CHAPTER 6

STORM-INFLUENCED DELTAIC DEPOSITS OF THE MIDDLE JURASSIC GAIKEMA SANDSTONE IN A MEASURED SECTION ON THE NORTHERN INISKIN PENINSULA, COOK INLET BASIN, ALASKA

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Middle Jurassic strata of the Gaikema Sandstone were deposited about 170 million years ago on a delta that was located on the western shoreline of the Cook Inlet basin (Detterman and Hartsock, 1966; LePain and others, 2011, 2013). The delta was built by swift, sediment-laden rivers that flowed southeastward from a mountainous volcanic terrane west of the Bruin Bay fault (fig. 6-1). Upon reaching the edge of the Jurassic sea, the rivers dumped abundant sand, gravel, and mud into a depocenter on the northern Iniskin Peninsula, about 240 km southwest of Anchorage (figs. 6-1, 6-2).

This report provides a preliminary description and interpretation of a detailed, 34-m-thick measured section in the Gaikema Sandstone on the south shore of Chinitna Bay at latitude 59.816°N, longitude 153.168°W (figs. 6-1–6-3). The sandstone in this measured section exhibits hummocky cross lamination and other features suggestive of storm-influenced deposition on the shallow-marine, seaward margin of the Gaikema delta.

Our field studies of the Gaikema Sandstone were conducted during 2013 and 2014 as part of a collaborative effort by the Alaska Division of Geological & Geophysical Surveys (DGGS), Alaska Division of Oil and Gas (DOG), and U.S. Geological Survey (USGS) to provide the public with reliable information on the geologic framework and petroleum resource potential of Cook Inlet basin (Gillis, 2013, 2014). Jurassic rocks in Cook Inlet, including the Gaikema Sandstone, are of economic interest because they could contain significant undiscovered petroleum resources (Bureau of Ocean Energy Management, 2011; Stanley and others, 2011a, 2011b, 2013a; LePain and others, 2013).

STRATIGRAPHIC SETTING, AGE, AND THICKNESS OF THE GAIKEMA SANDSTONE

The Gaikema Sandstone is one of six formations that make up the Middle Jurassic Tuxedni Group (fig. 6-4; Detterman and Hartsock, 1966; Detterman and Westermann, 1992). The Tuxedni Group was deposited in a spectrum of deep-marine, shallow-marine, and nonmarine environments and records a complicated history of relative rises and falls of sea level (LePain and others, 2013). In the lowermost part of the Tuxedni Group, the Red Glacier Formation consists mainly of mudstone, siltstone, and sandstone that were deposited in prodeltaic and relatively deeper-water marine environments (LePain and Stanley, 2015). The Gaikema Sandstone, Cynthia Falls Sandstone, and Bowser Formation are richly fossiliferous and represent coarse-grained deltas that prograded eastward and southeastward into the Jurassic sea (fig. 6-4). The Fitz Creek Siltstone and Twist Creek Siltstone are fine-grained units that were deposited during episodes of marine flooding. The mineralogical composition of sandstones in the Tuxedni Group indicates that the principal sources of sediment were Early Jurassic volcanic and plutonic rocks that were uplifted and eroded during the Middle and Late Jurassic (Helmold and others, 2013; Helmold and Stanley, 2015). Evidence from field investigations by DGGS and USGS suggests that the uplifted volcanic and plutonic rocks were located on the western, upthrown side of the Bruin Bay fault (fig. 6-1; LePain and others, 2011, 2013; Wartes and others, 2013).

In its type section along Gaikema Creek (figs. 6-1, 6-2), the Gaikema Sandstone conformably and gradationally overlies the Red Glacier Formation and is overlain conformably and abruptly by the Fitz Creek Siltstone. The Bajocian (Middle Jurassic) age of the Gaikema Sandstone is based on studies of abundant ammonites and other marine fossils (Detterman and Hartsock, 1966, p. 28; Imlay, 1984, p. 10; Detterman and Westermann, 1992, p. 53).

On the northern Iniskin Peninsula, the Gaikema Sandstone ranges in thickness from 150 to 260 m and consists of resistant, cliff-forming, green to gray sandstone with subordinate conglomerate, siltstone, and shale. Using the geologic map of Detterman and Hartsock (1966) we estimate that the base of our detailed measured section (fig. 6-5) is stratigraphically about 30–40 m above the covered contact between the Gaikema Sandstone and the underlying Red Glacier Formation.

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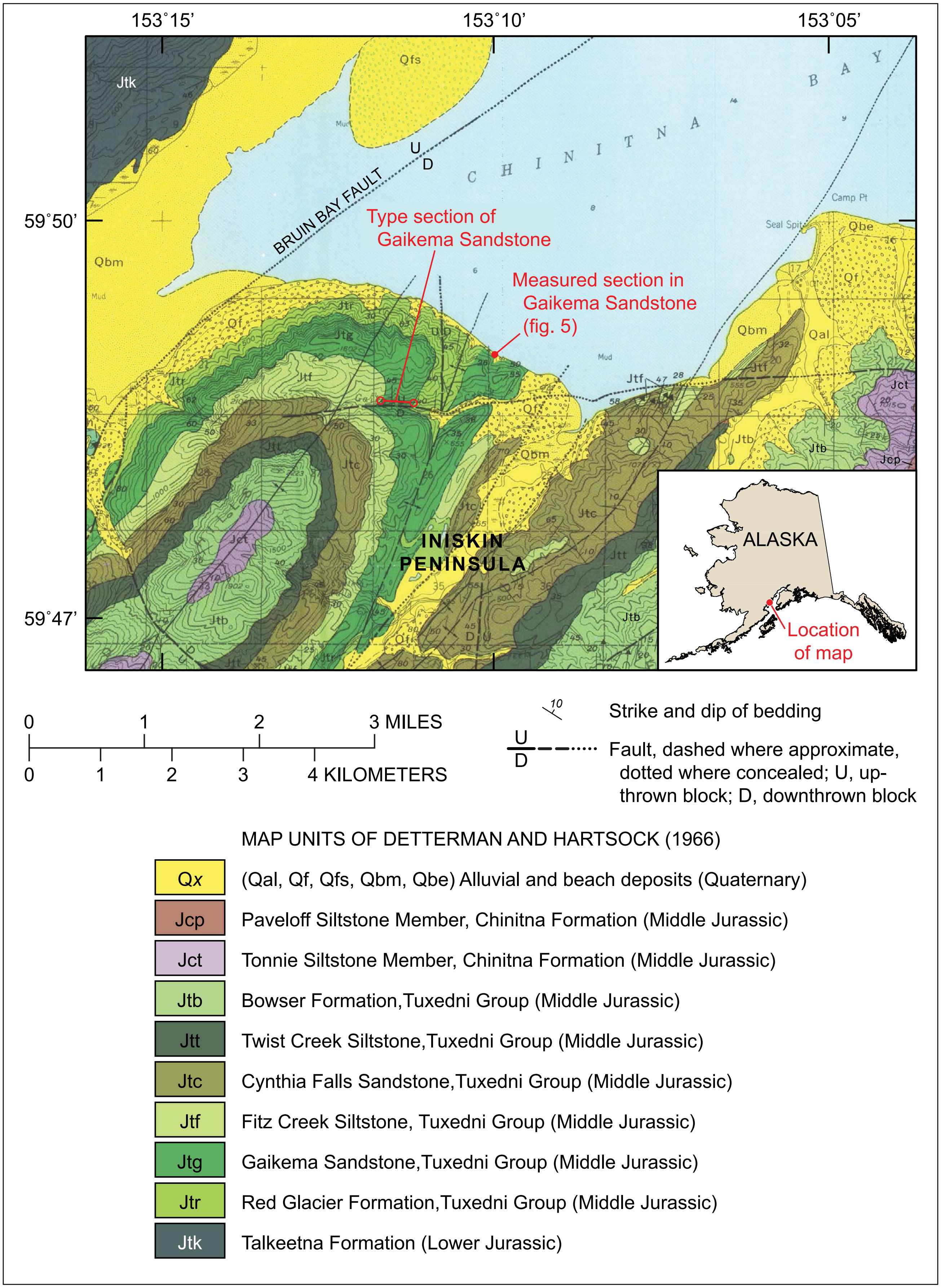

Figure 6-1. Map showing the northern Iniskin Peninsula, the location of the type section of the Gaikema Sandstone, and the location of our detailed measured section in the Gaikema Sandstone. Geologic map from Detterman and Hartsock (1966).

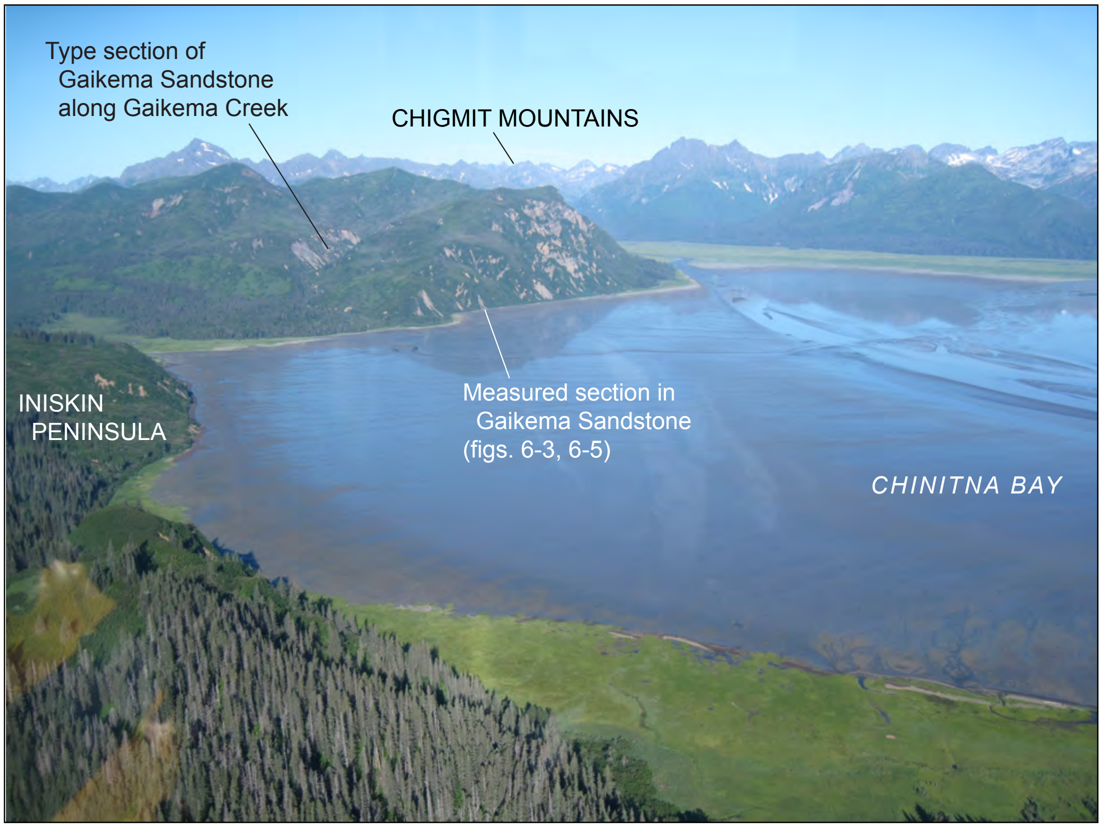

Figure 6-2. View to the west across Chinitna Bay and the northern Iniskin Peninsula toward the Chigmit Mountains, showing the type section of the Gaikema Sandstone along Gaikema Creek at photo left and our detailed measured section in the Gaikema Sandstone on the south shore of Chinitna Bay at photo center.

Figure 6-3. View, looking south from helicopter, of the south shore of Chinitna Bay and an outcrop of the Gaikema Sandstone; our detailed, 34-m-thick measured section is between the two white arrows. Bedding in this outcrop is upright, strikes N50°E to N60°E, and dips about 65° to the southeast (photo left). See figures 6-1 and 6-2 for location.

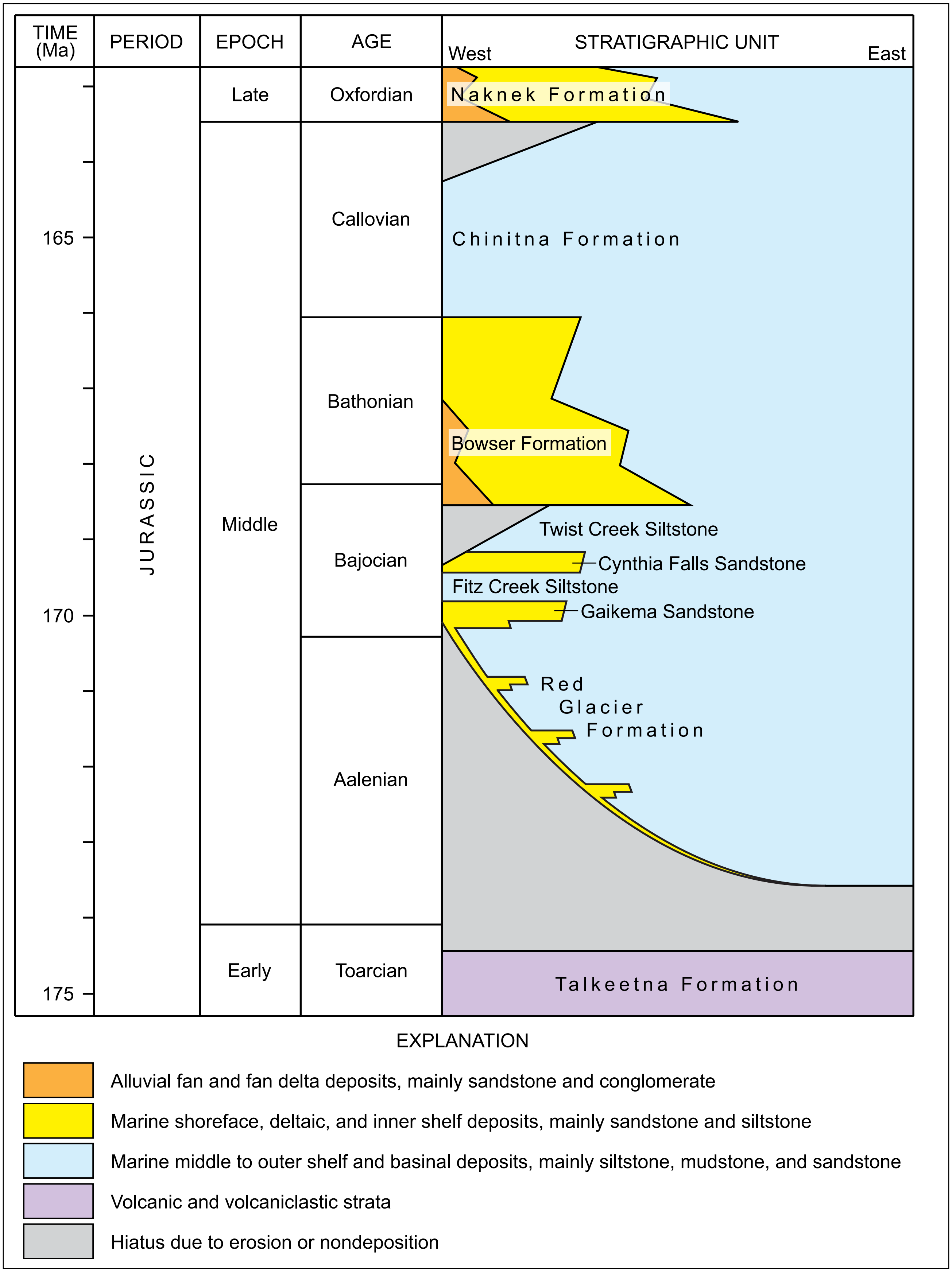

Figure 6-4. Schematic chronostratigraphic diagram showing Middle Jurassic stratigraphic units in the lower Cook Inlet basin, modified from LePain and others (2013, p. 44) using formation ages reported by Detterman and Westermann (1992), the geologic time scale of Cohen and others (2014), and field observations by the authors. The Tuxedni Group comprises the Bowser Formation, Twist Creek Siltstone, Cynthia Falls Sandstone, Fitz Creek Siltstone, Gaikema Sandstone, and Red Glacier Formation (Detterman and Hartsock, 1966).

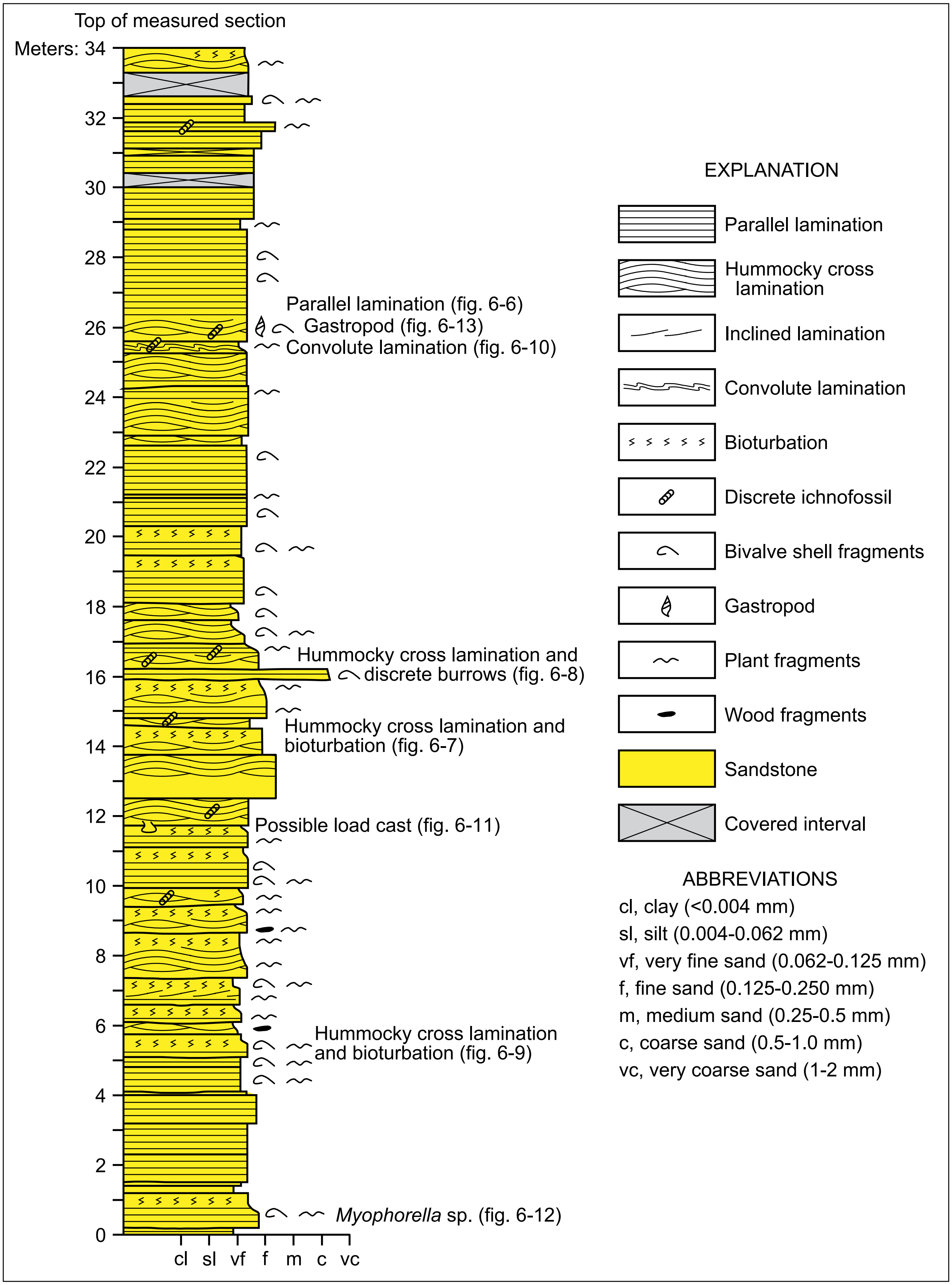

Figure 6-5. Detailed, 34-m-thick measured section of part of the Gaikema Sandstone. See figures 6-1–6-3 for location.

BRIEF DESCRIPTION OF THE DETAILED MEASURED SECTION

Sandstone in our detailed measured section (fig. 6-5) ranges in texture from very fine to coarse grained but is predominantly fine grained. The sandstone is medium to light gray-green on freshly broken surfaces, and weathers to gray-brown, orange-brown, and red-brown. The sandstone is hard and readily breaks apart into small blocks and slabs along fractures and planes of stratification (fig. 6-6).

The sandstone beds range in thickness from 10 cm to about 300 cm but most beds are in the range of 30–100 cm thick. Nearly all of the sandstone beds have sharp, erosional lower contacts that are immediately overlain by parallel laminated and/or hummocky cross-laminated sandstone (figs. 6-6–6-8). The laminated sandstone grades upward into bioturbated sandstone that exhibits color and textural mottling and is abruptly truncated by a sharp, erosional contact with laminated sandstone belonging to the next overlying bed (fig. 6-9). In some sandstone beds, lamination is cut by discrete ichnofossils (figs. 6-7, 6-8) that we tentatively identify as *Thalassinoides* on the basis of their resemblance to illustrations in Pemberton (1992, p. 188, 325, 391), Gerard and Bromley (2008, p. 39), and Pemberton and others (undated, p. 143–145). Convolute lamination is prominent in a bed about 25.5 m above the base of the measured section (fig. 6-10). A load cast was observed at about 11.75 m in the section (fig. 6-11).

Molluscan shell fragments are common in our measured section, but we found no unbroken, well-preserved fossils. However, about 0.4 m above the base of the section we found a fragment of a trigoniid bivalve that resembles *Myophorella* sp. and is suggestive of shallow, inner shelf water depths (fig. 6-12; Robert Blodgett, written communication, November 19, 2014). A poorly preserved, unidentified gastropod was found about 26 m above the base of the section (fig. 6-13). In some sandstone beds abundant disarticulated valves and broken pieces of small, unidentified bivalve mollusks are concentrated along laminations (fig. 6-14). Finely comminuted plant fragments, mostly smaller than 2 mm diameter and gray to black in color, are abundant throughout our measured section and in places are concentrated along certain laminae (fig. 6-15). Wood fragments up to 22 cm long and dark gray to black in color were observed at several horizons in the measured section (fig. 6-5).

PRELIMINARY INTERPRETATION OF THE DETAILED MEASURED SECTION

Parallel lamination and hummocky cross lamination are commonly found in the sandy deposits of ancient shallow marine settings that were influenced by periodic, intense storms (Plint, 2010). Plane lamination is formed by high-velocity unidirectional flow along a flat bed (Collinson and others, 2006), whereas the mechanism of formation of hummocky cross lamination appears to involve a combination of unidirectional and oscillatory flow generated by large storm waves (Cheel, 1978; Collinson and others, 2006; Dumas and Arnott, 2006).

Storm deposits, sometimes termed tempestites or event beds, are common in the geologic record and have been recognized at many locations throughout the world (for example, Dott and Bourgeois, 1982; Myrow and Southard, 1996; Plint, 2010). Drawing on plentiful published scientific literature on storm deposits, we suggest the following preliminary interpretation for the sandstone in our detailed measured section. Sand carried by rivers to the margins of the Gaikema delta was mobilized by storms and redeposited on the shallow offshore flank of the delta as layers with parallel lamination and hummocky cross lamination. During spells of fair weather between storms, the upper part of each laminated bed was reworked by sediment-churning organisms to form horizons of bioturbated sand. As the next storm started, the bioturbated horizon was eroded by waves and currents and then sharply overlain by a new layer of storm-deposited, laminated sand.

The detailed sedimentology and paleogeography of the Gaikema Sandstone are mostly unstudied and poorly understood. As a testable hypothesis to guide future work, we suggest that our detailed measured section may have been located on the northeastern flank of a sand- and gravel-dominated delta that was centered on the northern Iniskin Peninsula, as suggested by Detterman and Hartsock (1966).

PETROLEUM RESOURCE POTENTIAL

The potential of the Gaikema Sandstone to be a reservoir rock for petroleum is of interest because the Gaikema Sandstone directly and conformably overlies the Red Glacier Formation (fig. 6-4), which is thought to contain the principal source rocks of oil and associated gas in Cook Inlet basin (Magoon and Anders, 1992; Magoon, 1994; Lillis and Stanley, 2011; LePain and others, 2013; Stanley and others, 2013b; LePain and Stanley, 2015). About 8 km southwest of our detailed measured section a wildcat exploration well—the Iniskin Unit Beal 1—was drilled during 1954–1955 on the Fitz Creek anticline and tested minor shows of gas but no oil in the Gaikema Sandstone at depths of 748–788 m (Detterman and Hartsock, 1966, p. 74).

To facilitate better understanding of the oil and gas reservoir potential of the Gaikema Sandstone, during the 2013 and 2014 field seasons we collected rock samples for petrographic studies and analyses of porosity and permeability; preliminary results are reported by Helmold and Stanley (2015). In addition, three rock samples from our detailed measured section

Figure 6-6. Detail of sandstone outcrop about 26.5–27.0 m above the base of the measured section in figure 6-5, showing parallel lamination and fracturing. Hammer is about 30 cm long.

Figure 6-7. Detail of sandstone outcrop about 14.6 m above the base of the measured section in figure 6-5, showing dark, bioturbated sandstone at photo right overlain by lighter-colored sandstone with hummocky cross lamination and discrete ichnofossils tentatively identified as *Thalassinoides*. Hammer is about 30 cm long.

Figure 6-8. Detail of sandstone outcrop about 16.5–17.0 m above the base of the measured section in figure 6-5, showing hummocky cross lamination and discrete ichnofossils tentatively identified as *Thalassinoides*. Barrel of pencil is about 1 cm diameter.

Figure 6-9. Detail of sandstone outcrop about 5.75 m above the base of the measured section in figure 6-5, showing sharp, erosional contact at pencil point between light-colored, bioturbated sandstone at photo right and overlying dark-colored, possible hummocky cross-laminated sandstone at photo left. Barrel of pencil is about 1 cm diameter.

Figure 6-10. Detail of sandstone outcrop about 25.5 m above the base of the measured section in figure 6-5, showing convolute lamination; red arrow points to a discrete ichnofossil. Hammer is about 30 cm long. The mode of origin of the convolute lamination is unknown but may have entailed liquefaction and deformation of the sand in response to a trigger mechanism such as rapid deposition and sediment loading, downslope movement, or shaking by a Middle Jurassic earthquake.

Figure 6-11. Detail of sandstone outcrop about 11.75 m above the base of the measured section in figure 6-5, showing a load cast above and to photo left of pencil point. Red-brown, bioturbated sandstone at photo right is sharply overlain by light-colored, hummocky cross-laminated sandstone at photo left. Barrel of pencil is about 1 cm diameter.

Figure 6-12. Detail of sandstone outcrop and fossil bivalve at about 0.4 m above the base of the measured section in figure 6-5. The bivalve appears to be a trigoniid, possibly *Myophorella* sp. (Robert Blodgett, written commun., November 19, 2014). Barrel of pencil is about 1 cm diameter.

Figure 6-13. Detail of sandstone outcrop, showing poorly-preserved fossil gastropod about 26 m above the base of the measured section in figure 6-5. Barrel of pencil is about 1 cm diameter.

Figure 6-14. Detail of sandstone block from float recovered from near the 15–25 m interval in the measured section shown in figure 6-5. The sandstone is broken along a flat surface nearly parallel to lamination, revealing numerous bivalve shell fragments. Barrel of pencil is about 1 cm diameter.

Figure 6-15. Detail of sandstone block from float recovered from near the 10–15 m interval in the measured section shown in figure 6-5. The sandstone is broken along a flat surface nearly parallel to lamination and shows abundant dark plant fragments, mostly smaller than 2 mm diameter.

were analyzed for vitrinite reflectance by Mark J. Pawlewicz (U.S. Geological Survey, Denver, Colorado) and yielded values of 0.8–1.0 percent R_o, which are Mature I in the thermal maturity scheme of Johnsson and others (1993). These vitrinite reflectance values suggest maximum burial depths of about 4.5–7.7 km, using an equation that relates percent R_o to maximum burial temperature (Barker and Pawlewicz, 1986; Barker, 1988) and modern Cook Inlet geothermal gradients of 19–27°C/km (Lillis and Stanley, 2011), and assuming no significant variations in geothermal gradient from the Middle Jurassic to the present. The results of these and future investigations are expected to provide useful information for evaluation of the Gaikema Sandstone as a possible exploration target for commercial accumulations of hydrocarbons.

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