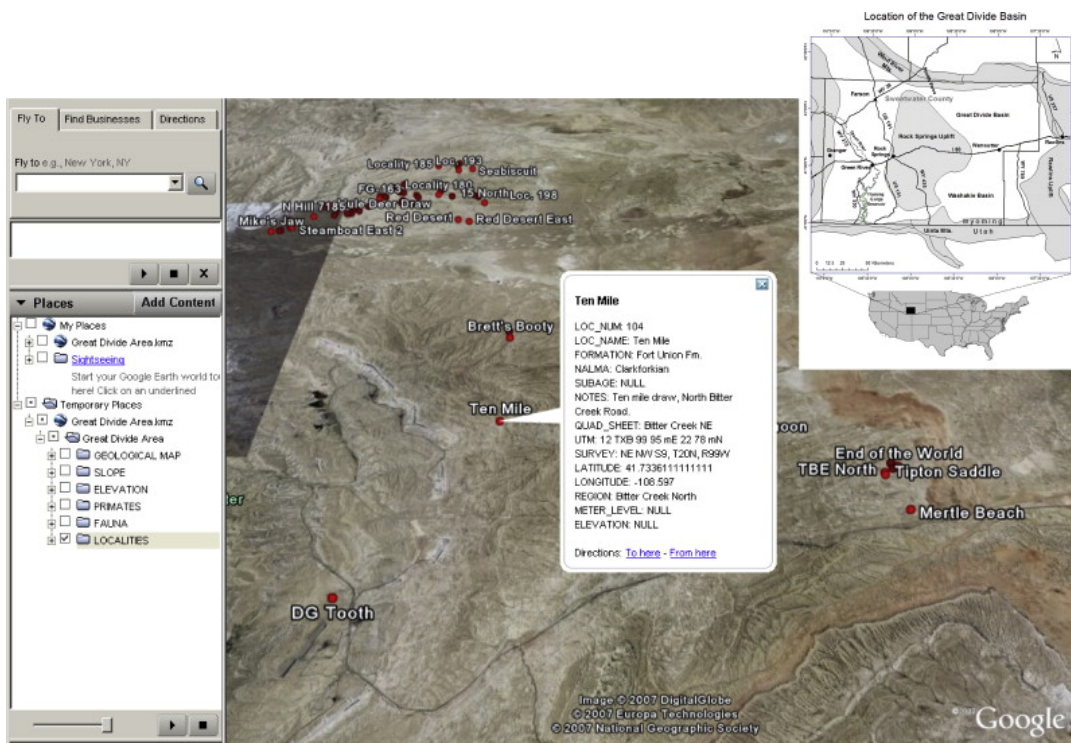

Fig. 1.

Great Divide Basin fossil LOCALITIES with field catalog data about locality "Ten Mile" displayed. Insert: Great Divide Basin.

In terms of its vertebrate paleontological resources, the Great Divide basin has historically been understudied and its ability to provide evidence about the evolution of early Tertiary mammals has been consistently underestimated. C.L. Gazin from the Smithsonian Institution's National Museum of Natural History was the first paleontologist to publish on the mammals of the Great Divide Basin (Gazin, 1952, Gazin, 1962 and Gazin, 1965). In a series of publications, he identified typical Wasatchian faunas from several localities within the Great Divide Basin, two of which (Tipton Buttes and Red Desert) were located and first collected by the USGS geologist George Pipiringos, 1955 and Pipiringos, 1961. After Gazin's several field seasons in the Great Divide in the late 1950s and early 1960s, and except for intermittent work by McGrew and others (McGrew, 1951, McGrew, 1971 and McGrew and Roehler, 1960), the Great Divide basin was not systematically or seriously prospected for mammalian fossils until 1994, when one of the authors (RLA) began a long-term project there. Anemone's Great Divide Basin Project has collected and catalogued approximately 7,000 mammalian fossils currently housed in the Department of Anthropology at Western Michigan University (the permanent repository for these fossils is the Carnegie Museum of Natural History). The fossils come from roughly 75 localities in deposits of the Wasatch, Green River, and Fort Union formations and can be dated biostratigraphically to both sides of the Paleocene-Eocene boundary (55 mya). Primates comprise nearly 10% of the mammals, approximately 400 of which are euprimates (e.g., Cantius abditus, Cantius frugivorous, Cantius trigonodus, Copelemur feretutus, Copelemur praetutus, Steinius vespertinus, Anemorhysis sp., and Absarokius abbotti) and another 250 representing plesiadapiforms (including Plesiadapis cookie, Plesiadapis dubius, Carpolestes nigridens, Microsyops angustidens, Chiromyoides major, Phenacolemur jepseni, and Phenacolemur pagei).

Methods

From the Great Divide Basin field catalog data, six map layers were created in ArcGIS (v.9.2; for interested readers, see Gorr and Kurland, 2005, for a step by step tutorial on how to create GIS map layers): (1) LOCALITIES (longitude and latitude of each fossil locality); (2) FAUNA (faunal list from each fossil locality including taxonomic and skeletal identification information); (3) PRIMATES (localities yielding primates, including taxonomic and skeletal identification information); (4) ELEVATION (30 m digital elevation models (DEMs) of the region accessed through the USGS National Elevation Dataset (available online at: http://ned.usgs.gov); (5) SLOPE (landscape slope, in degrees, derived from the DEMs); and (6) GEOLOGICAL MAP (1:500,000 scale geologic map of the region accessed through the USGS and the Wyoming GIS Center (available online at: http://www.sdvc.uwyo.edu). Using simple drop-down commands in ArcToolbox (ArcToolbox > 3D Analyst Tools > Conversion > To KML > Layer to KML), each of these layers was converted and saved into a Keyhole Markup Language (KML) file and then compressed using zip compression. This resulted in six files, each having a ".KMZ" extension which could be read by any KML client, including Google Earth.

In this format, each of these KML layer files can be sent as an email attachment to any interested party. Upon receiving such an attachment, all the recipient has to do is open their own version of Google Earth (v. 4.2; Google Inc., 2007; available online at: http://earth.google.com/) and then simply "drag and drop" the attached file onto their own Google Earth display. The map layers immediately appear draped over the Google Earth landscape. In addition, each layer can be turned on/off and rendered more/less transparent (using Google Earth tools) to reveal underlying map layers. The underlying data base (attribute table), or field catalog information in this case, is available in the Google Earth display as well. All of Google Earth's built-in tools—for example "tilting" of the landscape for better three-dimensional viewing, geographic coordinate data for each locality, and distance measurements between localities—are functional and automatic.

The "drag and drop" files initially appear under "Temporary Places" in the recipient's Google Earth display and can be moved by the user into "My Places" for permanent display at any time. The steps below were used to create Fig. 1, Fig. 2, Fig. 3, Fig. 4 and Fig. 5.
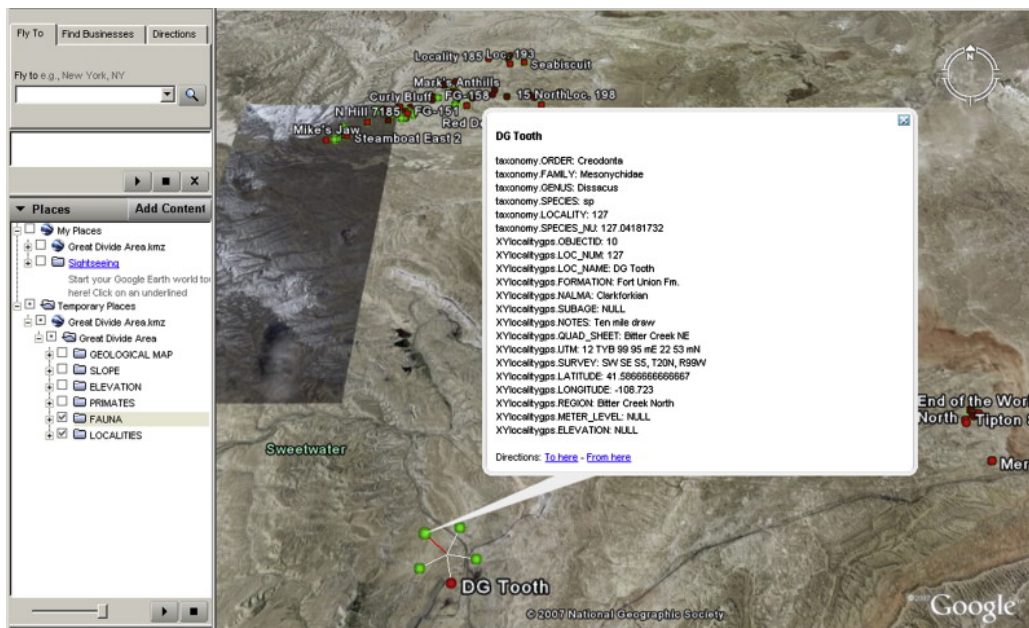

Fig. 2.

Starburst where green "balloons" provide field catalog data for each fossil specimen from locality DG Tooth and red "balloon" provides site data as in Fig. 1.
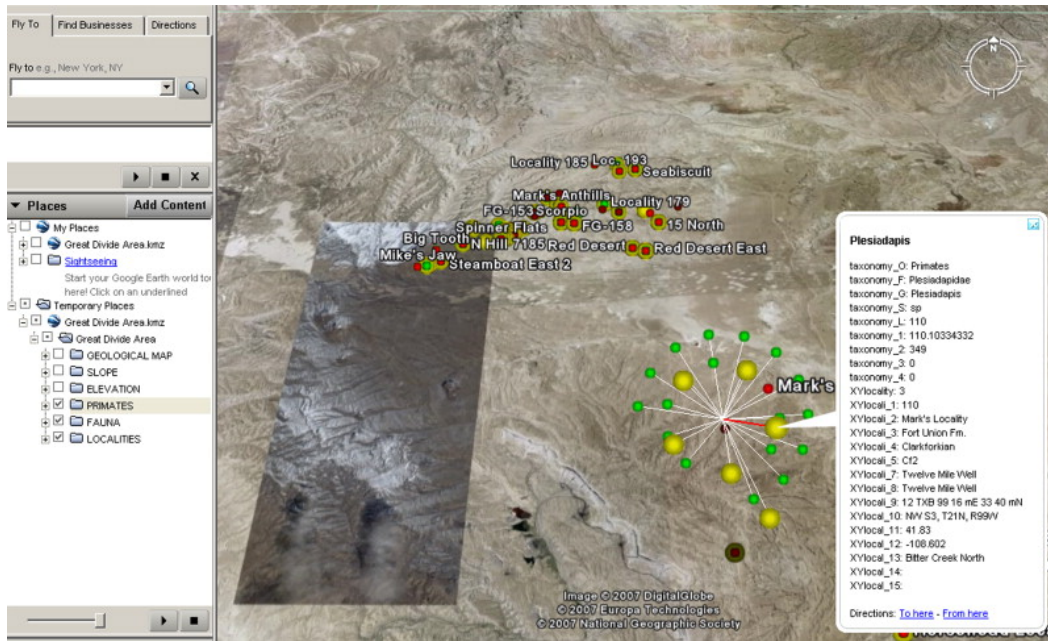
Fig. 3.

Starburst where yellow "balloons" provide field catalog data for each fossil primate from Mark's Locality, green "balloons" provide field catalog data for other fossils from the site, and the red "balloon" provides field catalog data for the site.
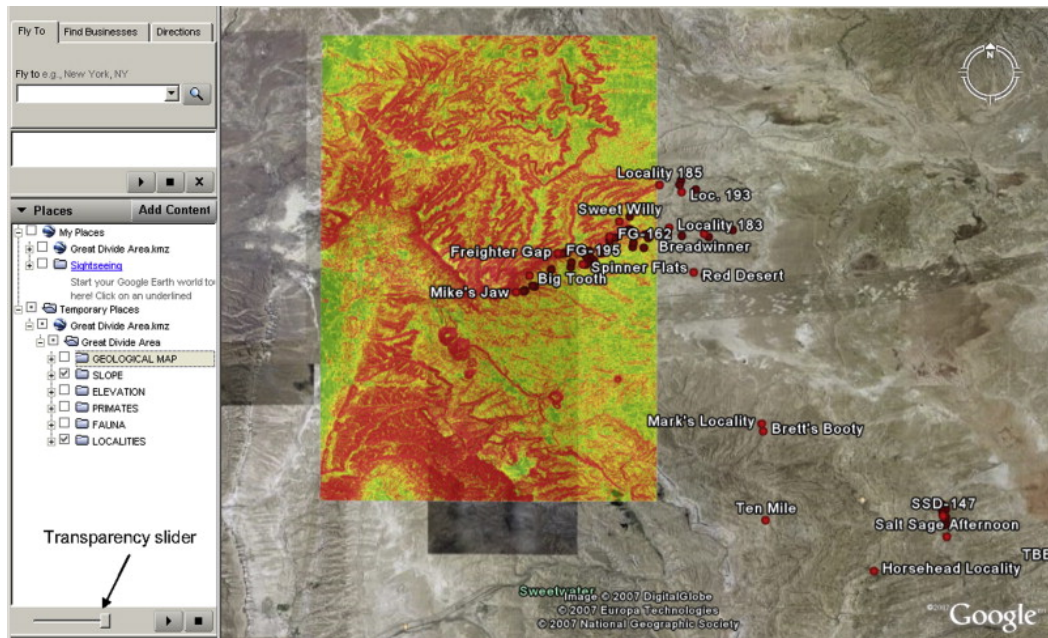

Fig. 4.

SLOPE (in degrees) draped over fossil area with steeper slopes color coded red and gentler slopes color coded green. Slope color key can be cut and pasted over display and transparency slider can be adjusted to "see through" slope layer to visualize underlying layers.
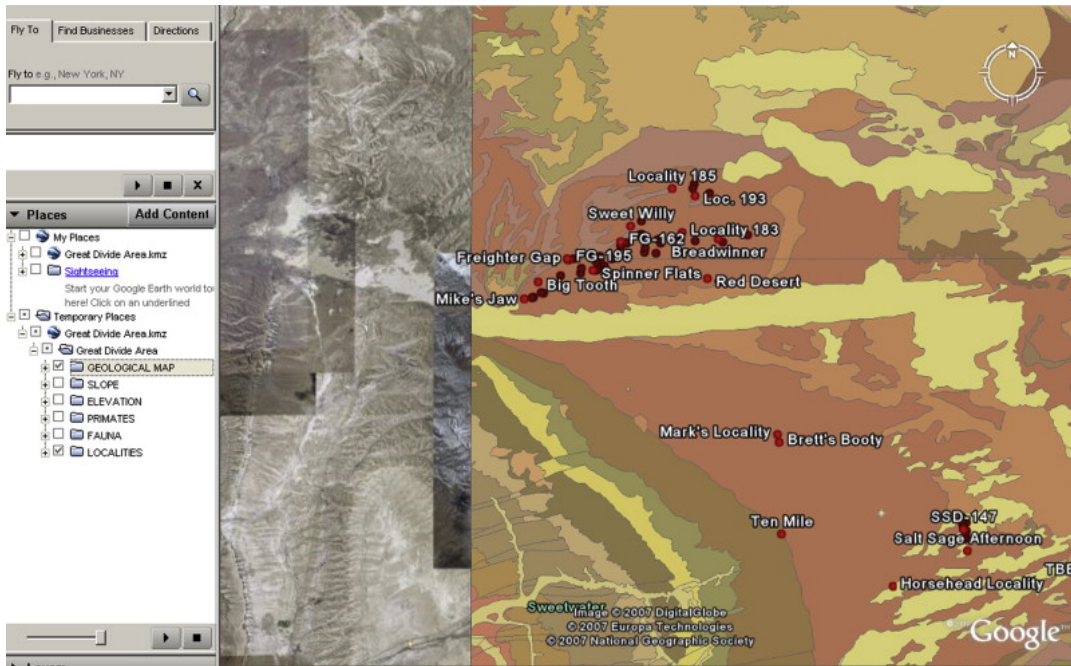

Fig. 5.

GEOLOGICAL MAP draped over fossiliferous area. Transparency slider can be used to "see through" map layer.

A specific example1

After "dragging and dropping" the .KMZ files into Google Earth, the recipient first selects the "LOCALITIES" layer. All fossil localities are displayed and labeled with a red "balloon". Clicking on each red "balloon" automatically displays all the available field catalog information about that site (Fig. 1). Second, the "FAUNA" layer is selected (green "balloons" appear over each of the red "balloons" for which there is faunal information). Clicking on each green/red "balloon" brings up a starburst of lines—clicking on the line leading to the red "balloon" gives fossil site information (as in step 1 above), while clicking on those leading to each green "balloon" gives information about every fossil specimen from that site that is recorded in the field catalog (Fig. 2). All this information can also be found by expanding the layers in Google Earth's table of contents. Third, the "PRIMATES" layer is turned on ("FAUNA" is turned off). This results in another starburst with the red "balloons" again providing locality data and the yellow "balloons" providing field catalog data about every fossil primate from that locality (Fig. 3). If one keeps the "FAUNA" layer turned on, the starburst will consist of red, green, and

yellow "balloons" denoting locality data, faunal data, and primate data, respectively. Finally, opening the SLOPE (Fig. 4), GEOLOGICAL MAP (Fig. 5), and ELEVATION layers (not shown), drape each of these layers over the landscape. The transparency slider in Google Earth can be used to change the transparency of any of these layers so that underlying layers can still be seen.

Conclusion

Here we show that map layers of paleontological interest, originally created in ArcGIS, can be shared with colleagues having no experience with or access to GIS as simply and easily as sending an email attachment. All that is required is access to the Web and Google Earth. Google Earth, as a powerful and freely downloadable geographic visualization tool, is accessed daily by millions of users worldwide. This opens up enormous possibilities for the free and easy dissemination of paleontological information in a visually meaningful and stimulating way to students, colleagues, and the interested general public around the world.

References

R.L. Anemone, W. Dirks, R. Watkins, B. Nachman, J. Van Regenmorter. A late Wasatchian mammalian fauna from the Steamboat Mountain-Freighter Gap area, Great Divide Basin, southwestern Wyoming. J. Vert. Paleontol., 27 (2007), p. 40A

G.C. Conroy. Creating, displaying, and querying interactive paleoanthropological maps using GIS: an example from the Uinta Basin, Utah. Evol. Anthropol., 15 (2006), pp. 217–223

Endlich, F., 1879. Report on the geology of the Sweetwater district. In: Hayden, F. (Ed.), Report on the Geology of the Sweetwater District. Washington, D.C., pp. 5–158.

C. Gazin. The lower Eocene Knight formation of western Wyoming and its mammalian faunas. Smithson. Misc. Collect., 117 (1952), pp. 1–82

C. Gazin. A further study of the lower Eocene mammalian faunas of southwestern Wyoming. Smithson. Misc. Collect., 144 (1962), pp. 1–98

Gazin, C., 1965. Early Eocene mammalian faunas and their environment in the vicinity of the Rock Springs Uplift, Wyoming. In: 19th Field Conference: Sedimentation of Late Cretaceous and Tertiary Outcrops, Rock Springs Uplift, pp. 171–180.

Google Inc. Google KML 2.1. Available from: http://code.google.com/apis/kml/documentation/kml_tags_21.html (2007) (accessed 20.08.07)

W. Gorr, K. Kurland. GIS Tutorial: Workbook for ArcView 9. ESRI Press, Redlands (2005)

Hayden, F., 1883. 12th annual report of the US geological and geographical survey of the territories: a report of progress of the exploration in Wyoming and Idaho for the year 1878. Washington, D.C.

King, C., 1877. Report of the geological exploration of the 40th Parallel. Professional Papers of the Engineer Dept., U.S. Army 2, 890.

Longley et al., 2001. P. Longley, M. Goodchild, D. Maguire, D. Rhind. Geographic Information Systems and Science. Wiley, New York (2001)

McGrew, P., 1951. Tertiary stratigraphy and paleontology of southcentral Wyoming. Wyoming Geological Association Guidebook 6th Annual Field Conference 54–57.

P. McGrew. Early and middle Eocene faunas of the Green River Basin. Rocky Mt. Geol., 10 (1971), pp. 65–68

McGrew, P., Roehler, H., 1960. Correlation of Tertiary units in southwestern Wyoming. Wyoming Geological Association Guidebook. In: 15th Annual Field Conference 15, 1586.

Pipiringos, G.N., 1955. Tertiary rocks in the central part of the Great Divide basin, Sweetwater County, Wyoming. Wyoming Geological Association Guidebook 10th Annual Field Conference.

G.N. Pipiringos. Uranium-bearing coal in the central part of the Great Divide Basin. U.S. Geol. Surv. Bull., 1099A (1961), pp. 1–104

H.W. Roehler. Description and correlation of Eocene rocks in stratigraphic reference sections for the Green River and Washakie basins, southwest Wyoming. U.S. Geol. Surv. Prof. Paper, 1506D (1992), pp. 1–83

H.W. Roehler. Introduction to Greater Green River Basin geology, physiography, and history of investigations. U.S. Geol. Surv. Prof. Paper, 1506A (1992), pp. 1–14