New Evidence on Cultural Relations in Northeastern Iran in the Parthian Period:

Results of Archaeological Excavations at Dibaj Damghan

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Archaeological research in Iran has devoted less attention to the northeastern part of the country than to other regions. However, northeastern Iran has been the location of important developments in human settlement from pre-history to the present. Although the Damghan region [Fig. 1] has been the location of significant historical events, in particular for the Parthian era we have lacked adequate data. Thus the results of research in the Dibaj Damghan area can help clarify issues regarding the material culture and the wider interactions of the region.

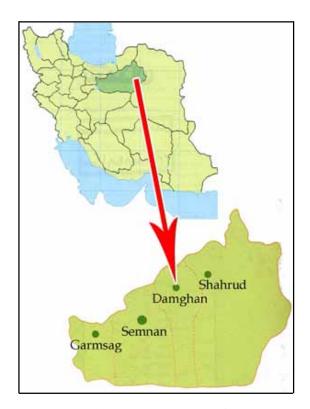


Fig. 1. Map showing the location of Damghan.

The Parthians were one of the tribes of the Dahi union who nomadized in the desert between the lower Oxus River (Amudarya) and the Caspian Sea. The Dahi interacted with the Massagets and other tribes which were immigrant or residing in villages of Central Asia (D'iakonov 1961/2001, p. 202; Schippmann 1980/2005, pp. 19-20). The word Parth has been confirmed in inscriptions of the early Sasanian dynasty. Local people used the Parthian language until the middle of the 4th century CE in southern Turkmenistan (including Margiana) and northeastern Iran (Media, Khorasan and Sistan) (Koshelenko et al. 1995, p. 55). Parthian expansion under Mithradates (Mehrdad) I (171-139 BCE) restored the ancient Achaemenid empire thus making the Parthians, as Ghirshman suggested, the connecting link between the Sasanian and Achaemenid dynasties (Clark 2007, pp. 439-46).

There is as yet no thorough archaeological investigation of the Parthian period of Iran's history (ca. 238 BCE to 226 CE). To date, the region to be discussed here, Dibaj Damghan, has seen limited excavations and archaeological survey which could contribute to a better understanding of the history of northeastern Iran. Not the least of the accomplishments of such work would be to illuminate the various artistic influences which shaped the material culture of the region. In excavations during 2008 and 2009, the author has added significantly to our knowledge of Parthian era settlements and clarified the cultural sequences in their development. She places this material in a comparative framework for adjacent areas of northeastern Iran, thus illustrating their interconnection with developments in Dibaj Damghan. It is significant that Dibaj Tepe (hill) is



Fig. 2. Dibaj Damghan Tepe as seen from the north.

located near Hecatompylos (Shahr-i Qumis), thus suggesting its special importance in the history of the "Silk Road."

Geographical position of the region

Dibaj Tepe [Figs. 2, 3] is located 53 km to the north of Damghan in a mountainous region with the geographical coordinates of N: 4041817 and E: 40 S 0249920. The Neyshabur (Nishapur) and Damghan plains form part of an East-West route extending from Afghanistan to Shahrud, sometimes known as the "Great Khorasan Road." Damghan itself is on the northern edge of the desert. That this route has been of great importance from about 4000 BCE down to the Sasanian period is demostrated by artifacts made of lapis lazuli, white marble and turquoise discovered at various historical sites (Hiebert and Dyson 2002, p. 116). The terrain of Iran generally is marked by mountainous borders and

interspersed barriers with valleys and by broad expanses of desert (Cambridge History 1968, Vol. 1, p. 15). Khorasan bordered on its northwest by the Gorgon and Atrek Rivers and in the north and northeast by the Kopet Dag

Fig. 4. Map showing the topography of Northeastern Iran.

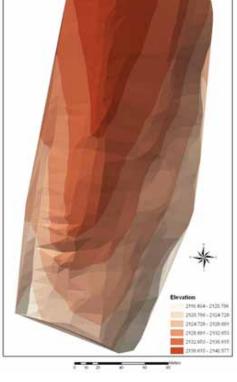


Fig. 3. Topographic map of Dibaj Tepe.

mountains and their subsidiary ranges [Fig. 4]. The Mashhad plain in the northeast is bordered on the north by the Kuh-e Hazar Masjid (Kopet Dag) range, whose highest peak rises to over 3000 m., and on the south by the Kuh-e Binalud and Kuh-e Shah Jahan mountains (Hiebert and Dyson 2002, p. 115; Eduljee 2007, p. 9).

Most ancient settlements were situated along the northern or southern borders of the mountains or were located in the mountain valleys, where there was a predictable supply of water and

edu/maps/middle_east_and_asia/txu-pclmaps-oclc-8322829_g_5.jpg> x Shahrud Mashhad Vevshabur x Damghan

Map source: Operational Navigation Chart ONC-G5 http://www.lib.utexas.

sufficient rainfall for agriculture. Beyond was uninhabitable desert.

Archaeological evidence and the history of the region in the Parthian era

Archaeological excavations have undertaken at Shahr-i Qumis, very probably the historic Hecatompylos, located on the "Great Khorasan Road" in the region of Damghan. The excavations uncovered hundreds of clay pots that can be dated from the beginning of the 1st millennium BCE on through the Achaemenid, Parthian and Sasanian periods (Hansman and Stronach 1970a, p. 30). Information recorded in China probably some time in the 2nd century CE includes this description of Parthia: "The main centre of the Kingdom of Anxi [Parthia] is the town of Hedu [Hecatompylos]... [Parthia] is several thousand *li* across. There are several hundred small towns" (Hill 2009, p. 23). Political consolidation of Parthia by Mithradates (Mehrdad) I (171–139 BCE) was accompanied by the expansion of Parthian territory to incorporate major cities such as Seleucia on the Tigris, Dura Europos and Susa.

Various finds at Shahr-i Qumis help establish its chronology. Seven coins attributed Orodes I (ca. 80–77 BCE) or his immediate predecessor were found in its Area VII. Ostraca (sherds) with Parthian inscriptions were also found in this building (Bivar 1981, pp. 81-2). They seem to relate to monetary donations, as do Parthian inscriptions found at Ak-depe and other sites in southern Turkmenistan (Livshits 1993, p. 75). Sixteen significant seals were discovered in Area V at Shahr-i Qumis (Bivar 1982, p.161).

While Shahr-i Qumis may have been a major political and military center, it was only one of a number of strategically located Parthian fortresses in northeastern Iran (Trinkaus 1981, p.35). Important archaeological discoveries in part dating from the Parthian period have been made along the Gorgon Wall and the defensive castles in the Gorgon Plain (Kiani 1982b, p. 9), the latter being an area which had previously been significant for the Achaemenids and then would continue to be of importance under the Sasanians. Construction in this region was especially impressive under the

Arsacid and Sasanian rulers (Kiani 1982a, p. 78). Archaeological investigations in 2007 based on the satellite images led to the discovery of sites along both the northern and southern sides of the wall. Pottery and other objects dated these to the Sassanian and the Parthian eras (Rekavandi et al. 2008, p. 153). Another of the locations of a significant Parthian presence in the northeast is Tureng Tepe, which was excavated between 1960 and 1975 (Boucharlat and Lecomte 1987, p.1). Parthian sites are also found in the valley of the Atrek River (Ricciardi 1980, p. 62-4). Just north of the present borders of Iran in Turkmenistan are

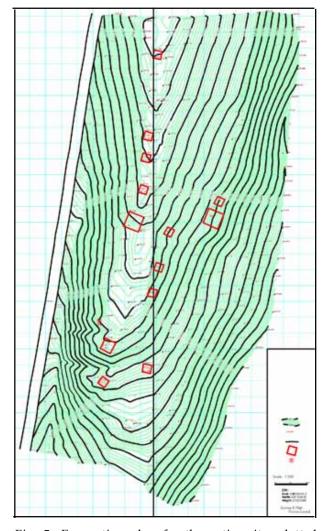


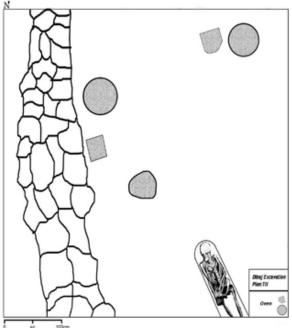
Fig. 5. Excavation plan for the entire site, plotted on a topographic map. The rectangular areas (red in the online version of this journal) are the excavation trenches. Readers should note that the original drawing includes very careful elevation measurements taken throughout the site, the details not visible here.

the important Parthian sites of Merv and Nisa. The density of settlement around Merv makes it very important for establishing a full chronology of the early history (Herrmann et al. 1996, p. 2). Nisa, excavated in the 1930s, was the first Parthian capital (Mongait 1959, p. 269; Pilipko 2008, p. 33; Curtis 2001, p. 299). Yet another Parthian settlement in southern Turkmenistan was in the Serakhs Oasis next to the Tajan River (Kaim 2008, pp. 128-9).

Architectural discoveries at Dibaj Tepe

After the surveying and gridding operations at this site, thirteen trenches of different dimensions were dug [Fig. 5]. In what follows, for three of





these trenches we will describe the architectural data, then the pottery and, finally, discuss their historical influences. A feature system of numbering has been used for reference.

Trench II

A trench was excavated with the dimension of 5×5 m oriented north-south on the top of the hill [Figs. 6, 7]. Judging from the buried remains, three graves found in the upper layers of this trench belong to the early Islamic era. The graves were placed on one level and in the west-east direction. The lower layers of the site were found to be related to the Parthian era.

Feature 1001. This structure includes a rubble wall with binding mud and has three rows in three columns extending from north to south.

Feature 1002. It is a round stove made of terra-cotta at a depth of 100 cm. The diameter of the stove's opening is 45 cm and its height is 15 cm.

Feature 1003. This structure also is a round stove made of terra-cotta and is located almost opposite Feature 1002 at a depth of 100 cm [Fig. 8]. The diameter of the stove's opening is 50 cm and its height is 18 cm.

Fig. 6 (upper left). View of Trench II from the south. Fig. 7 (lower left). Plan of Trench II.

Fig. 8 (below). The stove/oven of Feature 1003 in Trench II, seen from the south.





Fig. 9 (above). View of Trench VI from the northwest. Fig. 10 (right). Plan of Trench VI.

Feature 1004. This structure, a stove or an oven with an irregular form, is at a depth of 100 cm. The diameter of its opening is 38 cm and its height is 10 cm.

Trench VI

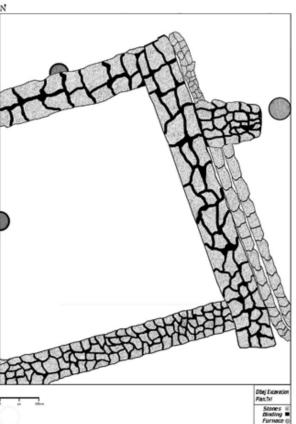
Trench VI was made in a north-south orientation on the south side of the hill and on a gentle slope [Figs. 9, 10]. Its dimensions were initially 5×5 m and then were extended to 7×7 m during excavation.

Feature 1001. This structure includes a rubble wall with binding mud extending from north of the trench to the south. The wall was constructed of stone rubble and river stones used in three rows and three columns. The wall is 550 cm long, 100 cm wide and 110 cm high.

Feature 1002. This structure is a rubble wall extending towards the west and attached to Feature 1001 from its beginning. This structure was made of river-stone rubble with binding mud in two rows and one column.

Feature 1003. This structure, at a depth of 95 cm, includes two rubble rows parallel to each other in the same direction [Fig. 11]. It is located to the right of Feature 1001 and has a regular shape. The distance between two rubble rows is 30 cm, and the space between

Fig. 11. Feature 1003 in Trench VI.







them has been filled with brick and flagstone. The wall has a length of 340 cm and a width of 30 cm.

Feature 1004. This structure includes a row of stones like a platform attached to Feature 1001 [Fig. 12]. This structure is also attached to Features 1002 and 1003.

Feature 1005. This structure is at a depth of 135 cm in a layer lower than Feature 1003 but like it and parallel to Feature 1003. The length is 340 cm and width 30 cm. This feature was constructed of parallel rows of flagstones oriented in the same direction and lying 30 cm apart.

Feature 1006. At a depth of 75 cm we found the remains of an oven. Part of this oven is inside the eastern edge of the trench. The diameter of this oven is 60 cm and its distance from the northern wall is 108 cm.

Feature 1007. At 85 cm depth next to Feature 1002 are the remains of a trench, inside which was very soft soil. The depth of this trench was 109 cm and its length was 47 cm.

Feature 1008. This structure is a stove. The diameter of its opening is 63 cm and its depth is 202 cm. A hole with a diameter of 10 cm was found in the wall of this stove, and its continuation with a diameter of 10 cm was found at a 10 cm distance from the opening of the stove on the floor of the trench. The soil inside this stove was very soft, mixed with some charcoal and fragmentary bones of a child. In addition, a completely corroded and broken iron knife was found on the floor of this stove.

Fig. 12. Feature 1004 in Trench VI.

All these structures together make a space like a room divided into rectangular areas by platforms, the result forming the most complete architectural space of this trench.

Trench IX

Trench IX is located on the west side of Dibaj Hill on a gentle slope.

Feature 1001. This structure is a wall found at a depth of 68 cm. It is constructed of rubble and flagstones in two rows and two columns. The length of this feature is 860 cm, its width is 65 cm and its height is 70 cm. A major part of the cultural objects were found at this depth, including pottery scattered all over the layer in this square.

Feature 1002. This structure is located at a depth of 120 cm on the eastern side of the trench. This feature is attached to the end of Feature 1001 at a right angle and is made of river rubble in three rows and two columns.

Feature 1003. This is a round oven found at a depth of 130 cm. The diameter of its opening is 20 cm and its height is 14 cm.

Feature 1004. This is a stove located next to Feature 1001 at a depth of 170 cm. Its height is 60 cm

Excavation was done in this trench down to the depth of 180 cm and stopped there, when no cultural objects were found.

In this excavation, the most complete — and indeed very considerable — architectural space was discovered in Trench VI. In general though, the limited architectural structures so far uncovered at the site indicate temporary and single-period residence.

The cultural objects found in the excavation

Pottery, which tends to be abundant, is usually the best evidence for establishing the chronology of ancient sites (Dark 1995/2000, p. 45). Study of the pottery, examining both its fabric and artistic style, not only can help determine the date of a settlement or stratum, but also can help in establishing some aspects of social conditions, historical changes and the nature of trading contacts (Orton et al. 1993, p. 23). Study

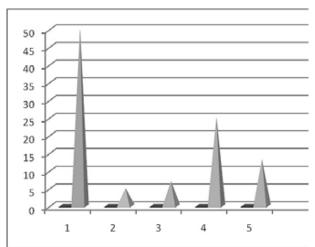


Fig. 13. Percentages of finds at Dibaj Tepe grouped by artifact type: 1. Ceramics. 2. Iron. 3. Glass objects. 4. Decorative beads. 5. Clay spindle weights.

of Parthian pottery of northeastern Iran may indicate influence on it by the pottery styles of neighboring regions in Central Asia. Insofar as there are similarities between the Parthian wares we have discovered and those of adjacent regions, we may be able to discuss the economic transactions and social interactions of different cultural zones.

A wide range of objects has been excavated at Dibaj Tepe [Fig. 13]. The Parthian ceramics include ordinary objects and kitchenware, dishes for food storage, and glazed dishes in red color. They are made of fine gravel, aggregate and sometimes lime.

In Trench V at a depth of 30 cm we found a broken brown agate signet ring with a scorpion image [Fig. 14]. The ring is 7 mm thick with a flat 2.3 x 1 cm oval-shaped surface cut on one side where the image was carved. Also discovered in this trench was a shell cap of a glass scent bottle, a glass bead and a clay spindle weight.

Trench VI yielded a bronze bracelet, an earring, ornamental beads, and clay spindle weights and earrings.

Several objects were discovered in Trench IX:

- 1. A seriously damaged bronze bowl with external diameter 5.5 cm, internal diameter 3.5 cm, and height 4.3 cm [Fig. 15].
- 2. At a depth of 95 cm, an intact crock. It is brown in color, has a thick clay coating, and on its shoulder has a small handle. Its dimensions are: height 81 cm, body diameter 185 cm, and diameter of the opening 19 cm [Fig. 16].
- 3. Next to this crock was another one used for storing grain [Fig. 17]. Its measurements are: height 91 cm, body diameter 79 cm, opening diameter 19 cm, bottom diameter 14 cm. Unlike

Fig. 14 (upper left). The signet ring with scorpion image from Trench V.

Fig. 15 (lower left). The broken bronze bowl from Trench IX.

Fig. 16 (middle). Ceramic crock with handle from Trench IX.

Fig. 17 (right). Ceramic crock from Trench IX.













Top to bottom:

- Fig. 18. Decorated ceramic vessel from Trench IX.
 - Fig. 19. Small ceramic crock from Trench IX.
 - Fig. 20. Beige ceramic crock from Trench IX.

the other crock, this one has no handle. There were two husks inside on the bottom.

- 4. There was a red-orange clay vessel (height 23 cm; body diameter 82 cm; bottom diameter 16 cm) with two small handles and rhombic decorative motifs carved in a horizontal band on its shoulder [Fig. 18].
- 5. A brown clay crock whose edge and handle have been damaged [Fig. 19]. Its height is 40 cm, body diameter 18 cm, bottom diameter 11 cm and opening diameter 6 cm.
- 6. A largely intact beige clay jug [Fig. 20]. It is 40 cm high, with an opening 20 cm. in diameter and body diameter 30 cm. A horizontal band of design has been carved on its shoulder.
- 7. At a depth of 110 cm in Trench XI, a glass scent bottle [Fig. 21].



Fig. 21. Glass scent bottle from Trench IX.

More than 1000 pottery sherds dating from the Parthian era have also been

discovered in excavations at this site [Figs. 22-25, next page]. The pottery is grey, beige, orange, red or brown and is made of temper, gravel and lime, with glazed surfaces. 22% of this pottery is brown, 13% grey, 20% beige, 13% orange and 32% red. The decoration consists of horizontal lines carved on the shoulders of the vessels. The vessels are pots, crocks, small and medium-size jars and bowls. 40% of the dishes discovered at Dibaj have no opening and 60% of them have an opening. Furthermore, the edge of most of the dishes slopes outward.

The pottery of this region is comparable with that from other regions of northeastern Iran in the historical era, which suggests that the wares are indigenous and that there was cultural homogenity across regions.





Tr-IV

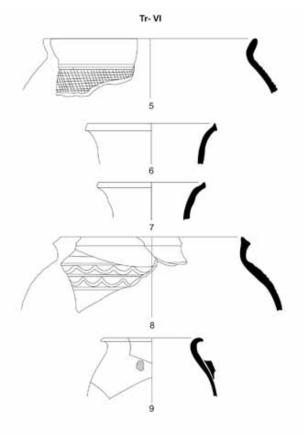


Fig. 22 (top left). Pot sherds from Trench VI.

Fig. 23 (bottom left). Drawing of pot sherds from Trench VI.

Fig. 24 (top right). Pot sherds from Trench IV.

Fig. 25 (bottom right). Drawing of pot sherds from Trench IV.

Conclusion

The excavation described here is a contribution to our better understanding of historical developments in northeastern Iran and the connection of that region with adjoining ones. The focus on the Parthian era is significant, since that dynasty ruled over a wide territory for several centuries and presided over one of the most important periods of Iranian history. It is impossible to understand the substantial achievements of their successors, the Sasanians, without looking closely at the Parthian period.

While excavations of Parthian sites to date have focused largely on major centers, there is a great deal to be learned by studying thoroughly a smaller site such as Dibaj Tepe. We feel that its artifacts improve our understanding of non-elite populations in the Parthian era. The architecture of the site suggests that it was used as a temporary and seasonal accommodation. The typology of the excavated potteries suggests that it might have been a shepherd's settlement. Most of the pottery has an open shape which is best suited to pastoral life. To establish the chronology, we have compared this pottery with that found at several other Parthian sites where the cultural objects are similar: Tureng Tepe in Gorgon (Boucharlet and Lecomte 1987), the Damghan Plain (Trinkaus 1981), the defensive wall in Gorgon (Rekavandi et al. 2008; Kiani 1982a, 1982b), the Atrek Valley in Khorasan (Ricciardi 1982) and Shahr-i Qumis in Damghan (Hansman and Stronach 1970a). This comparison suggests that the small shepherd community in Dibaj, even though it may have experienced inter-regional migration, never had significant interaction beyond the borders of this region of northeastern Iran. Additional proof of this can be seen by comparison and contrast with objects found in recent archaeological excavations focusing on sites connected with an immigrant tribe of Semnan.

The seal excavated at Dibaj Tepe would seem to have come from some regional center, but what it tells us about political and economic interactions of this particular settlement is unclear. While there are some other artifacts which likely were obtained from elsewhere in the region - the polished dishes with carved decoration, a bronze dish and some glass vessels - their number and quality suggests limited financial resources in this local community. The locally produced decorative objects are quite modest; spindle weights suggest that weaving was practiced. However, further study of this evidence and the accumulation of more material from additional excavation at the site may help clarify the nature of this local community and provide a better picture than we now have regarding regional and inter-regional interactions in northeastern Iran in the Parthian era.

About the author

Mahnaz Sharifi is a faculty member at the Iranian Center for Archaeological Research. She received her M.A. from the University of Tehran and is preparing to defend her Ph.D. on the Parthian period. She has participated in excavations in various regions of Iran: at Susa, Ramhormoz, Gorgon, Semnan and Damghan. Her published articles deal with both the prehistoric and historical periods. She may be contacted at <mhsharifi588@yahoo.com>.

References

Bivar 1981

A. D. H. Bivar. "The Second Parthian Ostracon from Qūmis (Qūmis Commentaries No. 3)." *Iran: Journal of the British Institute of Persian Studies* 19 (1981): 81–84 + 1 plate.

Bivar 1982

A. D. H. Bivar. Seal-impressions of Parthian Qumis (Qumis Commentaries No. 4)." *Iran: Journal of the British Institute of Persian Studies* 20 (1982): 161–76.

Boucharlat and Lecomte 1987

Rémy Boucharlat and Olivier Lecomte. *Fouilles de Tureng Tepe.* 1. *Les Périodes sassanides et islamiques*. Recherche sur les civilisations, Mémoires, 74. Paris: Ed. Recherche sur les civilisations, 1987.

Cambridge History 1968

The Cambridge History of Iran. 7 vol. in 8. Ed. W. B. Fisher et al. Cambridge: Cambridge University Press, 1968–1991; here, Vol. 1.

Clark 2007

James D. Clark. "Continuity and Change: the History of Ancient Iran in Three Works by A. T. Olmstead, Roman Ghirshman and Richard N. Frye." *Iranica Antiqua* XLII (2007): 419–50.

Curtis 2001

Vesta Sarkhosh Curtis. "Parthian Belts and Belt Plaques." *Iranica Antiqua* XXXVI (2001): 299–327.

Dark 1995/2000

Ken R. Dark. *Theoretical Archaeology*. London: Duckworth, 1995; tr. by Kamyar Abdi. Tehran: University Press Center, 2000.

D'iakonov 1961/2001

Mikhail Mikhailovich D'iakonov. Ocherk istorii

drevnego Irana [An Outline of the History of Ancient Iran]. Moskva: Izd-vo. vostochnoi literatury, 1961; tr. by Ruhi Arbab as *Tarikh-i Iran-i bastan*, Tehran, 1968; repr. 2001.

Eduljee 2007

K. E. Eduljee. "Zoroastrian Heritage" http://www.heritageinstitute.com/zoroastrianism/parthia/region.htm>.

Hansman and Stronach 1970a

John Hansman and David Stronach. "Excavations at Shahr-i Qūmis, 1967." *Journal of the Royal Asiatic Society of Great Britain and Ireland* 1970/1: 29–62.

Hansman and Stronach 1970b

John Hansman; David Stronach. "A Sasanian repository at Shahr-i Qūmis." *Journal of the Royal Asiatic Society of Great Britain and Ireland* 1970/2: 142–55.

Hiebert and Dyson 2002

Fredrik T. Hiebert and Robert H.Dyson Jr. "Prehistoric Nishapur and the Frontier between Central Asia and Iran." *Iranica Antiqua XXXVII* (2002): 113–49.

Herrmann et al. 1996

Georgina Herrmann, K. Kurbansakhatov and St. John Simpson. "The International Merv Project: Preliminary Report on the Fourth Season." *Iran: Journal of the British Institute of Persian Studies* 34 (1996): 1–22.

Hill 2009

John E. Hill. Through the Jade Gate to Rome. A Study of the Silk Routes during the Later Han Dynasty 1st to 2nd Centuries CE. An Annotated Translation of the Chronicle on the "Western Regions" in the Hou Hanshu. Lexington, KY.: Booksurge, 2009.

Kaim 2008

Barbara Kaim. "The Parthian Settlements in the Serakhs Oasis." *Parthica* 10 (2008): 129–34.

Kiani 1982a

Muhammad Yusuf Kiani. "Excavations on the Defensive Wall of the Gurgan Plain: A Preliminary Report." *Iran: Journal of the British Institute of Persian Studies* 20 (1982): 73–79.

Kiani 1982b

Muhammad Yusuf Kiani. Parthian Sites in

Hyrcania: the Gurgan Plain. Archäologische Mittelungen aus Iran, Ergänzungsband, 9. Berlin: Dietrich Reimer, 1982.

Koshelenko et al. 1995

Gennadii Koshelenko, A. Bader and V. Gaibov. 'The Beginnings of Christianity in Merv." *Iranica Antiqua* XXX (1995): 55–70.

Livshits 1993

Vladimir A. Livshits. "A Parthian Inscription on a Vessel from Ak-depe." *Iran: Journal of the British Institute for Persian Studies* 31 (1993): 75–76.

Mongait 1959

Aleksandr L'vovich Mongait. *Archaeology in the USSR*. Tr. and adapted by M. W. Thomson. Baltimore: Penguin, 1959 (1st ed., Moscow, 1955).

Orton et al.1993

Clive Orton, Paul Tyers, and A. G. Vince. *Pottery in Archaeology*. Cambridge; New York: Cambridge University Press, 1993.

Pilipko 2008

V. N. Pilipko. 'The Central Ensemble of the Fortress Mihrdatkirt. Layout and Chronology." *Parthica* 10 (2008): 33–51.

Rekavandi et al, 2008

Hamid Omrany Rekavandi et al. "Sassanian Walls, Hinterland Fortresses and Abandoned Ancient Irrigated Landscapes: the 2007 Season on the Great Wall of Gorgan and the Wall of Tammishe." *Iran: Journal of The British Institute of Persian Studies* 46 (2008): 151–78.

Ricciardi 1980

R. Venco Ricciardi. "Archaeological Survey in the Upper Atrek Valley (Khorasan, Iran). Preliminary Report" *Mesopotamia* 15 (1980): 51–72.

Schippmann 1980/2005

Klaus Schippmann. *Grundzüge der parthischen Geschichte*. Darmstadt: Wissenschaftliche Buchgesellschaft, 1980; tr. by Hushang Sadiqi as *Mabani tarikh-i Partiyan*. Tehran: Farzan, 2005.

Trinkaus 1981

Katheryn Maurer Trinkaus. "The Partho-Sassanian Northeast Frontier: Settlement in the Damghan plain, Iran." Unpubl. Ph.D. diss., University of Pennsylvania, 1981.