TRANSACTIONS OF THE KANSAS ACADEMY OF SCIENCE
Vol. 121, no. 1-2
p. 103-110 (2018)

Upland chert gravel in the Emporia, Kansas vicinity: New exposures, observations, and stratigraphic review

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Upland chert gravel deposits are common on high terraces, hilltops, and drainage divides across much of southeastern and east-central Kansas. Recent building and landscaping excavations have revealed chert gravel in several parts of northwestern Emporia on or near the divide between the Neosho and Cottonwood drainage basins. Assuming a late Pliocene age for highest chert gravel yields an average incision rate of ~1.3 cm per 1000 years. Chert gravel is typically found on high terraces and drainage divides north of east-west flowing stream valleys and west of north-south trending streams, which suggests regional crustal tilting downward to the south and east as a plausible mechanism to explain this widespread valley asymmetry. Much confusion surrounds the stratigraphy of upland chert gravel deposits on a regional basis. Improved age information and reconstruction of paleodrainage would be necessary to establish stratigraphic relationships of upland chert gravel deposits among the various drainage basins.

INTRODUCTION

Upland chert gravel deposits are common on high terraces, hilltops, and drainage divides throughout southeastern and east-central Kansas. These gravels have been known since the nineteenth century, and many ideas regarding their depositional history have been given over the years. Such ideas include deposits of a marine submergence (West 1885), outwash drift of glacial origin (Mudge in Parker 1884; Wooster 1934), and residual accumulations on a peneplain (Haworth 1896; Wooster 1914). Todd (1918, p. 190) noted that *along all the streams flowing eastward from the cherty strata of the Permian there are conspicuous terraces capped with chert gravel. They are usually on the north side of the streams.*

O'Conner (1953) demonstrated alluvial stream deposits as the origin of these gravels, which were transported from Flint Hills sources. According to Frye (1955, p. 80), *deposits of rounded chert gravels which occur extensively on the high terraces and uplands throughout the Flint Hills and Osage Cuesta Plains region are the result of stream action and that the source of the gravels was to the west of their present point of deposition*. All subsequent investigators have accepted this explanation for upland chert gravels south of the glaciated region (Aber 1985, 1988, 1997). The most recent study is that by Merriam and Harbaugh (2004), who undertook a thorough review of upland chert gravels in the Osage Cuesta region of eastern and southeastern Kansas. They summarized known facts (adapted from Merriam and Harbaugh 2004, table 2).

- Source of chert is Lower Permian limestones of the Flint Hills.
- Clast color varies from pale to dark brown and pebbles may be set in a reddish clay matrix.
- Clast roundness increases and color becomes darker eastward from the Flint Hills.
- Thickness varies from <1 m to about 6 m maximum.
- Preserved deposits may be found at several elevation levels, in the range 6 to 60 m above modern floodplains.
- Deposits are situated along major river valleys as well as divides paralleling these streams.
- Quartzite and other exotic pebbles are present in some, but not all, upland chert gravels.

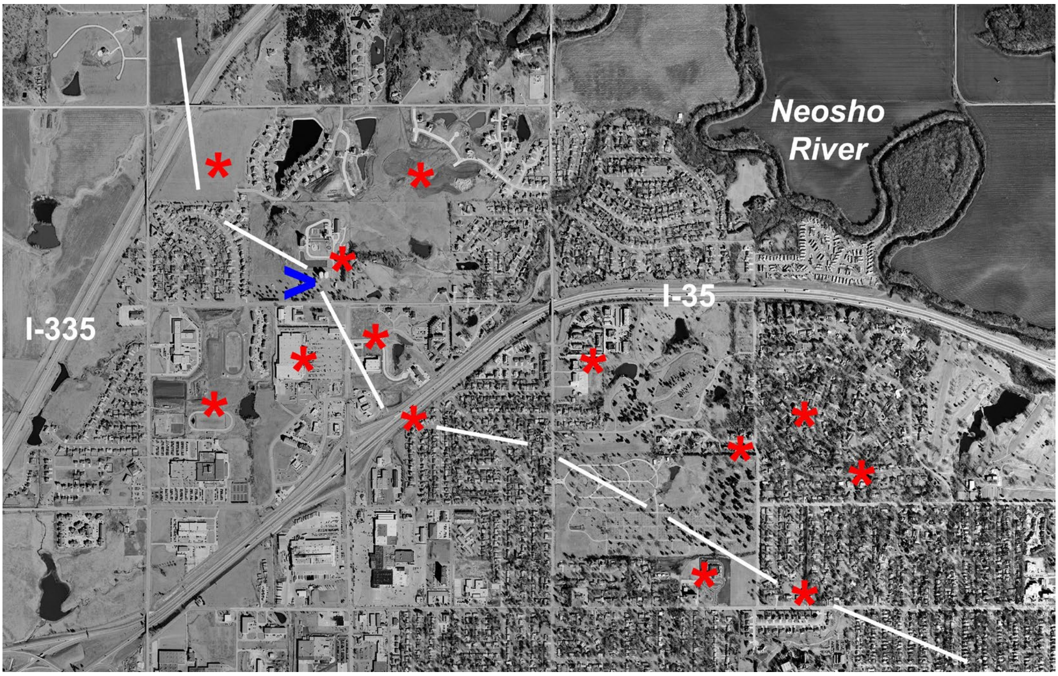

Figure 1. Upland chert gravel deposits in northwestern Emporia (red *), as indicated by the Olpe Series soil (Neill and Bell 1981). Dashed white line indicates approximate divide between the Neosho and Cottonwood drainage basins. Position of the water towers (blue >) shown in next figure. DOQ adapted from U.S. Geological Survey (USGS 2002).

Age of the chert gravel is considered to be Pliocene (Tertiary) and/or early to middle Pleistocene depending on topographic position and degree of weathering (Frye 1955; Merriam and Harbaugh 2004). Aber (1992) designated upland chert gravel deposits in the Walnut drainage basin as the Leon Gravel, a stratigraphic unit of formation rank. These deposits, on the western dip slope of the Flint Hills, were earlier noted by Bass (1929) and Frye (1955).

Chert gravel contains in many places rare pebbles of quartzite, granite, quartzose sandstone, and dark chert (Aber 1985, 1988, 1997). These exotic pebbles were derived from Ogallala-type alluvium in central and western Kansas and transported eastward across the Flint Hills by a through drainage. This eastward trunk drainage followed the present Missouri-Arkansas drainage divide and was later diverted southward (Frye 1955).

Emporia exposures

Hilltop chert gravel deposits are situated throughout the northwestern portion of Emporia, Kansas on or near the drainage divide between the Neosho and Cottonwood valleys (Figs. 1 and 2). Recent building and landscaping excavations have revealed chert gravel in this vicinity (Fig. 3). These exposures are typically short lived and soon are covered over by continued construction activity.

Chert gravel is typically ~½ m to 2 m thick, thoroughly leached, and oxidized; clay matrix displays moderate reddish-brown (10 R 4/6) color. The gravel rests on the Wood Siding Formation, which consists of poorly consolidated sandstone, siltstone, shale, and thin limestone beds. More than 60 quartzite and other exotic pebbles have been collected from Emporia exposures recently and during the past four decades (Fig. 4)

Figure 2. Overview toward the northwest showing distribution of upland chert gravel deposits (red*) in northwestern Emporia, Kansas. The water towers (left background) are located on a hill capped by chert gravel exactly on the divide between the Neosho and Cottonwood drainage basins (38° 25.635‘ N, 96° 13.064‘ W). Kite aerial photograph by the author and D. Leiker (2017).

Figure 3. Typical exposure of hilltop chert gravel in northwestern Emporia (38° 25.895’ N, 96° 12.882’ W). Gravel rests on weathered bedrock of the Wood Siding Formation. Note iron oxidation (reddish-brown) in the gravel and underlying bedrock. Photo by the author (2017).

Figure 4. Selected exotic pebbles collected from hilltop chert gravel deposits in northwestern Emporia. Largest specimen (upper left) is 7.3 cm long. Most are quartzite; pebble at lower left is granite.

Highest chert gravel exceeds 375 m (1220 feet) in elevation, and local topographic relief to the nearby Neosho River valley floodplain is >40 m. Assuming a late Pliocene age of 3 million years for the highest chert gravel deposits yields an average incision rate of ~1.3 cm per 1000 years. This is comparable with results of Dethier (2001) for stream incision during the past 600,000 years; he determined the average incision rate for the Neosho drainage basin is <5 cm per 1000 years.

Eastward from Emporia, the downstream gradient for the highest chert gravel deposits is ~1 m/km. The modern Neosho River valley gradient from Emporia to Neosho Rapids is ~0.95 m/km. This suggests local valley gradients have changed little during the past few million years, as previously remarked by Merriam and Harbaugh (2004). Since deposition of these gravels, however, the Cottonwood River has migrated southward a distance of at least 6.5 km (4 miles), as marked by a series of progressively lower and younger alluvial deposits and terraces, most noteably the Emporia terrace (Moore et al. 1951; O‘Conner 1953). This results in an average rate of lateral stream migration of ~2.2 m per 1000 years. These values suggest the rate of local southward stream migration is many times greater than the rate of vertical stream incision.

Regional upland chert gravel

Across east-central Kansas, these high-terrace and hilltop chert gravels correspond closely, in most cases, with the Olpe, Kenoma-Olpe, Olpe-Norge, or other Olpe soil complexes (Fig. 5; e.g. Penner et al. 1975). There are exceptions, however, in parts of the Flint Hills. In Chase and Morris counties, for example, high-terrace alluvial gravel is included in the Florence series, which represents residual (non-alluvial) chert deposits formed by in-place weathering of cherty limestone (Barker 1974; Neill 1974).

Many, but not all, upland gravel deposits are identified on current county geologic maps from the Kansas Geological Survey (KGS 2016). County geologic maps typically portray

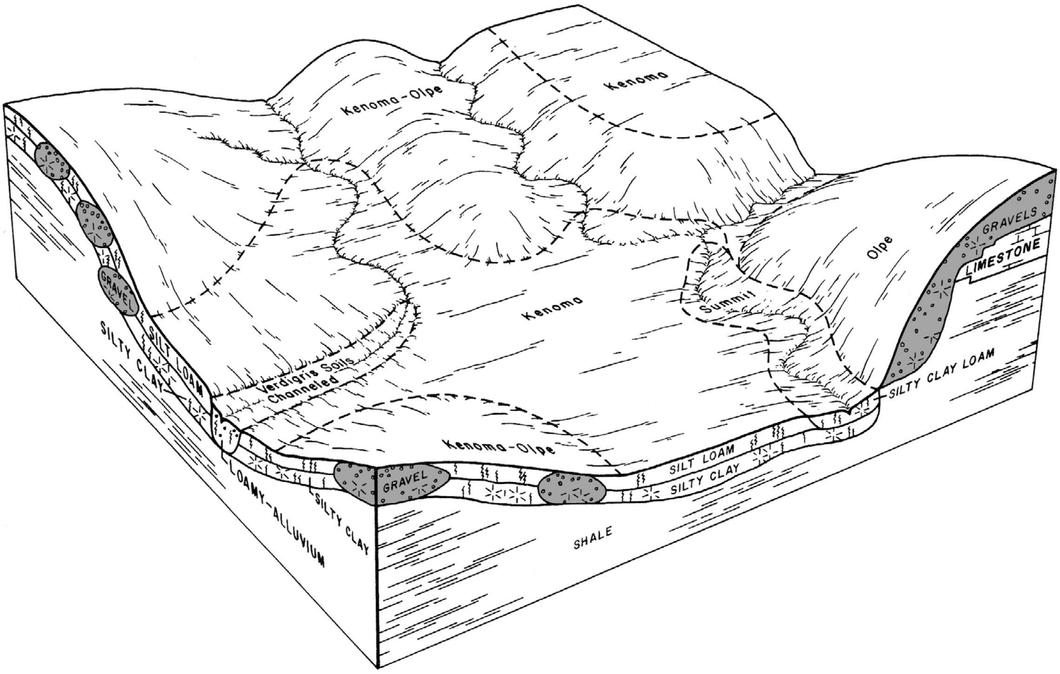

Figure 5. Schematic diagram showing typical positions of Olpe and Kenoma-Olpe soils in the landscape of Coffey County, east-central Kansas. Adapted from Swanson (1982, fig. 8).

only thicker and more-extensive upland chert gravel deposits. Many smaller or thinner occurrences are not included due to mapping criteria. Thus, distribution of upland and high-terrace alluvial chert gravel is more widespread than indicated by either existing soils or geologic maps.

In most cases, chert gravel is found on high terraces and drainage divides north of the valleys of east-west flowing streams, as for the Cottonwood River at Emporia, and west of north-south trending streams, as for the South Fork Cottonwood River valley in Chase County (Fig. 6). Merriam and Harbaugh (2004) considered possible causes such as asymmetry of tributaries, subtle regional tilting, or the Coriolis force. This is a widespread regional phenomenon, however, found along stream valleys regardless of stream flow direction and, thus, could not be explained by local tectonic or geomorphic processes. During long-term valley entrenchment, east-west streams have shifted southward, and north-south streams have shifted eastward. Regional crustal tilting downward to the south and east is a plausible mechanism for this widespread valley asymmetry (Aber 1997).

Upland chert gravel stratigraphy

Much confusion surrounds the stratigraphy of upland chert gravel. On several county geologic maps (KGS 2016), the formation unit Tg (Tertiary chert gravels) is depicted (e.g. Butler, Coffey, Greenwood, and Woodson). Other variants include QTg (Quaternary/ Tertiary chert gravel), as for Anderson County. In Lyon County, the equivalent formation is designated as Qth (Quaternary/Tertiary pre-Kansan), and for Osage County the map unit is TQ (Tertiary/Quaternary high terrace deposits). Also the symbol Ntd (Neogene terrace deposits) is utilized on some county maps (e.g. Allen, Neosho, and Wilson). In Chase County, low- and high-terrace gravel deposits are mapped together as Qt (Quaternary terrace). These variations reflect, in part, changing

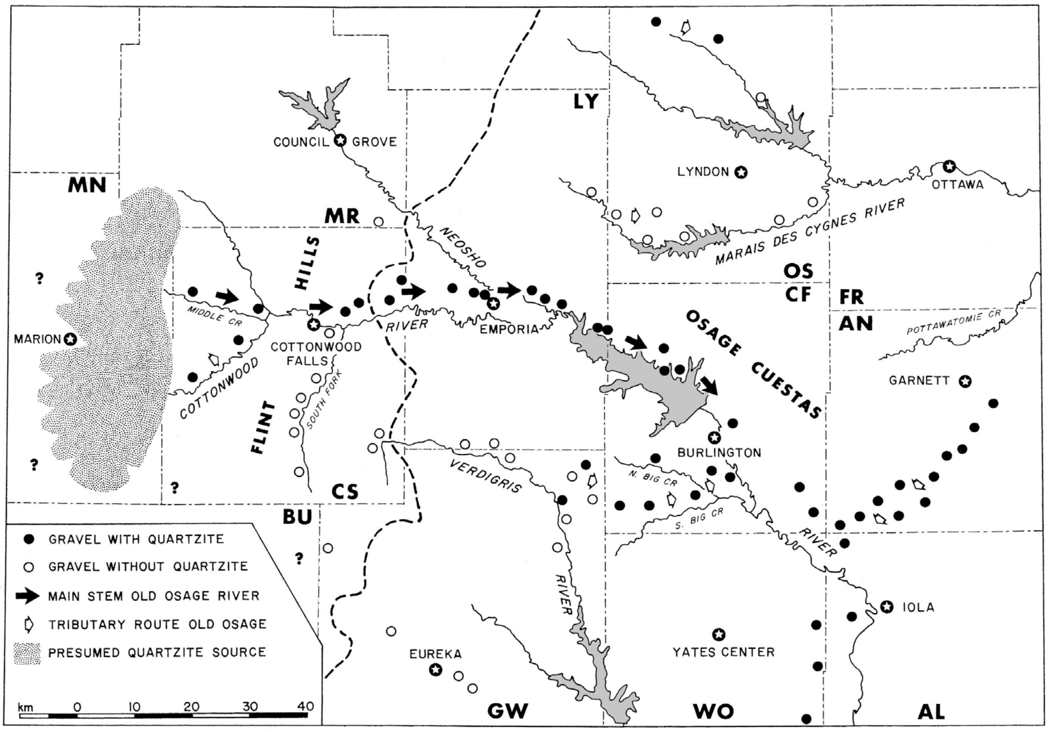

Figure 6. Distribution of upland chert gravel deposits across east-central Kansas. Representative sites are marked based on field identification as well as presence of Olpe soils. Quartzite and other exotic pebbles demonstrate drainage connections with sources in central and western Kansas. Dashed line indicates approximate boundary between the Flint Hills and Osage Cuestas; large reservoirs shown in gray. Adapted and updated from Aber (1988), and revised with data from Corley (2008).

stratigraphic terminology since the 1950s. Furthermore, these gravels are not included in the official stratigraphic nomenclature for Kansas (Zeller 1968; KGS 2013).

I earlier designated the Leon Gravel as a formation for upland chert gravel deposits in high-terrace, hilltop, and stream-divide positions in the Walnut drainage basin of Butler and Cowley counties (Aber 1992). The paleodrainage indicated by these gravels is largely parallel to modern streams flowing toward the west and south on the western dip slope of the Flint Hills. To the east of the Flint Hills, across the Verdigris, Neosho, and Marais des Cygnes drainage basins, upland chert gravel deposits display similar compositional characteristics, topographic positions relative to modern stream valleys, and presumed ages as the Leon Gravel. It seems probable, therefore, that all these gravels share a common alluvial genesis. Those gravels with exotic pebbles were deposited by through drainage systems from the west; whereas, those without exotics represent local stream deposits.

Whether the stratigraphic unit Leon Gravel should be expanded to include similar gravels in other drainage basins east of the Flint Hills remains an open question. More quantitative age information and reconstruction of paleodrainage would be necessary to establish stratigraphic relationships of upland chert gravel deposits among the various drainage basins.

Acknowledgments

Thanks to P. Johnston and T. Peterson for calling attention to new exposures of chert gravel in the Emporia vicinity and assisting with field observations in 2017. Two anonymous reviewers offered comments and suggestions for improving and focusing this article.

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