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Geometry of the Pleistocene Rock Bodies and Erosional Surfaces Around Ames, Iowa

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Five rock bodies and four major erosional surfaces are recognized in the subsurface; these are a lower till (Kansan?), a middle till (Tazewell?), a middle silt, an upper till (Cary), and a complexly interconnecting sand and gravel body. Erosion surfaces occur at the top of each rock body. The lower till is confined to the Squaw Buried Valley where it reaches a maximum thickness of 100 feet. The middle till averages 40 feet in thickness but ranges from 100 feet in buried valleys to absent over bedrock topographic highs. The middle silt is largely confined to the Squaw Buried Valley where it reaches thicknesses of 60 feet. The Cary till mantles the area, reaching thicknesses of over 100 feet in bedrock valleys and thinning to less than 25 feet over bedrock uplands. The distribution of the rock bodies suggests that the Squaw Buried Valley ceased to be the major drainage after Kansan (?) deposition and that the amount of pre-Tazewell (?) erosion was sufficient to remove all Kansan (?) drift from the uplands. The discontinuous distribution of the middle silt and Tazewell (?) till on the bedrock uplands indicates that erosion by the Cary glacier removed much of these rock bodies. The shape of the modern landscape mimics the shape of the buried bedrock valleys, though the relief in the area decreased from over 100 feet in pre-Kansan times to around 50 feet in pre-Cary times. The comparison of depositional landforms on the Cary surface to the till thicknesses suggests that washboard moraines, transverse features and circular features become dominant with progressively greater till thicknesses.

INDEX DESCRIPTORS: Iowa, Pleistocene, Till Distribution, Buried Bedrock Valleys, Continuum Model of Glacial Landforms.

Data from the topography of the bedrock surface and on the geometry of the Pleistocene-age rock bodies overlying that surface have been amassed for the Ames area through a series of geohydrologic studies (Backsen, 1963; Schoell, 1967; Sendlein and Dougal, 1968; Akhavi, 1970; Kent, 1969). The accumulated data consist of well logs, borehole logs and electrical resistivity and seismic information such that 356 data points are available for a 138-square-mile area including and extending to the north of Ames, Iowa. The study area thus covers the northwest portion of Story County and adjacent parts of Boone and Hamilton counties. Because the previous studies were directed toward defining the Ames aquifer system, a sand and gravel body lying within the bedrock valleys, the correlation and interpretation of the other Pleistocene-age rock bodies were not considered in detail. This paper is an attempt to utilize these available data to interpret the Pleistocene geology of the Ames area.

Several previous works describe aspects of the Pleistocene geology of the Ames area. Beyer (1898) presents a general description. Ruhe and Scholtes (1955) and Smith (1921) described several outcrops in the area. Gwynne (1942a, 1942b), Foster (1969) and Foster and Palmquist (1969) describe the surface landforms of Cary age in the area. Wallace (1961), Walker (1966) and Ruhe (1969) describe post-glacial modifications of the glacial landforms. Twenter and Coble (1965) describe the bedrock topography of the area.

Five rock bodies and four erosional surfaces are recognized in the Ames area. Schoell (1967) and Backsen (1963) recognized a lower, middle and upper till, a middle silt between the middle and upper till and a sand and gravel body of composite age. Ruhe and Scholtes (1955) described the middle and upper till and the middle silt units from outcrops in the immediate Ames area. Through the use of radiocarbon dating, they were able to show that the upper till is Cary in age (14,000 ybp) and that the middle silt was a composite unit of loess overlying laminated silts spanning the Tazewell interval (16,000-20,000 ybp). The middle till was assumed by them to be Iowan though a possible Kansan age was not ruled out. With the demise of the Iowan glaciation (Ruhe, 1969), a Tazewell age is suggested for the middle till. The lower till is tentatively considered to be Kansan because of its limited distribution in the deepest bedrock valleys. A fourth till may exist in the area, because four oxidized zones are reported in the log of one well north of Ames (well no. 414, Schoell, 1967).

Isopachous maps were constructed for each Pleistocene-age rock body and structure contour maps were drawn on most of the erosion surfaces. The well and geophysical data were used to construct the bedrock topographic map (Backsen, 1963; Schoell, 1967). The geophysical data were found to be inadequate to distinguish between till bodies or between till and silt bodies, though it could distinguish the aquifer. For this reason, only the well and borehole data were used to construct the isopachous maps.

RESULTS

The bedrock topography in the study area is characterized by two south-trending valleys joining at Ames (Figure 1A). The elevation on the floor of the western valley, the Squaw Buried Valley, ranges from 900 feet in the north to 750 feet just south of the junction with the eastern valley at Ames. The floor of the eastern valley, the Skunk Buried Valley, ranges in elevation from 900 feet in the north to 800 feet at Ames where it joins the Squaw Buried Valley. The relief on the bedrock surface averages 200 feet between the Squaw Buried Valley and the upland around Gilbert, and 150 feet between the Skunk Buried Valley and the Gilbert Upland.

The 50-foot difference in elevation between the floors of the buried valleys at their juncture in Ames suggests a composite age for the bedrock surface. The lower elevations associated with the floor of the Squaw Buried Valley suggest that it is the older of the two valleys and that it was the

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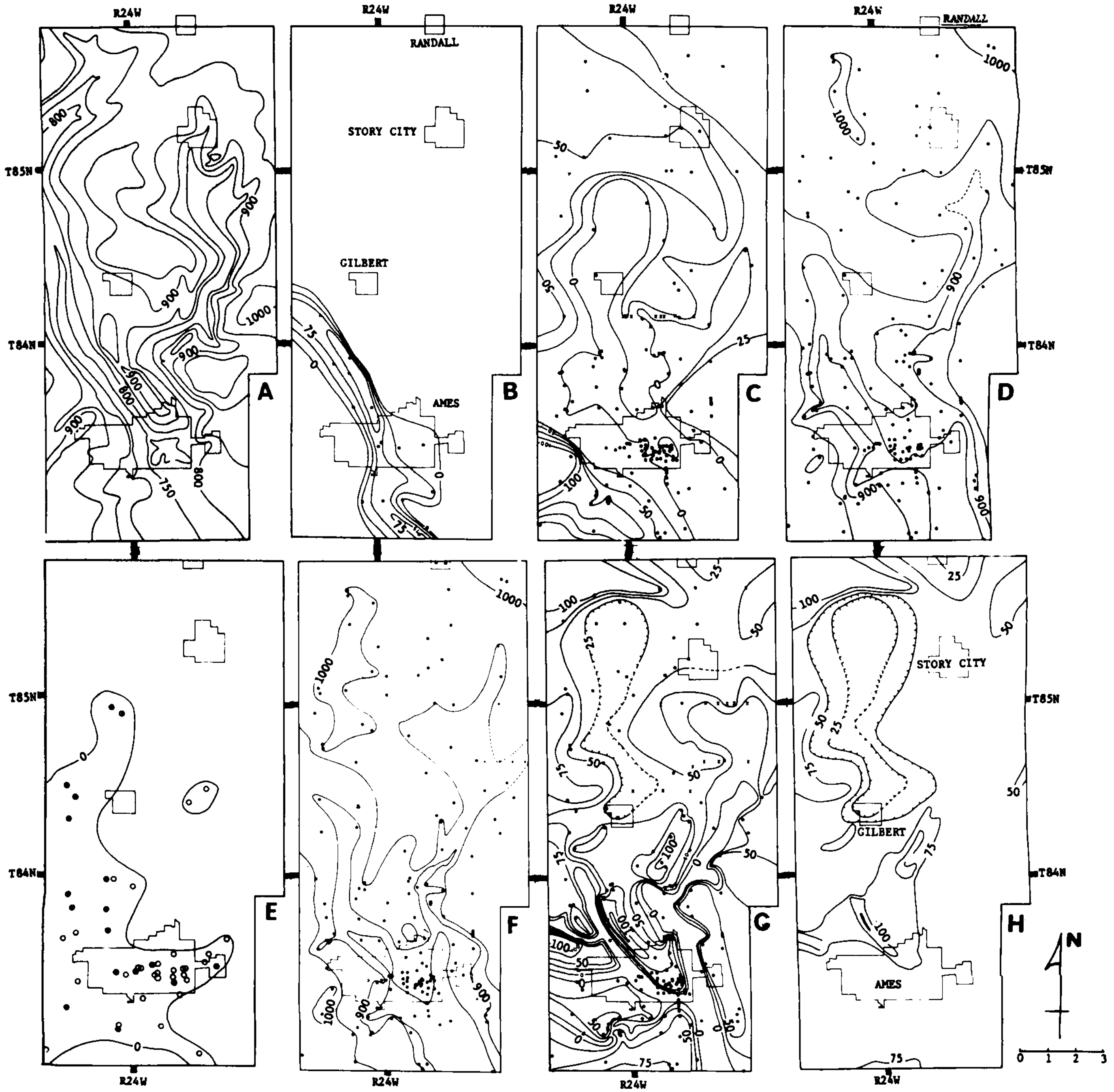
Figure 1. Distribution of rock bodies and erosional surfaces in the Ames area. Circles represent borehole data and crosses geophysical data. (A) Bedrock topographic map (modified from Backsen, 1963; Schoell, 1967). (B) Isopachous map of lower till (Kansan?). (C) Isopachous map of middle till (Tazewell?). (D) Topography of the surface developed on the middle till (Tazewell?). (E) Distribution of the middle silts. Open circles = less than 10 feet; half-filled circles = 10-25 feet; solid circles = greater than 25 feet. (F) Topographic surface developed on the middle till and middle silts. (G) Isopachous map of the upper till (Cary), uncorrected for post-glacial erosion. (H) Isopachous map of the upper till, corrected for erosion.



major drainage in the area during pre-Kansan (?) time (Beyer, 1898; Backsen, 1963). The higher elevations associated with the floor of the Skunk Buried Valley suggest that it was either a very small tributary valley or not a tributary of the Squaw Buried Valley and that the present connection to the Squaw Buried Valley was established at a much later time.

The lower till (Kansan?) is confined to the Squaw Buried Valley, where it has an average thickness of 65 feet (Figure 1B). The till is described in well logs and boreholes as being very dark grey, clayey with few pebbles. The lower till is overlain by sand bodies in all wells, and the upper oxidized zone is rarely reported (Backsen, 1963). The elevation on top of the lower till ranges from 850 feet in the north to 800 feet at the south at Ames. The 800-foot elevation at Ames places the top of the lower till at the same elevation as the floor of the Skunk Buried Valley at Ames. This coincidence suggests that the bedrock connection to the Squaw Buried Valley, as well as most of the Skunk Buried Valley, was eroded in the post-Kansan (?) interval when the lower till was stripped from the bedrock uplands.

The middle till (Tazewell?) averages 40 feet in thickness but ranges from 50 to 100 feet within the buried valleys to absent on the bedrock uplands (Figure 1C). The middle till is described in well logs as being dark grey and clayey with few pebbles. It is separated from the lower till by sand lenses and from the upper till by the middle silts, sand lenses or, rarely, an oxidized zone. Backsen (1963) reports 25 feet of oxidized zone at the top of the middle till, and Beyer (1898) and Smith (1921) report a "Ferreto zone." In a few places the middle and upper tills could not be separated. The absence of the middle till on the bedrock upland around Gilbert and in the northeast corner of the study area (compare Figures 1A and 1C) suggests removal of the till by post-Tazewell (?) erosion.

The surface on top of the middle till (Figure 1D) mimics the bedrock topographic surface (Figure 1A) in that a Squaw Valley and Skunk Valley are evident. The post-middle till surface has a relief of 60 feet along the Squaw Valley and 74 feet along the Skunk Valley, and a total relief of 200 feet within the study area. The post-middle till surface, as reconstructed in Figure 1D, reflects pre-upper till (Cary) erosion and is thus probably more subdued in relief than was the pre-erosion surface.

The middle silt (Tazewell) is largely confined to the Squaw Valley, where it reaches thicknesses of 60 feet (Figure 1E). The thickness of the middle silt is highly variable, so that an isopachous map was not practical. According to Backsen (1963) its average thickness is 30 feet. The rapid variations in thickness are probably related to a combination of post-middle silt erosion and the composite character of this silt unit—loess overlying laminated silts of probable floodplain origin (Ruhe and Scholtes, 1955). The greater thickness of the silt in the valleys on the middle till probably reflects the presence of the laminated silt unit. The absence of the middle silt on the bedrock uplands reflects pre-upper till erosion. If the upper unit is loess, as interpreted from the Clear Creek outcrop by Ruhe and Scholtes (1955), then the upper unit of the middle silt probably extended across the uplands. Since 12 to 15 feet of loess outcrops along Clear Creek, at least this much of the middle silt unit was removed from the uplands.

The upper till (Cary) mantles the study area and averages 50 feet in thickness, but ranges in thickness from over 100 feet in the buried valleys to locally less than 10 feet over the bedrock uplands (Figures 1G and 1H). The extreme variation in thickness evident in Figure 1G is the result in large part of post-glacial stream incision. Figure 1H was constructed by ignoring low till thickness along the modern streams and should better represent the pre-erosion thickness variations. The Altamont Moraine, as mapped by Ruhe (1969), is represented by the 100-plus feet of till in the northwest corner of the study area. The upper till is described in well logs and in outcrop (see Ruhe and Scholtes, 1955) as a yellow to light grey sandy loam.

The surface on the upper till, when corrected for post-glacial erosion, ranged in elevation from less than 1,000 feet to slightly over 1,100 feet (Figure 2). The lower elevations around Ames reflect the Buried Skunk Valley, whereas the higher elevations along the north margins of the area reflect the Altamont Moraine in the northwest and a bedrock upland in the northeast. The reconstructed surface is probably incorrect in that the Squaw and Skunk valleys do not appear. Because the modern Squaw Creek and Skunk River have reoccupied the buried valleys, it is logical to assume that a depression occurred on the post-upper till surface. The relief on the initial surface was slightly over 100 feet. After post-glacial erosion, the total relief is 300 feet in the area with the local relief along Squaw Creek being 75 feet and along Skunk River being 125 feet (Table 1).

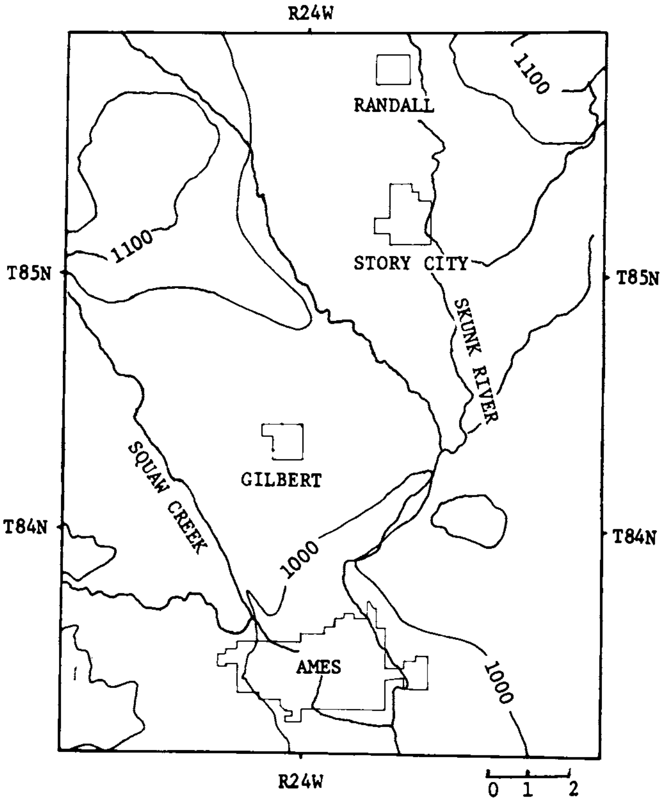


Figure 2. Topographic map of the surface on top of the upper till, corrected for post-glacial erosion.

TABLE 1. LOCAL RELIEF VARIATIONS

Valley	*Average Local Relief (Feet)*		*Average Elevation (Feet)*		
	Upland Over Bedrock Upland (Range)	Upland Over Bedrock Valley (Range)	Upland Over Bedrock Upland (Range)	Upland Over Bedrock Valley (Range)	Present Flood-plain (Range)
Squaw	76	56	995	970	913
(N = 7)	(60-90)	(40-65)	(990-1000)	(960-980)	(890-930)
Skunk	126	73	1053	983	900
(N = 3)	(100-160)	(60-80)	(1020-1080)	(960-1000)	(810-910)

DISCUSSION

Three aspects of the data presented are worthy of discussion; these are the mimicking of the bedrock topography by three successive land surfaces, the erosion of the lower and middle tills and the middle silt, and the relationship between surface forms on the Cary till and the thickness of the Cary till, i.e., the glacial continuum model of Clayton (1972).

A comparison between the bedrock topographic map (Figure 1A) and the lower till isopachous map (Figure 1B), the post-middle silt surface (Figure 2F) and post-upper till surface (Figure 2), indicates that after each glacial phase the surface drainage re-occupied the bedrock valleys. Local exception to this generalization occurred (Sendlein and Backsen, 1966; Sendlein and Dougal, 1968) but the "fit" is good, as indicated by the degrees of coincidence between the present main drainage and the bedrock topography (Figure 1A). The continued reoccupation of the bedrock valleys by the major drainage suggests that either each drift sheet or each ice sheet was sufficiently thin to mantle the bedrock surface, so that a depression remained along the axes of the bedrock valleys. The crevasse fill along Squaw Creek (Foster and Palmquist, 1969) suggests a thin Cary-age glacier and localization of supraglacial drainage along Squaw Creek. The implications of this mantling phenomenon are twofold: first, the present major drainage largely follows bedrock valleys, and second, areas of lower elevation or lower local relief adjacent to a modern stream may overlie a buried bedrock valley. The coincidence of modern and bedrock valleys and the differences in local relief between areas located over buried bedrock uplands and those over bedrock valleys (Table 1) verify this generalization for the Ames area.

The local absence of the lower and middle tills and the middle silt on the bedrock uplands suggests their removal by subsequent erosion. Variations in thickness can be the product of either depositional differences and/or subsequent differential erosion, in this case, either by glaciers or runoff and streams. The thickness variations of the upper till over the Gilbert bedrock upland (Figure 1H) are indicative of depositional variations. Walker (1966), in his study of postglacial upland bogs, found evidence for only six feet of lowering. Therefore, the estimated 30-foot average variation in upper till thickness can be related to deposition. Assuming the same depositional variation for the middle till as exists for the upper till, the average 40-foot thickness of the middle till over the Gilbert bedrock upland suggests about 20 feet of local subsequent erosion. The complete absence of lower till on the bedrock upland cannot be completely attributed to interglacial erosion because over 15 feet of Kansan till persists on bedrock uplands south of the Des Moines Lobe. The maximum thickness of the lower till in the Squaw Buried Valley is similar to the maximum thickness (125 feet) of the upper till in the valley. If the same 2:1 variation between maximum till thickness in valley and average till thickness over uplands existed for the lower till as exists for the upper till, then 50 feet of lower till can be inferred as having existed over the bedrock uplands. The upper unit of the middle silt is loessial in origin and about 15 feet thick. Its local absence indicates that 15 feet of loess has been eroded from the bedrock uplands.

The thickness of lower till, middle till and middle silt removed by water erosion relative to that removed by glacial erosion is difficult to infer. The problem may be attacked by comparing the amount of post-glacial erosion to the time available for nonglacial erosion of the lower and middle tills. Approximately six feet of lowering has locally occurred on the present uplands in the 13,000 years since deglaciation, for an average erosion rate of 0.5 feet/1,000 years based upon data that were obtained from bogs, which are closed systems. However, if we assume that similar open systems exist adjacent to main valleys, these data may be used as an approximation. If the middle till is assumed to be Tazewell in age, deglaciation occurred around 18,000 ybp (Ruhe, 1969), and the Cary advance occurred around 14,000 ybp, then 4,000 years are available for water erosion. At 0.5 feet/1,000 years, an average maximum of two feet of middle till could be eroded. This rate is a maximum because the loess of the middle silt unit was deposited during this 4,000-year interval. If the amount of water erosion is negligible, then the 20 feet of middle till and 15 feet of loess that were eroded from the Gilbert and other bedrock uplands must have been removed by the advancing Cary glacier. How much lower till was removed by the Tazewell glacier or by the subsequent Cary glacier is difficult to estimate, but it could be about 15 feet.

The incorporation of 20 feet of middle till and 15 feet of loess into the average 50 feet of Cary till suggests that 80 percent of the Cary till locally may consist of reworked older materials. Ruhe and Scholtes (1955) describe a block of loess included within the Cary till along Clear Creek.

Clayton (1972) formulated a continuum model for the origin of glacial morainal forms. The bases of the model are the assumptions that all till is ablation till, that till is brought to the ice surface by thrusting and that the depositional landforms are related to ice stagnation and to till thickness. According to the model, as till thickness increases the landforms change from washboard moraines to transverse trends to circular features to irregular topography. A comparison of percentage of each of these landforms within a square mile to the thickness of the upper, Cary-age till allowed a partial quantification of Clayton's model (Figure 3). The relationship between till thickness and landform was not as close as one would like. Some areas of thin till were dominated by transverse trends rather than washboard moraines and some areas of very thick till could not be distinguished from those areas with thin till. However, the basic assumptions in Clayton's model may not apply to all the landforms in the model. For instance, the washboard moraines have been considered

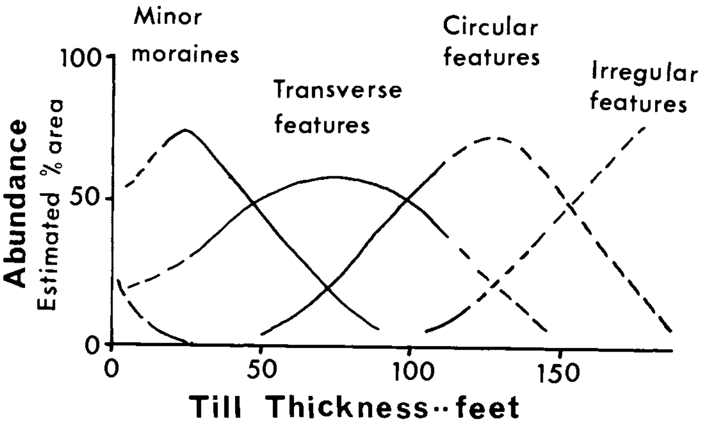


Figure 3. Relationship between thickness of Cary till and the abundance of specified glacial landforms developed upon that till. All abundances were visually estimated from aerial photographs. Curves are generalized from few points.

as lodgement features by Elson (1957), waveforms (Foster and Palmquist, 1969) and push moraines (Gwynne, 1942a).

SUMMARY

Three till bodies, one silt body and a sand and gravel body, all of Pleistocene age, are recognized in the Ames area. The shapes and distribution of these bodies suggest that the Squaw Buried Valley is older than the Skunk Buried Valley, that after each successive glaciation the drainage reoccupied the buried bedrock valleys, that each successive glacier locally eroded older materials, and that more till was deposited in buried valleys than on the bedrock uplands. A comparison of surface landforms to the thickness of the upper till suggests that washboard moraines, transverse features and circular features are dominant when the till thickness is 20, 75 and 125 feet, respectively.

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