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Devonian-Mississippian Transition in Central Texas

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ABSTRACT

The Devonian-Mississippian transition outcrops of central Texas are here described summarily and assigned to a new stratigraphic unit, the Houy Formation. The beds included are mainly Upper Devonian, but partly Lower Mississippian. Locally a basal fraction may be Middle Devonian. Although the deposits included are diverse and their associations complex, the maximum surface thickness so far known is only about 17 feet.

The principal subdivisions, in their usual ascending order, are the Ives Breccia Member (Plummer *in* Bullard and Plummer, 1939), the Doublehorn Shale Member (new), and a thin unnamed phosphoritic interval. Commonly, however, one or more of these members is absent, and rocks not assigned to any member are present. The Ives Breccia Member includes lag deposits of detrital chert of varied age and source. The Doublehorn Shale Member includes black, fissile, spore-bearing shale of Late Devonian age which in a few exposures grades upward into shale of Early Mississippian age. The phosphatic beds are partly Late Devonian and partly Early Mississippian. Remnants of the Doublehorn Shale Member have been found only along the eastern side of the Llano region, but the other units are more widely distributed, and rocks assignable to the Houy Formation are to be looked for between Ordovician and Upper Mississippian deposits anywhere around the Llano region.

Although most abundant in the upper beds, phosphatic inclusions occur locally throughout the Houy Formation. This gives a stamp of unity to the sequence and distinguishes it from the immediately underlying beds as well as from the overlying Chappel Limestone of later Early Mississippian age. The Houy is also a unit of more than average radioactivity and is readily detected in the subsurface by radioactive drill-hole logging.

It correlates with the Late Devonian and earliest Mississippian black-shale sequences of other Midcontinent and Midwestern areas. Four of the six conodont zones (Hass, 1947; 1956a; 1956b) in deposits of this age in Ohio, Tennessee, Oklahoma, and Arkansas are recognized also in central Texas.

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INTRODUCTION

The stratigraphic record of the Llano region, Texas, between Early Ordovician and Pennsylvanian time is a complex of formerly extensive units, the remnants of which have been described piecemeal as they have been discovered. In the case of the transition beds here under discussion, it was the writers' original intention to reserve publication until a comprehensive report on the stratigraphy and paleontology of all these relict Paleozoic formations could be prepared. As completion of such a work still faces considerable delay, it now seems advisable to publish essential data on the Devonian-Mississippian transition beds and bring their nomenclature up to date.

Undescribed or unnamed rocks recently found in the Llano region include, in upward succession, (1) coarse-grained limestone with fossils indicating equivalence to the Onondaga Limestone of Early or Middle Devonian age, (2) additional deposits of Late Devonian and Early Mississippian age, of which a few have been mentioned in print (Barnes, 1951, p. 7; 1956, p. 21–22); and (3) a phosphorite deposit of Early Pennsylvanian age which is the subject of a separate report by Barnes (1954).

Although the megafossils from the coarse-grained Devonian limestone suggest to Cloud a

PLATE 2.—HOUY FORMATION AT BURNAM BRANCH AND HOUY RANCH AND IVES BRECCIA MEMBER AT TYPE SECTION AND AT KING SPRING SECTION

FIGURE 1.—General view of type section of Houy Formation at juncture of Burnam Branch and Doublehorn Creek, Burnam ranch (Pl. 1, section 8 in part).

FIGURE 2.—Detail at upper part of section shown in Figure 1 of this plate, at contact between the Houy and Barnett formations. Chappel Limestone is missing and upper hammer rests on thin phosphorite bed at top of Houy Formation (USGS coll. 15552-C). Hole below and to right of lower hammer is site of USGS coll. 3926-SD.

FIGURE 3.—Greenish silty shale of probable late Middle or early Late Devonian age, dug through at depth of 2 feet, beneath 3 feet of Ives Breccia Member and resting on similar Ives-like chert in Doublehorn Creek on Rubin Houy ranch (Pl. 1, section 9). Ives is early Late Devonian age at this place, and both it and green shale are included in the Houy Formation.

FIGURE 4.—Blocks of Ives Breccia Member at type site Plate 1, section 2, from a kodaslide by W. Charles Bell.

FIGURE 5.—Smooth surface of Ives Breccia Member (×3/5) showing large amount of relatively fine matrix, King Spring (Pl. 1, section 3; also Pl. 3, Fig. 6).

PLATE 3—HOUY FORMATION, CHAPPEL LIMESTONE, AND BARNETT FORMATION AT FOWLER RANCH AND KING SPRING SECTION

FIGURE 1.—Hammer on upper phosphorite of Houy Formation in middle of photograph. Doublehorn Shale Member below (4 feet thick to creek level) and petroliferous shale of Barnett Formation above. Loc. 27T-6-42D, Plate 1, section 7 in part. Chappel Limestone is missing at this site.

FIGURE 2.—Chappel Limestone 3 feet thick, preserved in small collapse structure 100 feet east of Figure 1 of this plate.

FIGURE 3.—Trench section through 8 feet of weathered Doublehorn Shale Member of Houy Formation, Ives Breccia Member or highly cherty beds of the Stribling Formation (x) beneath and Chappel Limestone (Cc) above. C_1, C_2, and C_3 indicate subdivisions of loc. 27T-6-42C, equivalent to USGS colls. 3924-SD, 3922-SD, and 1555O-C of. Plate 1, section 7. Exposure is at left side of Figure 2 of this plate.

FIGURE 4.—Loc. 27T-6-42B, 500 feet eastward down the draw from Figure 1 of this plate. Four- to 12-inch-thick Chappel Limestone (Cc) arches over Doublehorn Shale Member of Houy Formation from hammer at left to Cc at right.

FIGURE 5.—Doublehorn Shale Member dug and blasted out beneath 5-inch-thick Chappel Limestone (Cc) near right side of Figure 4 of this plate. B_2 and B_4 indicate subdivisions of loc. 27T-6-42B, corresponding to USGS colls. 3923-SD and 15551-C of Plate 1, section 7.

FIGURE 6.—King Spring section (Pl. 1, section 3). Hammer at left rests against 2- to 11-inch-thick argillaceous limestone of early Kinderhook age (USGS colls. 15541-C, 15542-C, 15543-C), on top of which (i) is a 12- to 18-inch-thickness of the Ives Breccia Member (USGS coll. 3919-SD), both of the Houy Formation (*see* Pl. 2, fig. 5.

FIGURE 1

FIGURE 2

FIGURE 4

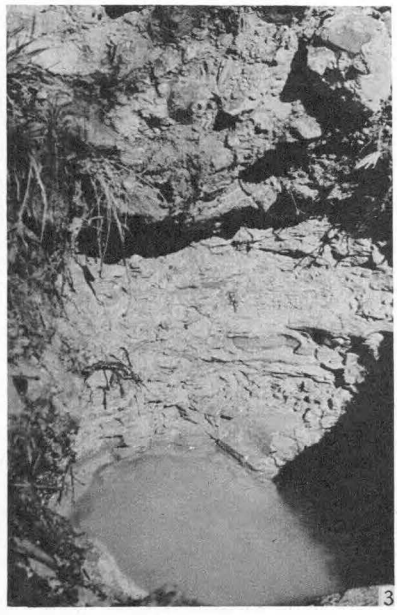
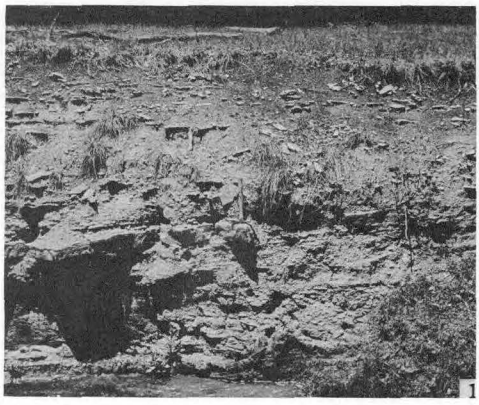
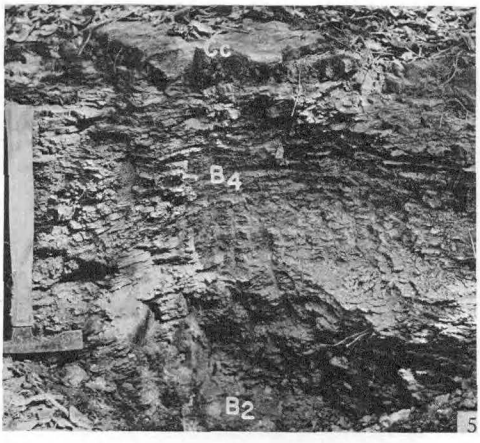


FIGURE 3

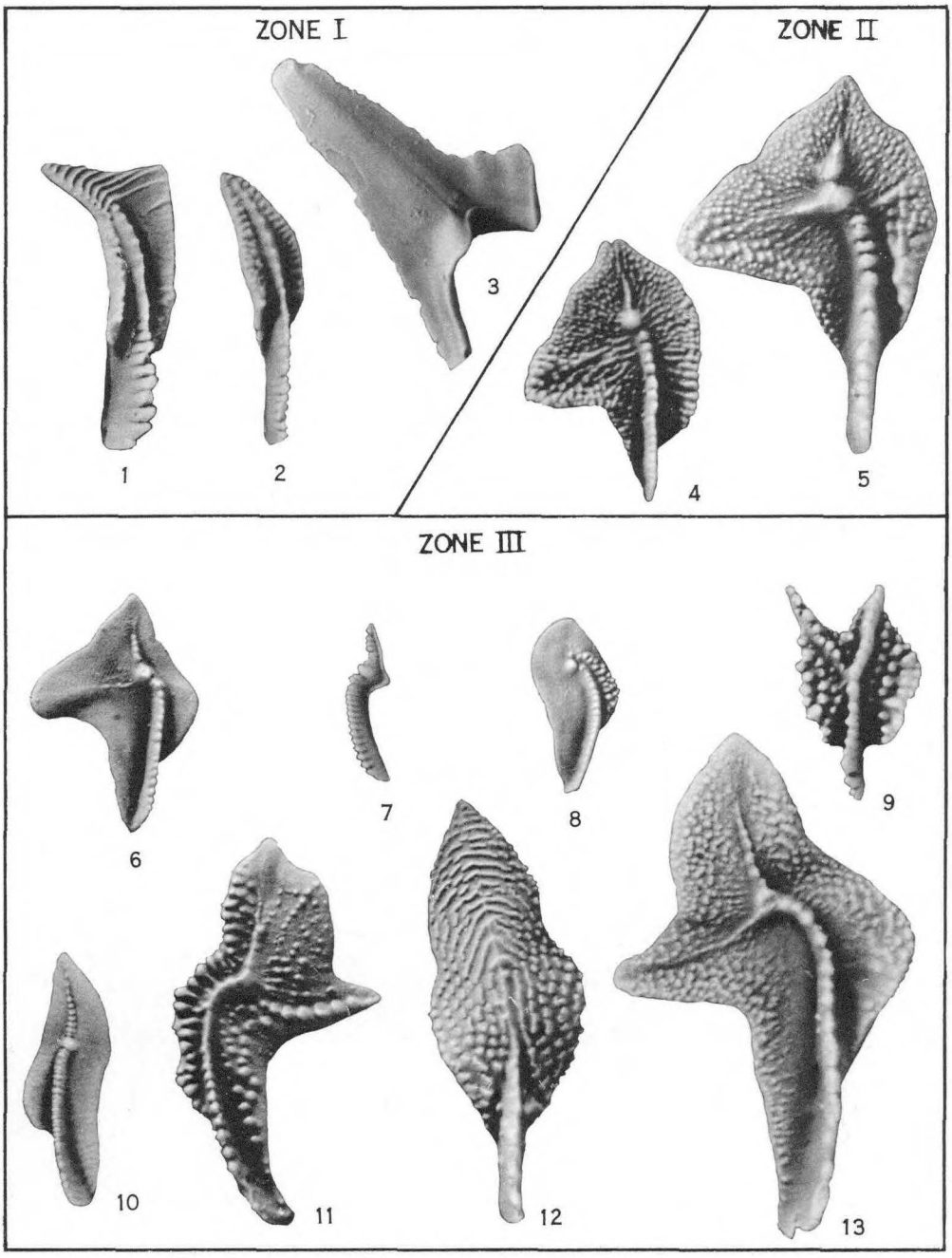
FIGURE 5

HOUY FORMATION AT BURNAM BRANCH AND HOUY RANCH AND IVES BRECCIA MEMBER AT TYPE SECTION AND AT KING SPRING SECTION

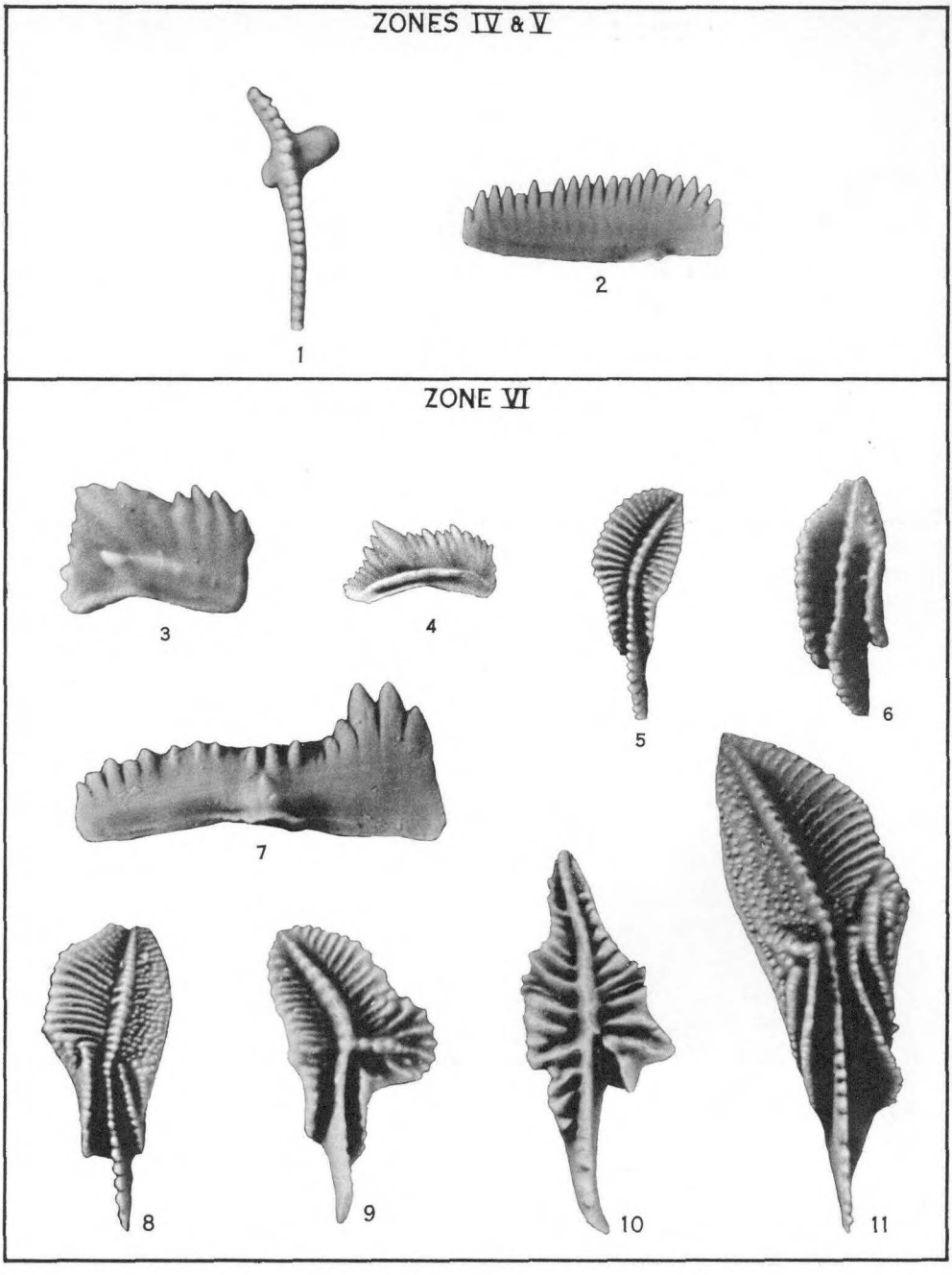




HOUY FORMATION, CHAPPEL LIMESTONE AND BARNETT FORMATION AT FOWLER RANCH AND KING, SPRING SECTION



REPRESENTATIVE CONODONTS OF THE HOUY FORMATION



REPRESENTATIVE CONODONTS OF THE HOUY FORMATION

slightly higher position in the Onondaga sequence than the type Stribling, the field relations so far observed are obscure, and the limestone could be below or equivalent to the microgranular limestone, dolomite, and chert of the Stribling Formation. A point favoring a relatively high position for the coarse limestone is that nothing similar to it has been found between typical Stribling and a thin and irregular interval of sparingly glauconitic impure limestone (Barnes *et al.*, 1953, Fig. 1) that is now provisionally considered basal Stribling.

The phosphorite of Pennsylvanian age, provisionally referred to the basal part of the

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PLATE 4.—REPRESENTATIVE CONODONTS OF THE HOUY FORMATION

All magnifications ×26. All specimens except Figures 2 and 7 from USGS coll. 9264-C (Pl. 1, section 10). Illustrated specimens selected for quality, despite fact that all except those represented by Figures 4 and 5 are considered to have been reworked.

FIGURE 1.—*Polygnathus linguiformis* Hinde. Oral view, hypotype, U.S.N.M. 114904.

FIGURE 2.—*Polygnathus pennata* Hinde. Oral view, hypotype, U.S.N.M. 127851. Locality about 5 miles southeast of Lampasas, in Burnet County, on north side of Pillar Bluff Creek (Barnes *et al.*, 1947, Fig. 3, loc. TF-294), USGS coll. 3940-SD.

FIGURE 3.—*Neoprioniodus alatus* Hinde. Lateral view of inner side, hypotype, U.S.N.M. 127852.

FIGURE 4.—*Palmatolepis unicornis* Miller and Youngquist. Oral view, hypotype, U.S.N.M. 127853.

FIGURE 5.—*Palmatolepis subrecta* Miller and Youngquist. Oral view, hypotype, U.S.N.M. 127854.

FIGURE 6.—*Palmatolepis subperlobata* Branson and Mehl. Oral view, hypotype, U.S.N.M. 114826.

FIGURE 7.—*Palmatolepis gracilis* Branson and Mehl. Oral view, hypotype, U.S.N.M. 114827. Locality about 4 miles southeast of bridge over Colorado River at Marble Falls, Burnet County, along north side of ranch road. USGS coll. 9053-C.

FIGURE 8.—*Palmatolepis quadrantinodosa* Branson and Mehl. Oral view, hypotype, U.S.N.M. 114821.

FIGURE 9.—*Ancyrognathus bifurcata* (Ulrich and Bassler). Oral view, hypotype, U.S.N.M. 114834.

FIGURE 10.—*Palmatolepis glabra* Ulrich and Bassler. Oral view, hypotype, U.S.N.M. 114822.

FIGURE 11.—*Palmatolepis rugosa* Branson and Mehl. Oral view, hypotype, U.S.N.M. 114831.

FIGURE 12.—*Polylophodonta confluens* (Ulrich and Bassler). Oral view, hypotype, U.S.N.M. 114849.

FIGURE 13.—*Palmatolepis perlobata* Ulrich and Bassler. Oral view, hypotype, U.S.N.M. 114830.

PLATE 5—REPRESENTATIVE CONODONTS OF THE HOUY FORMATION

All magnifications ×26. All specimens except Figures 3–6 from USGS coll. 9264-C (Pl. 1, section 10). Elsewhere in the United States, Figure 1 is characteristic of zone IV; Figure 2 of zones IV and V; Figures 3–6 and 8–11 of zone VI; and Figure 7 of zones V and VI. Illustrated specimens selected for quality, although those illustrated by Figures 1 and 2 are considered to have been reworked. All but Figures 3 and 6 are from the same locality.

FIGURE 1.—*Spathognathodus disparilis* (Branson and Mehl). Oral view, hypotype, U.S.N.M. 114854.

FIGURE 2.—*Spathognathodus inornatus* (Branson and Mehl). Lateral view of inner side, hypotype, U.S.N.M. 115121.

FIGURE 3.—*Pinacognathus profunda* (Branson and Mehl). Lateral view of inner side, hypotype, U.S.N.M. 114977; near section 4 of Plate 1; from exposure now covered by fill from road cut made in 1950. USGS coll. 8653-C.

FIGURE 4.—*Elictognathus lacerata* (Branson and Mehl). Lateral view of inner side, hypotype, U.S.N.M. 127855.

FIGURE 5.—*Siphonodella duplicata* (Branson and Mehl). Oral view, hypotype, U.S.N.M. 115132.

FIGURE 6.—*Polygnathus inornata* E. R. Branson. Oral view, hypotype, U.S.N.M. 115135; near section 4 of Plate 1; from exposure now covered by fill from road cut made in 1950. USGS coll. 9008-C.

FIGURE 7.—*Spathognathodus aciedentatus* (E. R. Branson). Lateral view of inner side, hypotype, U.S.N.M. 115148.

FIGURE 8.—*Siphonodella duplicata* (Branson and Mehl) var. A. Oral view, hypotype, U.S.N.M. 115140.

FIGURE 9.—*Siphonodella lobata* (Branson and Mehl). Oral view, hypotype, U.S.N.M. 115150.

FIGURE 10.—*Pseudopolygnathus prima* (Branson and Mehl). Oral view, hypotype, U.S.N.M. 114940.

FIGURE 11.—*Siphonodella quadruplicata* (Branson and Mehl). Oral view, hypotype, U.S.N.M. 115146.

Marble Falls Limestone, also needs to be better understood before its nomenclatural disposal can be satisfactorily resolved.

The deposits which remain for consideration in this paper, then, are those—clustering around the Devonian-Mississippian boundary—that constitute the Houy Formation.

The authors wish to acknowledge frankly that they are still very much puzzled about the proper relationships of these beds and faunas even though they have seen a probably very high percentage of the available data on them. Nevertheless, the stratigraphic nomenclature is one of convenience; the interpretations are subject to revision when better evidence is found.

GENERAL FEATURES OF THE HOUY FORMATION

The general features and age relations of the Houy Formation are shown in Plate 1; a view of the type section in Figure 1 of Plate 2; and views of various units in Plates 2 and 3. Its more complete sections characteristically include, in upward succession, (A) 1–3 feet of chert breccia, the Ives Breccia Member of mainly Late Devonian age (Pl. 2, figs. 3–5; Pl. 3, fig. 6); (B) 2–15 feet of black, fissile shale, the Doublehorn Shale Member of younger Late Devonian and possibly earliest Mississippian age (Pl. 2, fig. 2; Pl. 3, figs. 1, 3–5); and (C) 2 feet or less of phosphoritic material of Early Mississippian and, at places, Late Devonian age (Pl. 2, fig. 2; Pl, 3, fig. 1). These deposits show abrupt variations in thickness and associations. Their maximum observed surface thickness, however, is 17 feet, and their geographic distribution has a broadly consistent pattern.

Lenses of chert breccia (and locally conglomerate) referred to the Ives Breccia Member have been found along the eastern, northern, and western sides of the Llano region, but the Doublehorn Shale Member crops out only along the eastern side of the region, and the most westerly known occurrence of the upper phosphatic beds is along San Saba River at the eastern edge of McCulloch County. Overlapping Cretaceous deposits conceal the possible outcrop belt of the Houy Formation in the southwestern part of the region. It is not known whether the apparent absence of the Houy in mapped portions of the Riley Mountains 11 miles southeast of Llano is due to nondeposition or later removal, but possibly the center of the Llano uplift was insular in Late Devonian and earliest Mississippian time.

The lowest and presumably oldest deposits of the Houy Formation are beds or pockets of siliceous limestone with chert fragments, or silty calcareous shale that occur locally beneath the Ives Breccia Member (Pl. 1, section 11).

Next in order, and in most places the basal unit of the formation, is the Ives Breccia Member, rarely as much as 3 feet thick (Pl. 2, fig. 3). The chert fragments or nodules that constitute the bulk of the breccia at most places are locally derived, are freshly fractured or preserve the form of nodules, and are evidently little-moved lag breccias that accumulated near or at the source of supply in low places on the floor of the invading sea. In some places the breccia fragments thin out downward to be replaced by sandstone (Pl. 1, section 2) or siliceous limestone (Pl. 1, section 1). Where the Doublehorn Shale Member is missing but both Ives-type breccias and phosphatic beds are present these are likely to be inseparably mixed (Pl. 1, sections 4, 10, 12).

The Ives Breccia Member is the only unit of the Houy Formation that has previously been classified in a formal arrangement of names. Plummer considered it to be a member of the Mississippian Chappel Formation, both in his original description (*in* Bullard and Plummer, 1939, p. 15) and in his final publication (Plummer, 1950, p. 27).[1] Cloud and Barnes (1948, p. 44, 48) also considered the Ives to be Mississippian, but distinct from the Chappel Limestone and of formational rank. Although they recognized its intimate association with probable

[1] Plummer's Espey Creek Limestone Member of the Chappel Formation (Plummer, 1950, p. 22–23, 26, 28) is the same as the Chappel Limestone (Sellards, 1933, p. 92; Cloud and Barnes, 1948, p. 49–52), excluding the basal 15 inches referred by him to the Chappel at Espey Creek (Pl. 1, section 6). Plummer's Whites Crossing Coquina Member (Plummer, 1950, p. 24–26, 28), also referred by him to the Chappel Formation, is an echinodermal limestone facies in the lower part of the Barnett Formation (Cloud and Barnes, 1948, p. 45, 56–57). The "King Creek marl member" of Plummer's Chappel Formation (Plummer, 1950, p. 23, 26, 27) is an argillaceous limestone that has been surely identified only at its type site on King Creek (Pl. 1, section 3),

Devonian as well as with Mississippian rocks, they excluded from it similar deposits of known early Late Devonian age and overstressed its Mississippian aspects. New stratigraphic evidence partly summarized in Plate 1 shows Ives-type breccias beneath deposits of demonstrable Devonian age at a number of localities and confirms the earlier conclusion by Hass from conodont studies that chert breccias of this type occur at two or more levels within the Upper Devonian and possibly also in highest Middle Devonian. In fact, all the now unquestioned Ives outcrops that are also unquestionably in normal position and unequivocally dated have turned out to be Devonian. At several other places, however, the field relationships indicate either an early Mississippian age or a mixing with or infiltration by Mississippian deposits after the original deposition of the breccia (Pl. 1, sections 3, 4, 10, 12). This new evidence also leads to the suppression of the Zesch Formation of Barnes *et al.* (1947, p. 137–139), for it is a partial synonym of the Ives Breccia.

The principal unit of the Houy Formation, the Doublehorn Shale Member (Pl. 1, type section 8), is a black, fissile, radioactive (about 0.01 per cent equivalent uranium), spore-bearing shale from which, at places, large silicified pieces of the wood of *Callixylon* (identified by R. A. Scott, U. S. Geological Survey, letter of April 6, 1956, to Cloud) have weathered free. As *Callixylon* is generally considered distinctive of the Upper Devonian, its discovery reinforces the evidence of the conodonts that the black shale is in large part of Late Devonian age. At some places, however, it also includes Mississippian rocks (Pl. 1, section 7). Its maximum thickness is 15 feet, and it thins to disappearance.

The upper or phosphoritic unit of the Houy Formation, 2 feet or less thick, contains fish bones that have been determined by Dunkle and Wilson (1952) to be *Dinichthys* cf. *D. terrelli* Newberry and an unidentifiable arthrodire. *D. terrelli* and its relatives seem to be restricted to the Ohio Shale of Late Devonian age and its equivalents. Devonian conodonts have been found also in some of the phosphatic beds (Pl. 1, sections 5 and 11). The same or closely associated beds, however, contain *Sedenticellula* aff. *S. hamburgensis* (Weller) and other brachiopods considered indicative of earliest Mississippian (Cloud and Barnes, 1948, Pl. 44, figs. 12–16; *cf.* Plummer, 1950, Pl. 5, figs. 13 a–b) as well as Early Mississippian conodonts. Thus the phosphoritic beds also seem to be partly Devonian and partly Mississippian, or to include extraneous fossils from one or the other source. Some beds are radioactive. The equivalent uranium content of random samples from section 6 (Pl. 1) was determined as 0.01–0.006 per cent (Personal communication, B. A. McCall, U. S. Geol. Survey, May 17, 1956). Another sample, from a thicker zone at section 5 (Pl. 1), contained 0.02 per cent equivalent uranium (Personal communication, Roosevelt Moore, U. S. Geol. Survey, July 18, 1956).

Although phosphoritic or highly phosphatic beds seem everywhere to be lower Kinderhook, uppermost Devonian, or both, scattered phosphatic pellets are likely to occur anywhere in the Houy Formation, including the Ives Breccia Member. No appreciable amount of phosphate has been seen by the authors in the overlying Chappel Limestone (Pl. 3, figs. 2, 3–5) or elsewhere in central Texas below the Barnett Formation (Pl. 3, fig. 1) except in the Houy Formation and a disappearingly thin zone at the base of the Stribling Formation.

It is, nevertheless, evident that the deposits included in the Houy Formation comprise several distinctive lithic types and may well be an unnatural agglomeration of discrete microunits. It is generally possible, also, through laboratory studies of the conodonts found in them, to assign a probable age to any given thin interval, bed, or pocket of the Houy Formation. The separate occurrences which have not, how-

where it constitutes a few inches of the Houy Formation. Although it contains conodonts and megafossils of early Kinderhook sorts, the type "King Creek marl" occurs beneath the Ives Breccia Member (Pl. 3, fig. 6), which has here yielded only Devonian types of conodonts. Indeed, the numerous crack fillings, collapse structures (Pl. 3, fig. 2), and otherwise displaced deposits of the region are probably responsible for the mixture of "Chappel" fossils illustrated by Plummer (1950, Pl. 5). These include forms characteristic of the Lower Devonian (Plummer, 1950, Pl. 5, figs. 10, 11, 16, 21, 22), the lower or middle Kinderhook (Figs. 13a–b), and post-Kinderhook Mississippian (Figs. 1, 7–9). The upper Kinderhook (and partly ?lower Osage) Chappel Limestone proper is represented most distinctively by Plummer's Figures 23a–b of *Shumardella, obsolens* (Hall).

ever, been classified to the consistent satisfaction of the authors in the field are too closely related and too small to map separately at a useful quadrangle scale. Practical considerations thus leave no satisfactory alternative to a "lumping" formational name for the entire transition complex—characterized lithically by phosphate content and radioactivity that is higher than usual for the area.

CONODONT ZONES AND CORRELATION

The Houy Formation is the representative in central Texas of the widespread Upper Devonian and Lower Mississippian black-shale succession that includes such well-known eastern and midcontinent deposits as the Chattanooga, Ohio, New Albany, and Woodford shales. The basal beds of this succession are low Upper Devonian (or possibly high Middle Devonian), and the topmost beds are Mississippian (lower Kinderhook). Six conodont zones have been recognized within this sequence (Hass, 1947; 1956a; 1956b). Although these zones are transitional to one another in the boundary intervals, their modal characteristics are generally well defined, and all except one (zone V of this report) have been recognized over such a large area as to minimize the probability of significant overlap between them.

Although four of these zones have been recognized in the Houy Formation (Pls. 1, 4, 5), this zonation is not so well defined in the Llano region as elsewhere, presumably because individual beds of the Houy are commonly thin, discontinuous, and mixed. As a result, many collections from the Houy contain, in association, conodonts that are segregated at two or more stratigraphic levels where the black-shale succession is thick and well developed, as in central Tennessee and central Ohio. For present purposes these conodont zones are designated I to VI in order of upward succession.

The evidence for the zone assignment of beds in the sections illustrated in Plate 1 is not presented in detail in this paper. However, numerous collections were studied, and faunal lists were prepared for the collections that came from the sections listed in Plate 1. On that plate, these collections and the appropriate zone symbol serve as control points within the Houy Formation. Nearly all these collections contain some of the pertinent index conodonts illustrated on Plates 4 and 5 or listed in the discussion that follows.

ZONE I: The oldest beds of the Houy Formation are considered to be early Late Devonian (or possibly late Middle Devonian). They include the lower half of the Ives Breccia Member (formerly the Zesch Formation) at section 1, the entire Ives at sections 8, 9, and 11, and the pocket filling beneath the Ives at section 11. Conodonts characteristic of this zone include *Polygnathus linguiformis* Hinde, *P. pennata* Hinde, and *Neoprioniodus alatus* Hinde (Pl. 4, figs. 1–3). These species have been found in the Genundewa Limestone Lentil of the Geneseo Shale of western New York, the base of the Dowelltown Member of the Chattanooga Shale along the Eastern Highland Rim of central Tennessee (Hass, 1956b), and the lower part of the Dowelltown Member of the Chattanooga Shale in north-central Tennessee. One or more of them are also in the basal portion of the middle division of the Arkansas Novaculite in Hot Spring County, Arkansas (Hass, 1956a) and the basal beds of the Woodford and New Albany shales (Hass, 1956b).

ZONE II: Collections from loose slabs indicate that beds slightly younger than those assigned to zone I are in the Doublehorn Shale Member of the Houy Formation at sections 7, 8, and 9. Zone II conodonts are also present in the basal phosphoritic beds of the Houy at section 6. The conodonts representative of this zone include *Ancyrognathus euglypheus* Stauffer, *Palmatolepis subrecta* Miller and Youngquist, *P. marginata* Stauffer, and *P. unicornis* Miller and Youngquist (Pl. 4, figs. 4, 5). Although *P. unicornis* in some areas ranges into zone I, it is more commonly found in association with zone II species. All the species mentioned have been found in the Dowelltown Member of the Chattanooga Shale of central Tennessee (Hass, 19S6b). Some of them have also been recognized in the Olentangy Shale of Ohio, a restricted part of the middle division of the Arkansas Novaculite at Caddo Gap, Arkansas, and Woodford Shale in Oklahoma.

ZONE III: Zone III is represented by the upper half of the Ives Breccia Member at section 1,

and by all the Ives at sections 2 and 3. This zone is also in the Doublehorn Shale Member at sections 5, 7, and 11. Conodonts characteristic of zone III include *Ancyrognathus bifurcata* (Ulrich and Bassler), *Palmatodella delicatula* Bassler, seven species of *Palmatolepis* (of which six are illustrated on Pl. 4), *Polylophodonta confluens* (Ulrich and Bassler), and *Neoprioniodus mutabilis* Branson and Mehl (Pl. 4, figs. 6–13). These conodonts occur in the lower faunal zone of the Gassaway Member of the Chattanooga Shale of central Tennessee (Hass, 1956b). Some or all of them have been recognized in the Gowanda Shale Member of the Perrysburg Formation and overlying Upper Devonian beds of western New York; in restricted parts of the Ohio, New Albany, and Woodford shales; and in the middle division of the Arkansas Novaculite.

ZONES IV AND V: Zone IV, which has been recognized in the Cleveland Shale Member of the Ohio Shale and the upper faunal zone of the Gassaway Member of the Chattanooga Shale, and zone V, which is tentatively based on the restricted occurrence of a few species in the basal Bedford Shale of Ohio, have not been recognized in the Houy Formation. However, some Houy collections have yielded specimens, possibly reworked, of *Spathognathodus disparilis* (Branson and Mehl), considered characteristic of zone IV; *S. inornatus* (Branson and Mehl), considered characteristic of zones IV and V; and *S. aciedentatus* (E. R. Branson), considered characteristic of zones V and VI (Pl. 5, figs. 1, 2, 7). If the time ranges of these species were the same in central Texas as in other areas, their failure to segregate zonally suggests either subsequent erosion or total by-passing of the sediments with which they would be normally associated. The alternative interpretation—that zone III conodonts in central Texas persisted through the time interval of zones IV and V—would be a more attractive one if the local sequence were thicker and less interrupted.

ZONE VI: The youngest beds of the Houy Formation are of Early Mississippian (early Kinderhook) age. They are present at sections 3, 4, 6–8, and 10–12. The phosphorite at section 5 may also belong with this group of deposits. All these collections contain an apparently mixed association in which early Kinderhook and Late Devonian conodonts of zone III predominate. In most of these collections, Mississippian specimens outnumber those from the Devonian, but in the phosphorite at section 5 Devonian species far outnumber the Mississippian representatives. Some of the conodont species which, as a group, characterize zone VI are: *Dinodus fragosus* (E. R. Branson), *Elictognathus bialata* (Branson and Mehl), *E. lacerata* (Branson and Mehl), *Pinacognathus profundo,* (Branson and Mehl), *Polygnathus communis* Branson and Mehl, *P. inornata* E. R. Branson, *Pseudopolygnathus prima* Branson and Mehl, and five species of *Siphonodella* (Pl. 5, figs. 3–6, 8–11). Some or all of these have been recognized in the Sunbury Shale of Ohio and eastern Kentucky, Campbell's Falling Run Member of his (1946) Sanderson Formation and his Henryville Formation of Indiana, the Bushberg Sandstone Member of the Sulphur Springs Formation and the Hannibal Shale of Missouri, the topmost beds of the Chattanooga Shale of northeastern Oklahoma, the topmost beds of the Woodford Shale of Oklahoma, in beds near the top of the middle division of the Arkansas Novaculite at Caddo Gap, Arkansas, and the greater part of the Maury Formation of Tennessee (Hass, 1956b).

REFERENCE SECTIONS

General Statement

The best-exposed and most nearly complete section of the Houy Formation is at the juncture of Burnam Branch with Doublehorn Creek in an eastward extension of the R. M. Burnam ranch (Fig. 1B; Pl. 1, section 8; Pl. 2, fig. 1). A more conveniently accessible and by now well-known section (Barnes, 1953; 1956, p. 21–23) is that on Doublehorn Creek, just downstream from Houy Branch, on the Rubin Houy ranch (Fig. 1A; Pl. 1, section 9). The best section, at Burnam Branch and Doublehorn Creek, is chosen as the type, but the formational name is taken from the reference section on the Houy ranch. Both are in southeastern Burnet County, Texas. Faunal data and stratigraphic relationships of both sections and similar information for a selection of compar-

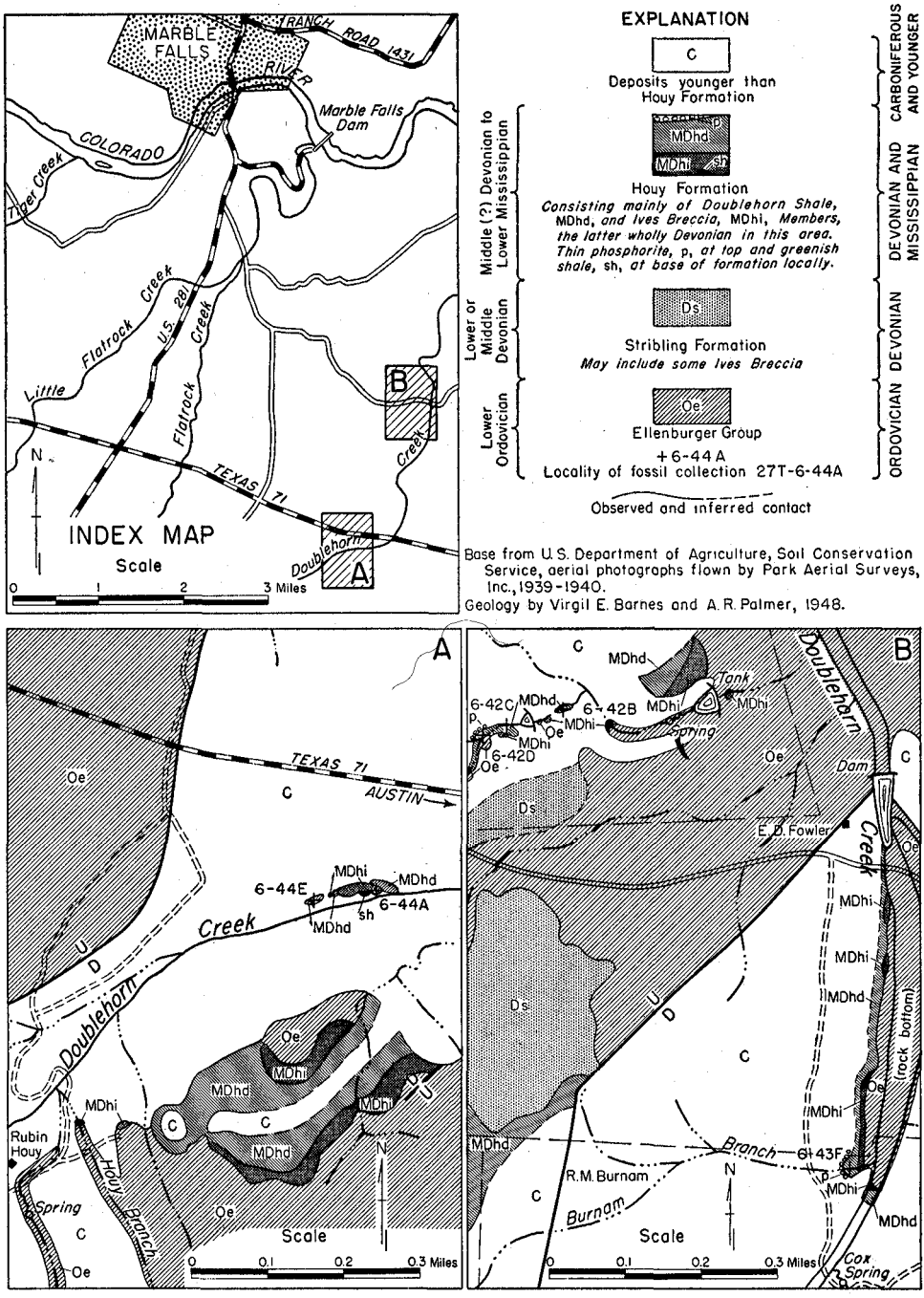

FIGURE 1.—GEOLOGIC MAPS ALONG DOUBLEHORN CREEK, SOUTHERN BURNET COUNTY, TEXAS

able sections around the Llano region are summarized in Plate 1.

Burnam Branch

The type section of the Houy Formation and the Doublehorn Shale Member is along Burnam Branch where it enters Doublehorn Creek. This is field locality 27T-6-43F[2] on Figure 1B. The following description, and section 8 on Plate 1, is supplemented by data from a submerged sequence in the bed of Doublehorn Creek.

Mississippian
- Barnett Formation (20 feet ±)—soft, somewhat fissile, punky-weathering shale with intercalated dark-brownish-gray limestone beds and lenticular concretions 1–2.5 inches thick. Contains *Lingula, Orbiculoidea, Leiorhynchus carboniferum* Girty, and conodonts of middle Mississippian (Meramec) age (Hass, 1953). Terminates upward against overhanging 4-foot ledge of black, spiculiferous Marble Falls Limestone of Early Pennsylvanian age.
- Chappel Limestone (0.3 feet)—gray, inequigranular limestone with scattered pelmatozoan columnals and upper Kinderhook conodonts. Crops out below water in natural pool on Doublehorn Creek, but missing in section up Burnam Branch.

Devonian and Mississippian
- Houy Formation (17.5 feet ±)
  - Phosphoritic member
    - Brown phosphorite containing bone fragments. USGS coll. 15552-C has abundant Kinderhook (zone VI) and a few Upper Devonian conodonts..... 0.2 feet
    - Phosphorite similar to above, in laminae 0.1–0.5 inches thick..... 0.2 feet
  - Doublehorn Shale Member—mainly black, fissile, dolomitic, spore-bearing shale, of which random samples were determined by James Schopf to have equivalent uranium content of 0.011 (coll. 3927-SD)-0.008 per cent (USGS coll. 3926-SD). A semiquantitative trace-elements analysis of a sample from USGS coll. 3927-SD was published by H. A. Tourtelot (1956, p. 76) under the number 116639. Upper foot includes some punky-weathering, silty-appearing, lighter-colored, less-fissile shale than seen below. USGS coll. 3926-SD contains Upper Devonian conodonts of zone III, among which *Palmatolepis glabra* is especially abundant. Conodonts of zone II were also found in a float slab (USGS coll. 3927-SD), and a loose piece of silicified wood was identified by R. A. Scott as the Upper Devonian genus *Cattixylon*... 15 feet
  - Ives Breccia Member—coarse angular chert breccia and fractured chert, with siliceous and calcareous matrix and containing round, pea-sized phosphatic pellets. Contains low Upper Devonian conodonts (zone I) in USGS colls. 3928-SD and 3929-SD.. 2 feet

Houy Ranch

The principal supplementary section of the Houy Formation in on the Rubin Houy ranch, along Doublehorn Creek just downstream from Houy Branch and about 1.5 miles south-southwest from the type section. To reach this site from the intersection of U. S. Highway 281 and Texas Highway 71 drive 2.9 miles east, turn south through a gate 0.3 mile to the northwest bank of Doublehorn Creek and walk downstream (east-northeast) about 300 yards.

At this place (Fig. 1A, loc. 27T-6-44A) the following section is partially exposed:

Mississippian
- Barnett Formation (16 feet ±, lower 7 feet well exposed)—dark-brown to gray petroliferous shale and gray calcareous shale with thin chert beds, small turbinate rugose corals in calcareous shale about a foot above the base, compressed *Leiorhynchus carboniferum* Girty, and *Orbiculoidea* sp. on bedding surfaces of chert, and middle Mississippian (Meramec) conodonts in the shale (Hass, 1953).
- Chappel Limestone (2 feet)—medium to dark-gray inequigranular limestone with scattered pelmatozoan columnals, small rare brachiopods and trilobites, and conodonts of Kinderhook (Chouteau) age.

Devonian
- Houy Formation (10–13 feet ±)
  - Doublehorn Shale Member (type section of new unit)—black, fissile, spore-bearing shale (mainly covered) of which a random sample was determined by James Schopf of the USGS to have 0.008 per cent equivalent uranium. USGS coll. 3930-SD, from float, contains Late Devonian (zone II) conodonts 5–8 feet ±
  - Ives Breccia Member
    - Massive lag-breccia consisting mostly of locally derived large (several inches) fragments and unbroken nodules of chalcedonic and microgranular chert such as is typical of the Stribling Formation. Large angular blocks of Lower Ordovician dolomite of the Honeycut Formation are locally included within or surrounded by the chert breccia. USGS colls. 3931-SD and 3932-SD, from sparse matrix of phosphatic-siliceous debris, contain early Late Devonian (zone I) conodonts..... 3 feet

[2] This is the form of locality numbers assigned by the Bureau of Economic Geology, The University of Texas. Numbers preceded by TF are Cloud's field numbers. Others are U. S. Geological Survey permanent locality numbers. Detailed locality data are on file at the apppropriate institution. Approximate location is shown on the inset index map on Plate 1.

Yellowish-green to greenish-gray shale with inarticulate brachiopods and rare *Polygnathus linguiformis* Hinde (USGS coll. 3933-SD). Exposed by digging into stream bed beneath breccia..... 2 feet

Chert similar to that above the shale, except that it is altered to a depth of nearly an inch and in part is coated by travertine. This unit normally is beneath water level and has been seen out of water only by Barnes on September 21, 1956, when Doublehorn Creek was completely dry. Bottom not exposed..... ?

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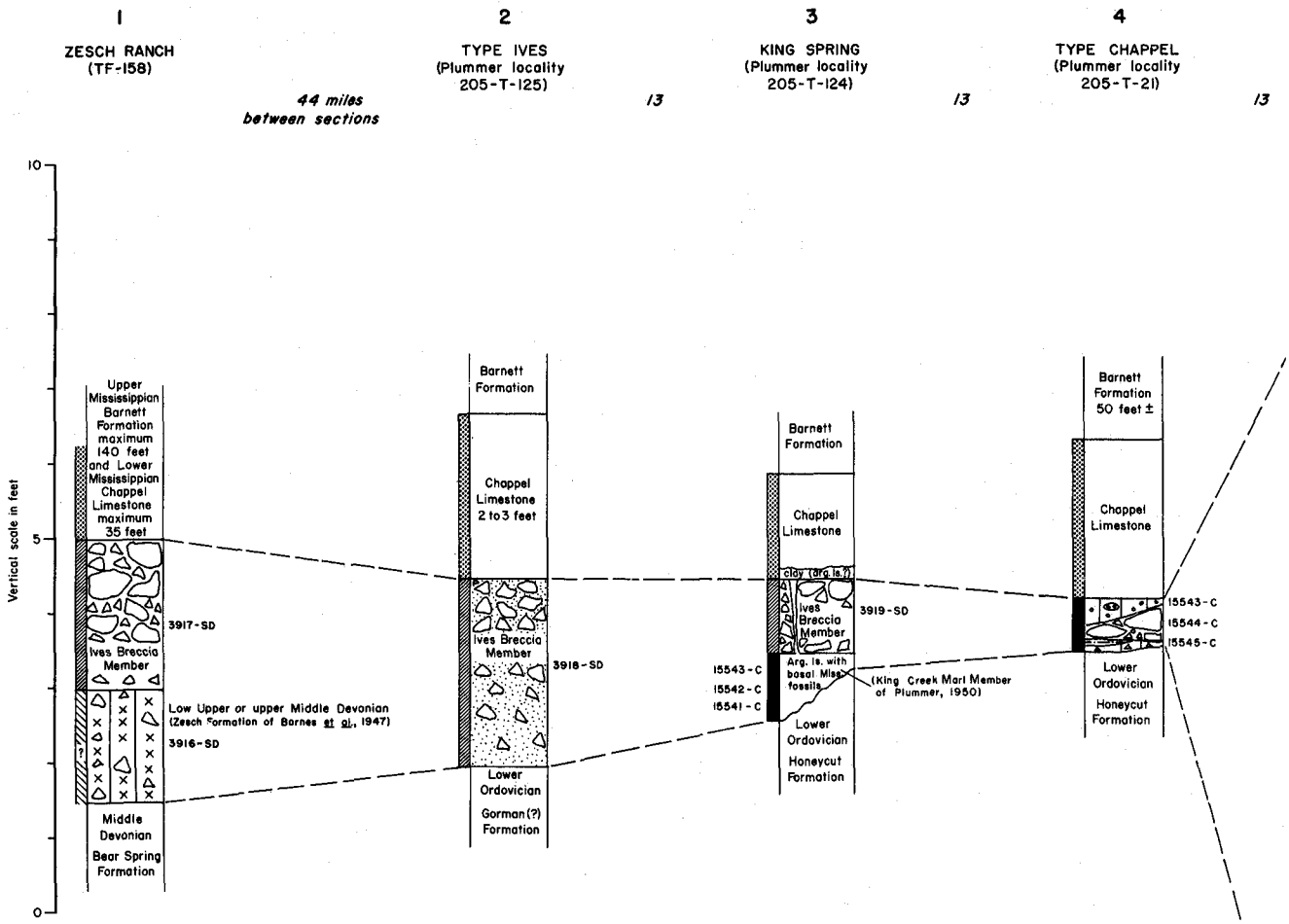
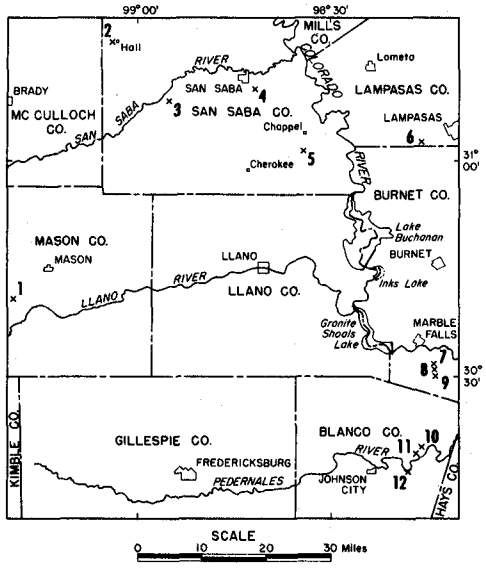
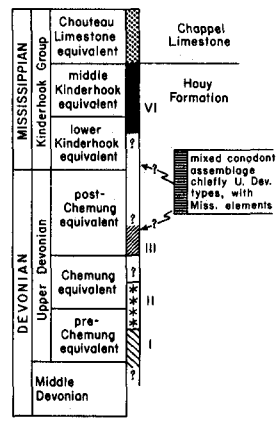




INDEX MAP

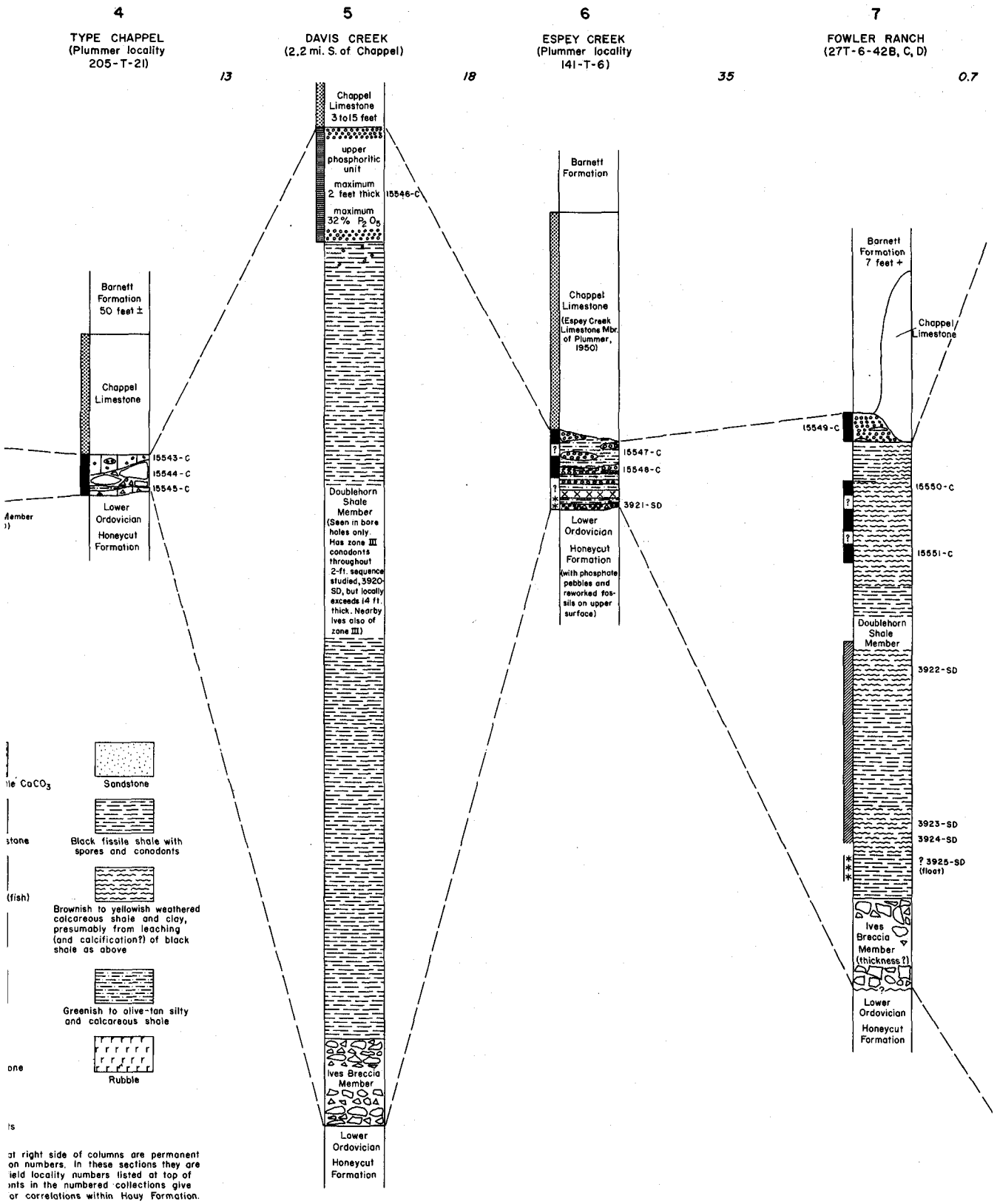


Faunal equivalence of Houy Formation and capping beds of Early Mississippian age

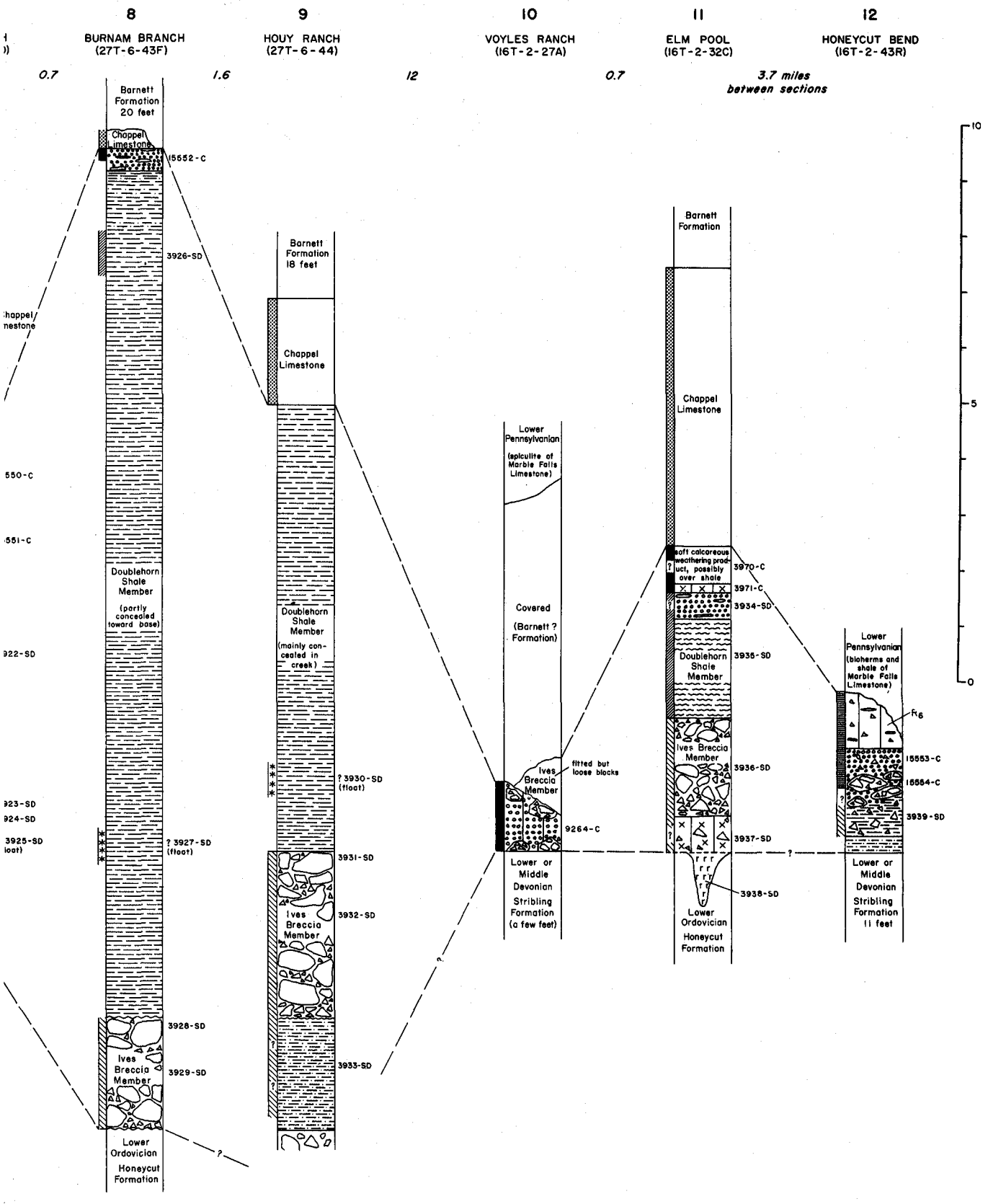
EXPLANATION

Phosphorite with little $CaCO_3$
Phosphatic limestone
Bone fragments (fish)
Limestone
Chert
Siliceous limestone
Chert fragments
Sandstone
Black fissile shale with spores and conodonts
Brownish to yellowish weathered calcareous shale and clay, presumably from leaching (and calcification?) of black shale as above
Greenish to olive-tan silty and calcareous shale
Rubble

Numbers mainly at right side of columns are permanent U.S.G.S. collection numbers. In these sections they are subordinate to field locality numbers listed at top of columns. Conodonts in the numbered collections give principal basis for correlations within Houy Formation.



KEY SECTIONS OF THE HOUY FORMATION


8
BURNAM BRANCH
(27T-6-43F)
9
HOUY RANCH
(27T-6-44)
10
VOYLES RANCH
(16T-2-27A)
11
ELM POOL
(16T-2-32C)
12
HONEYCUT BEND
(16T-2-43R)
0.7
1.6
12
0.7
3.7 miles
between sections
Barnett Formation 20 feet
Chappel Limestone
15552-C
3926-SD
Doublehorn Shale Member
(partly concealed toward base)
3928-SD
Ives Breccia Member
3929-SD
Lower Ordovician
Honeycut Formation
? 3927-SD (float)
Barnett Formation 18 feet
Chappel Limestone
Doublehorn Shale Member
(mainly concealed in creek)
? 3930-SD (float)
3931-SD
Ives Breccia Member
3932-SD
3933-SD
Lower Pennsylvanian
(spiculite of Marble Falls Limestone)
Covered
(Barnett ? Formation)
Ives Breccia Member
fitted but loose blocks
9264-C
Lower or Middle Devonian
Stribling Formation (a few feet)
Barnett Formation
Chappel Limestone
soft calcareous weathering product, possibly over shale
3970-C
3971-C
3934-SD
Doublehorn Shale Member
3935-SD
Ives Breccia Member
3936-SD
3937-SD
3938-SD
Lower Ordovician
Honeycut Formation
Lower Pennsylvanian
(bioherms and shale of Marble Falls Limestone)
15553-C
15554-C
3939-SD
Lower or Middle Devonian
Stribling Formation 11 feet
10
5
0