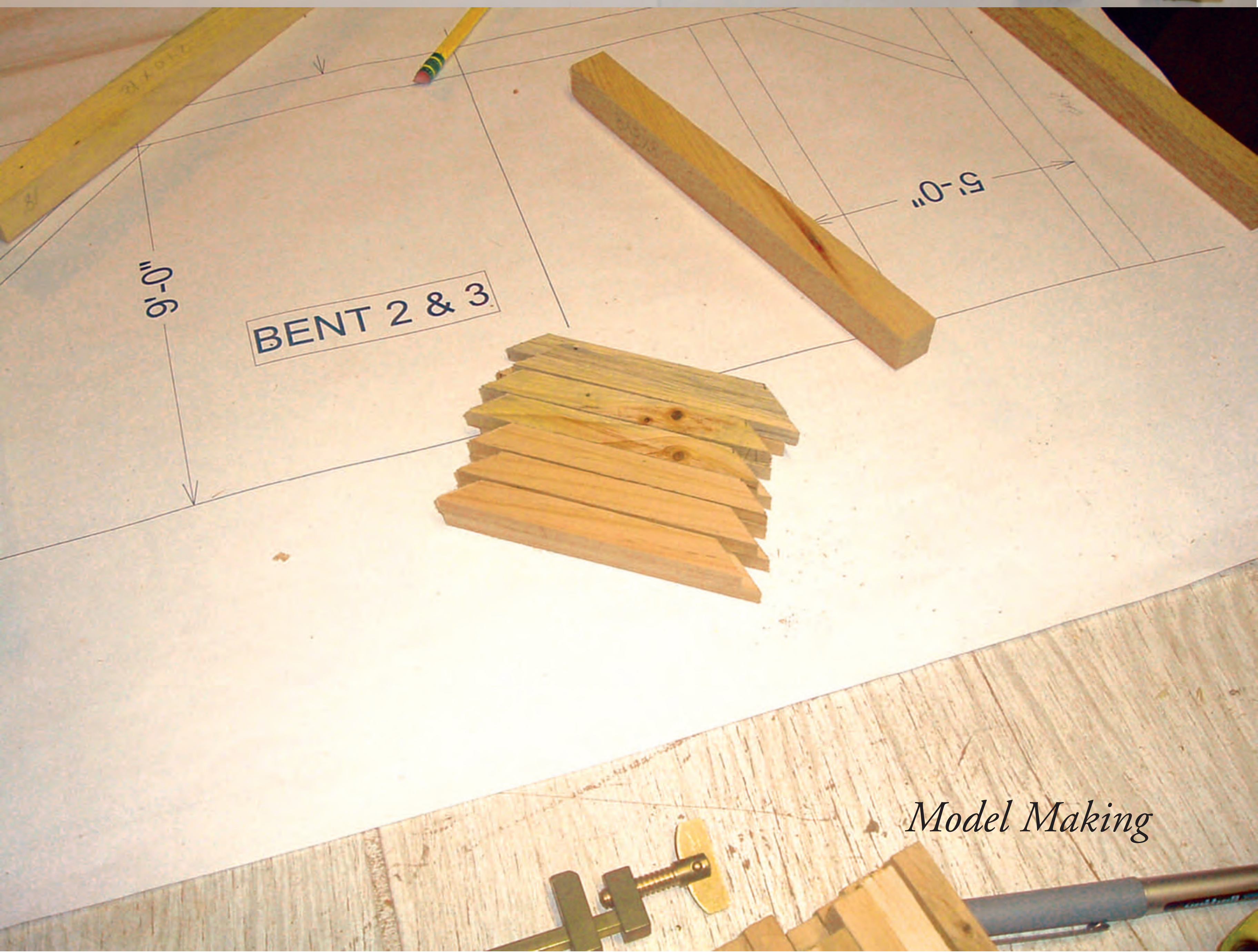
TIMBER FRAMING

JOURNAL OF THE TIMBER FRAMERS GUILD

Number 115, March 2015



Model Making

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CONTENTS

On the front cover, model timbers awaiting disposition, above, and set of braces cut to length awaiting bent assembly, below. Member lengths are obtained by laying stick over scale drawing and transferring measurement. Photos Jim Rogers. On the back cover, scribing old timber to new during a steeple restoration in France, from Gilles Mermet's Carpentry: Traditional craft of the future, *reviewed on page 4. Photo by Gilles Mermet.*

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TIMBER FRAMING, Journal of the Timber Framers Guild, appears in March, June, September and December. The journal is written by its readers and pays for interesting articles by experienced and novice writers alike.

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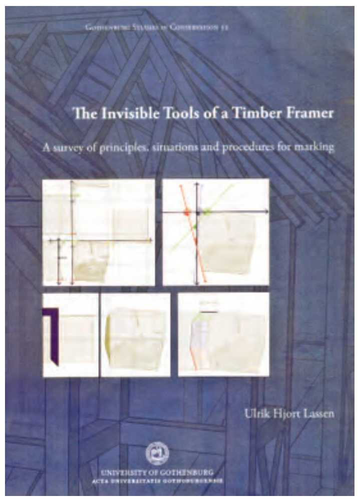
BOOKS

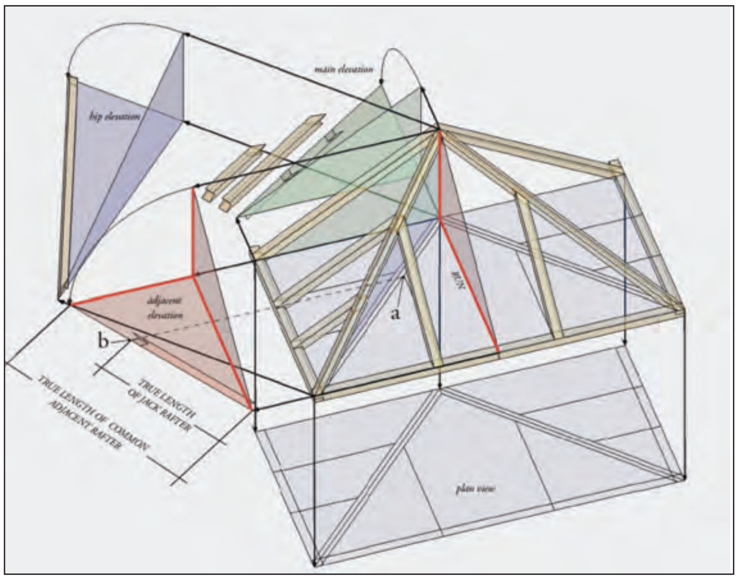
Layout Worldwide

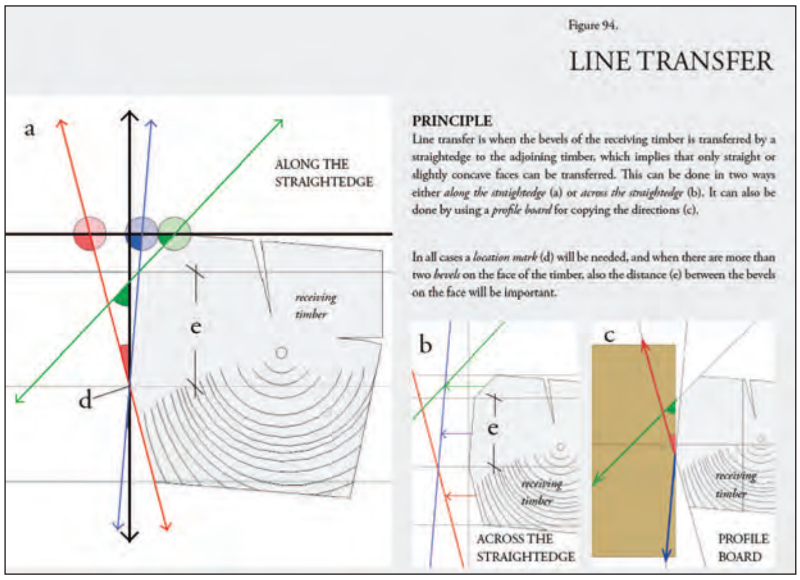
The Invisible Tools of a Timber Framer: A survey of principles, situations and procedures for marking, by Ulrik Hjort Lassen. Gothenburg, University of Gothenburg, Gothenburg Studies in Conservation No. 32, 2014. In English. ISBN 978-91-7346-785-8, 8¼ in. x 10¼ in., 238 pages, copiously illustrated. Available as a free PDF download at hdl.handle.net/2077/35598 or in print from the publisher by emailing acta@ub.gu.se. Softcover, 212SEK.

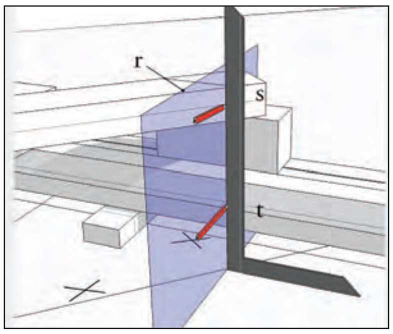


ULRIK Lassen's doctoral thesis in conservation started out as a study of the craft of log construction, whose traditions have a long and rich history in Scandinavia. As he explains in his preface, during his three years of research his focus slowly shifted to timber framing methods, especially those that deal with irregular material, which he found fascinating. Adept in European languages and a beginning carpenter by training in his native Denmark, Lassen traveled widely searching for ways to expand his practical research while still being a working craftsman. He worked on projects across Europe—historic manor houses in Denmark, *maisons de colombage* (half-timbered houses) in France and *skiftesverk* in Sweden (timber framing with usually horizontal tenoned log wall infill in vertical grooves; *pièce-sur-pièce*)—and attended seminars with Japanese carpenters in Germany. His linguistic abilities gave him an advantage in the exchange of knowledge with the often reticent carpenters he worked beside—even with the Japanese.

The result is perhaps the most extensive survey that exists on timber frame layout and marking systems commonly in use around the world today. Richly illustrated with colored photographs and drawings, this work takes us on a serpentine tour of our craft, returning often to the procedures and approaches—the invisible tools—that we share with timber framers from diverse backgrounds who face essentially the same problems and situations. This knowledge is often internalized and nonverbal and is only evident in the skilled execution of their work.



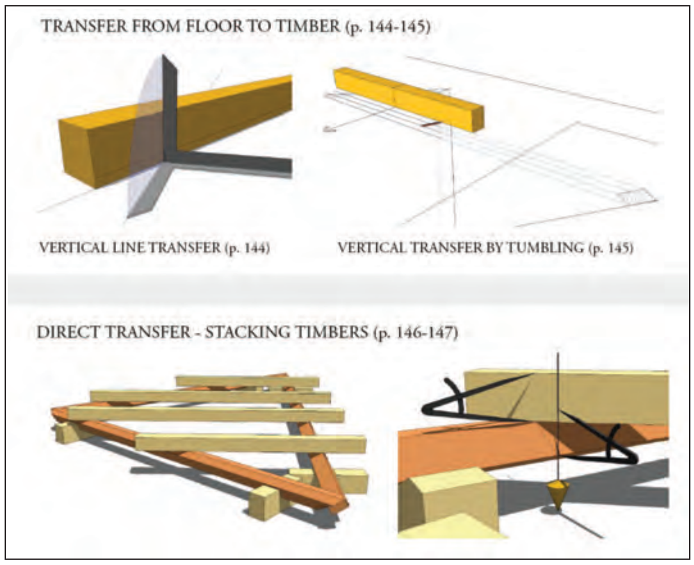




Above, reference planes and developed drawing explain roof layout.

Left, brace layout with framing square. A plumb bob may also be used.

Right and above right, line transfer methods.



Illustrations from Ulrik Lassen, *The Invisible Tools of a Timber Framer*

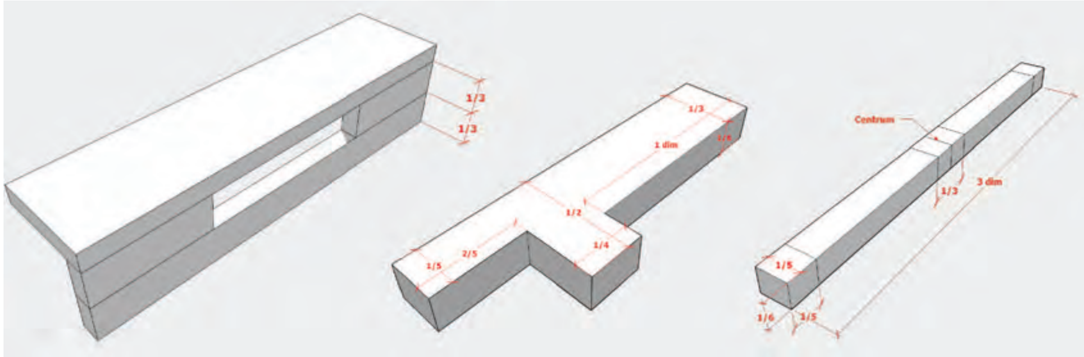
The tour starts with a survey of the existing literature on layout and marking and a photojournal of the projects that Lassen worked on during his study. Some of the names of the mentoring individuals and groups will be familiar to Guild members: the UK Carpenters Fellowship, Kezerou-Kai, Petr Ruzicka, Anders Frøstrup, François Calame. Lassen describes the experimental model, a cross-shaped gazebo with hips and valleys that he built in his own shop to practice and document the various systems. Next comes a more detailed explanation of various procedures that many of us would recognize as variations of scribe rule, square rule, tumbling, double-cutting and mapping. The author describes these as *methods of transfer*, such as direct transfer, line transfer, transfer by reference (and otherwise). The main value of this section is in seeing the detailed drawings showing tools and step-by-step procedures that distinguish each approach.

The next chapter describes the various marking situations defined by the meetings of the timbers in the case-study project. These are classified as simple meetings (square and inclined meeting in one plane) and advanced meetings such as compound joinery in a hipped roof. Lassen then uses the various transfer methods described in the previous chapter to evaluate their comparative merits in executing the layout of the different joints, including scarf joints. Tools such as bevel gauges, plumb bobs, dividers, framing squares and templates are shown in applying the techniques.

There is not much written elsewhere about scribing procedures other than what can be found in the pages of this journal, the UK Carpenters Fellowship's periodical *The Mortice and Tenon*, or Rupert Newman's 2005 book *Oak-Framed Buildings* (reviewed in TF 81). The French and English have been the primary sources of knowledge about plumb-bob scribing, and English-speaking timber framers will find many French terms and methods explained here. Projects are shown using *picage* (marking), *trait rameneret* (the "bring-me-back" line) and other details that may not be explained as fully in other sources, at least not in English. A glossary of terms and extensive bibliography as well as a YouTube video round out the information presented.

The three-dimensional realm these processes inhabit lends itself to the use of SketchUp as the medium for the illustrations. We see how to transfer irregular shapes from one piece to another, how to establish and work with reference planes and how construction geometry and developed drawing contribute to the layout.

The text gets fairly ponderous at times with cross-referencing to other sections and sources—but this is a doctoral thesis, and rules must be followed regarding citations, references and the methodology of the research. While this doesn't make for easy reading, at least the material is based on practical applications all timber framers can relate to. The procedures are exhaustively detailed, and the excellent SketchUp drawings keep one from getting too lost in the written explanations. Indeed, in reading the text I found myself thinking many times "I've been here before," and I don't mean in my work but in this very book. In looking back I found some repetition, but I think it reflects the common principles of layout—plumb, level and square—that underlie all the layout systems carpenters around the world use. There is more than one way to skin a cat, and although carpenters in different countries favor certain methods, the principles and applications are the same, and the versatile craftsperson will have them all at hand in the toolbox.



Wooden marking templates used in Lassen's case study. From left, Danish *ko,* edge-reference for mortises and tenons; Norwegian *ku,* using proportions of timber; and wooden straightedge with longitudinal divisions to mark scarf joinery, which can also be used in combination with another template to position the scarf.

The thesis is available in English as a free PDF download, or in print from the publisher (see top of review for links). Print copies are limited in supply but useful if you have trouble downloading large files (or just prefer print). Appendices A and B supplement the book. Appendix A, included with the book, is a condensed version of plumb-line scribing procedure configured as a shop manual. Ulrik Lassen has also put together a 30-minute video narrated in Danish, titled *Piquer au Plomb,* showing plumb-line procedures and viewable at youtube.com/watch?v=dWAqY_M2uFM. Appendix B, a separate download (or included on the CD that comes with the hard copy), is a photographic journal of the construction of the case-study gazebo. —Will Beemer

Will Beemer (willb@heartwoodschool.org) is a founding member of the Guild, served two terms on the board in the 90s and then as co-executive director for 11 years. He directs the Heartwood School for the Homebuilding Crafts in Washington, Massachusetts, and has written many articles on basic and advanced timber framing techniques in Timber Framing *and* Fine Homebuilding *magazines.*

French Carpentry

Carpentry: Traditional craft of the future, by Gilles Mermet. Paris, Éditions de La Martinière, 2013. 11¾ in. x 12½ in., 220 pages, copiously illustrated. In English, translated from the French by Eleanor Rylance. ISBN 978-27-3245-748-2, softcover, €40. Librairie du Compagnonnage (librairie-compagnons.com), phone 1+48 87 88 14, fax 1+48 04 85 49 (in France, dial prefix 0; from US, prefix 011+33). Ask for Alex, who speaks English. Shipping €35.

GILLES MERMET is a photojournalist, not a timber framer, and so this book doesn't include the detailed technical procedures that we find in Ulrik Lassen's thesis. But Mermet takes the reader on a journey through the world of carpentry as practiced in France, from the traditional methods that built the great cathedrals to the contemporary techniques and materials that push the envelope of engineered timber structures. This large-format book is filled with beautiful photographs of carpentry venues—workshop floors, construction sites, design offices. From conception through *épure* (floor layout), marking the timber and on to cutting and raising, each chapter gives historical and technical perspective during the construction of a variety of projects, be it castle roof, panelized house or soccer stadium. Materials range from French oak to glulams, tools from the *bisaiguë* (twybil) to automated cutting machines.

The book also traces the journey that young French apprentices may follow to become master carpenters, trained to be designers, geometers, artists, mechanics, engineers and computer numerical control (CNC) machine operators as well as woodworkers. Since *Le Trait* (as French scribe and its associated techniques are collectively known) is listed by UNESCO as an "intangible cultural heritage," the book serves as a rallying tool to emphasize its importance in developing great artisans and great buildings. The Association ouvrière des compagnons du devoir et du tour de France, the French trades league, as well as over a dozen construction companies in France specializing in traditional wooden buildings, were instrumental in the funding and development of this book; they above all realize these skills are endangered in the modern world and would convince us that learning French scribe and drawing remains important in the age of 3D software and CNC machines, the "culmination of thousands of years of experience and observation, the logical end-result of rational thought process."

The book examines graphical methods of representing pieces of wood in space. *Rembarrement*, which dates to the 13th century, is the developed drawing of the entire piece, all its faces and their intersections with other pieces. *Sauterelle* is a more economical method, developed at the end of the 18th century, that draws only the various planes of intersection, giving the angles and lengths without accounting for timber section. (See my "When Roofs Collide," TF 70, 71, 73.) *Croche*, perfected during the Renaissance, develops the exact shapes of curved pieces such as an eyebrow dormer or a tangent handrail. Our own Dave Carlon reported that working with a *compagnon* on the Cabildo Project, the 1992 reconstruction of an 18th-century roof frame in New Orleans (TF 24), was like "learning from a 700-year-old carpenter." If you appreciate the traditions of a craft that also enthusiastically embraces the future, add this book to your library. If you want to show someone why you became a timber framer, hand them the book. —W. B.

1 Apprentices in France still learn developed drawing by hand.

2 After drawing *épure* on floor, apprentice prepares timber to section and length, then lays it on drawing to transfer layout.

3 Fitting dormer rafters over mechanism and head of wind shaft at windmill in Mareuil-sur-Lay (Vendée).

4 Hundegger joinery machine needs just a little help.

5, 6 Carpenter trims outer end of dragon beam while roof frame for conical tower at Mesnière-en-Bray (Seine-Maritime) is raised in background. Château roofs were rebuilt after fire.

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Photographs from Gilles Mermet, *Carpentry: Traditional craft of the future*

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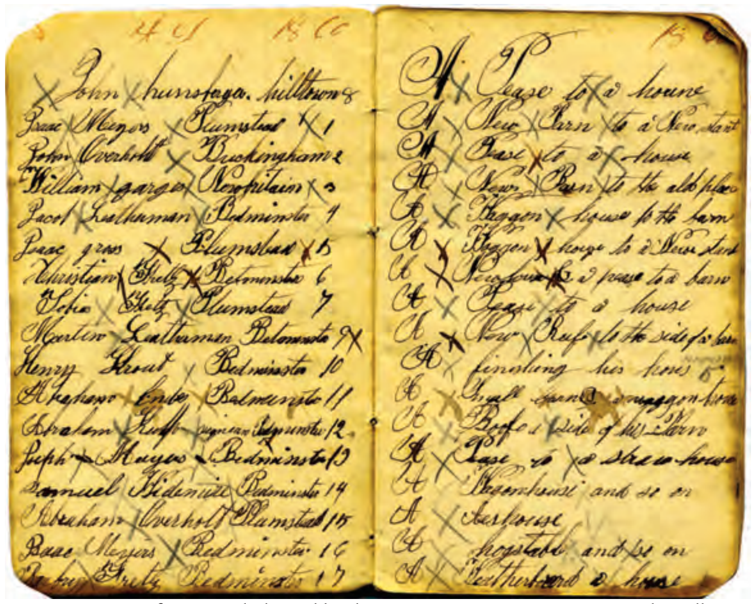
Jeffrey L. Marshall

1 Closed forebay barn about 36x72 ft., Bedminster Township, Bucks County, Pa., dated 1810.



Page images from Overholt workbook, Mennonite Heritage Center, Harleysville, Pa.

2 Joseph G. Overholt's list of customers, their locations and brief descriptions of the work he did for them, dated 1860.

A 19th-Century Bucks County Workbook

CONTEMPORARY drawings of 19th-century barn framing, such as for the typical Pennsylvania barn in Fig. 1, are rare. Joseph G. Overholt (1832–1905), built houses and barns and left a workbook including sketches of barns for clients in Bucks County, Pennsylvania. Overholt, born and raised in the county, was descended from German Mennonites who immigrated in the early 18th century and bought land in Bedminster and Plumstead Townships. He spoke German and his education was in that language at the Deep Run School, where he learned the calligraphic art of *fraktur* to be seen in his workbook (Fig. 2). Judging from the hymnals, handwritten music and other materials he left behind, in addition to his carpentry work Overholt wrote music and was a singing teacher at Deep Run Mennonite Church, where he worshiped as well.

The workbook survives as a partial record of his carpentry work. The document lists customers' names and locations and brief project titles, and includes sketched or drawn elevations and plans, many of barns or parts of barns and bearing clients' names. The names of clients on the drawings, however, do not appear to correspond with the list.

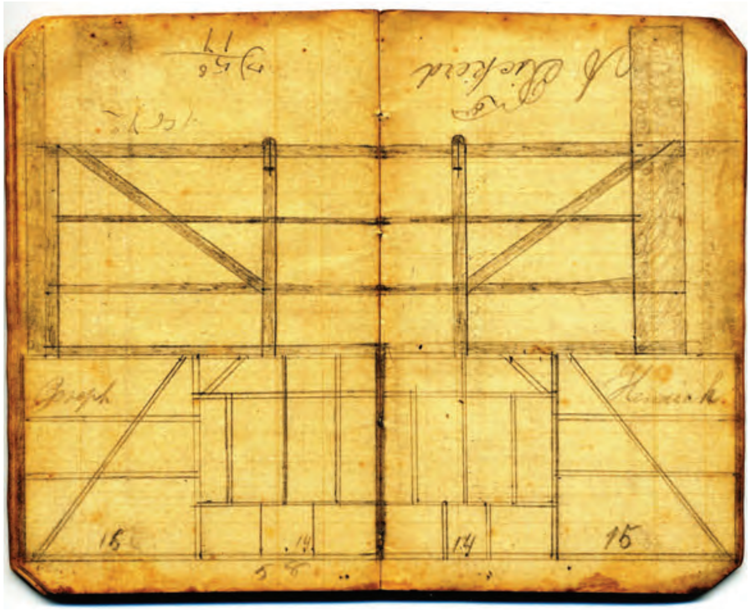
Overholt's book has three drawings for a barn built for Joseph Henrich (elsewhere Hendrich), shown in Figs. 3, 5 and 6. The forebay of the Henrich barn (Fig. 3) is drawn inverted on the same pages of the book as what appears to be a forebay built for A. Rickerd in 1872 (Fig. 4). The latter sketch proposes hidden bolts in the bottoms of the queenposts to make the tension connections to the lower chord. Generally, the nuts for such bolts are hidden in slots behind the exterior sheathing on the reference face, and the bolts thread in from below. The necessary bolt heads and washers are depicted unclearly. One heel of the truss rests on the *Peilereck* (pillar-corner), the L-section masonry corner supporting a forebay corner post, but the opposing heel does not.

The Henrich forebay drawing (Fig. 3) also appears to depict a queenpost truss but does not offer details of the connections or reveal whether what might be upper truss chords are in fact German-style bracing. The Henrich drawing shows five bents and four bays totaling 58 ft., the Rickerd drawing four bents and three bays, with dimensions possibly indicated by the numbers seen lower right. The drawing of the Henrich gable end (Fig. 5) depicts purlin plates on posts with short down bracing to stabilize the posts. Overholt also apparently laid out the lower level of the barn, the stable, here with three individual stalls under the forebay, a feed aisle (*Fuddergang* in Pennsylvania German dialect) and a large area typically designed for cattle (Fig. 6). The feed aisle could be reached from a door in the gable end and a door under the forebay. There is another large stall with access from the gable end. This layout suggests that the house was oriented to the left of the barn.

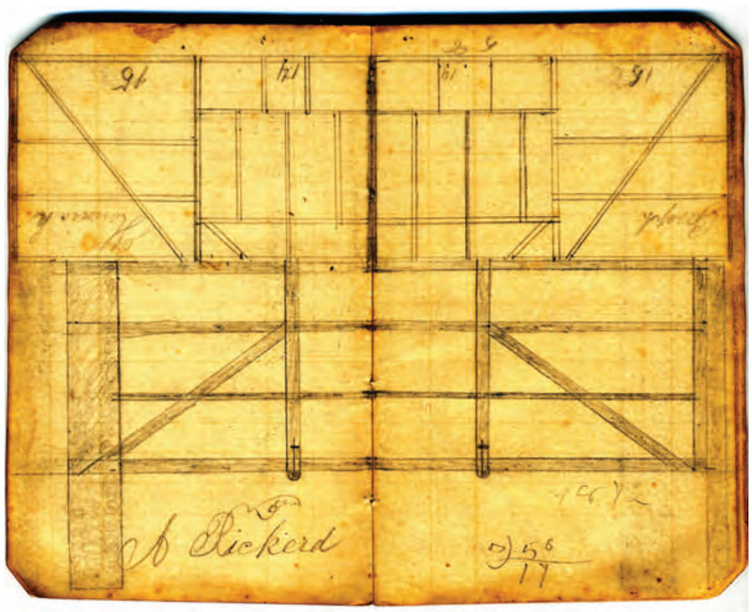
Moses Kulp's barn (Fig. 7) was 40 ft. deep with principal purlins supported by canted purlin posts, in turn supported by braces at approximately the same angle as the roof rafters. The section shows the rafters tapering from heel to roof peak. The long braces from tie to sill are typical of German framing style and probably are lap jointed at their ends, as shown, though Overholt's drawing style is not reliable at crossings and connections. Note the decoratively cut rafter tails.

The Moses Kulp forebay wall section, indicated at 56 ft. long (Fig. 8), shows the framing for winnowing doors in the center bay. It also has long diagonal braces, at an unusually low angle resulting from the long end bays. Overholt appears to be debating whether to reinforce the braces or perhaps the wall plate with additional braces, and at what angle to set them to the major braces. The approximation of a queenpost truss (compare with Fig. 4) lacks a straining beam at the upper bearing points of the diagonal struts, though perhaps the wall plate above and the winnowing door header combined are expected to serve the purpose.

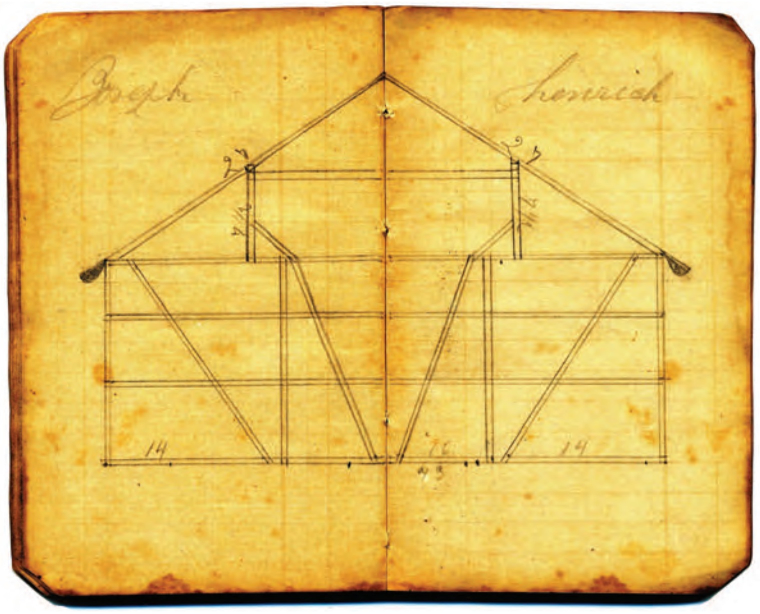
One of the diagnostic features of a Pennsylvania bank barn is a framed portion projecting out over the barnyard stable doors and generally referred to as a forebay (although, as it runs parallel to the ridge, the space properly would be called an aisle). Many forebays were purely cantilevered but others were supported by end walls (Fig. 1), posts or masonry conical piers, especially when the forebays were added to earlier structures. (See Robert Ensminger, *The Pennsylvania Barn,* 2003, for a definitive discussion of open and closed forebays.) The contrasting style of barn was named



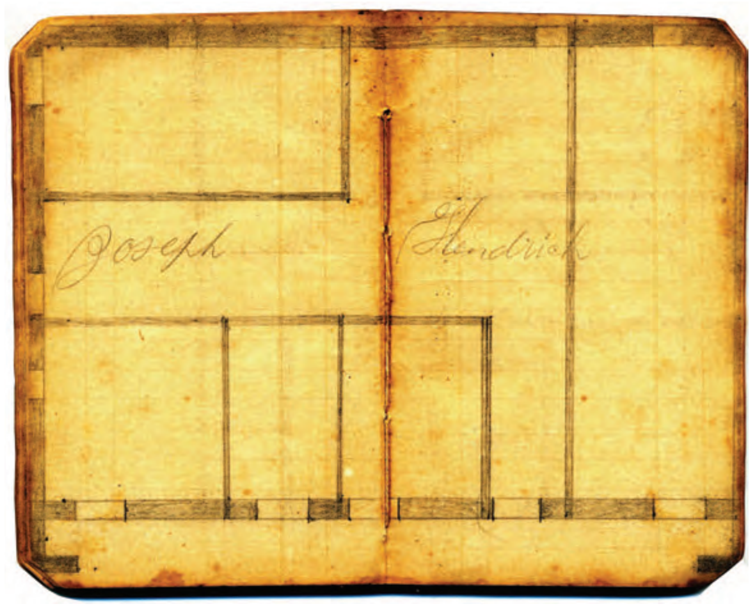
3 Joseph Henrich barn forebay, four bays 15,14,14,15, total 58 ft.



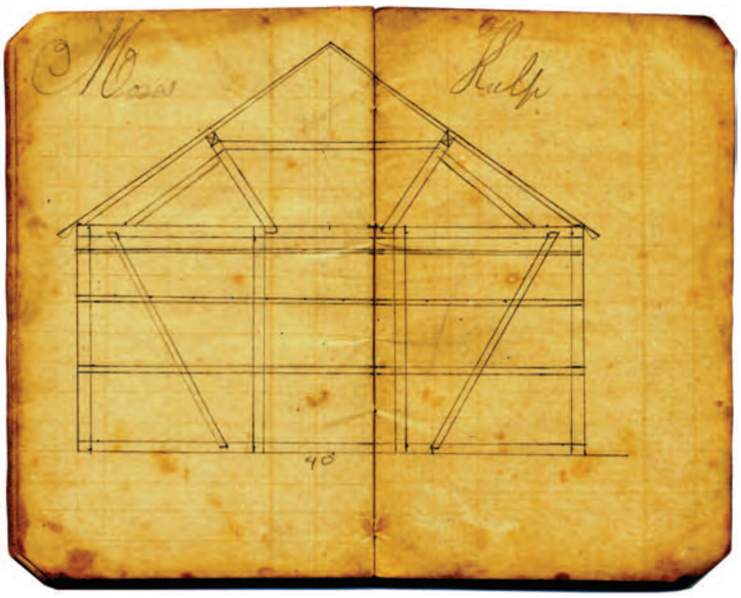
4 Fig. 3 inverted to show A. Rickerd forebay, dated 1872.



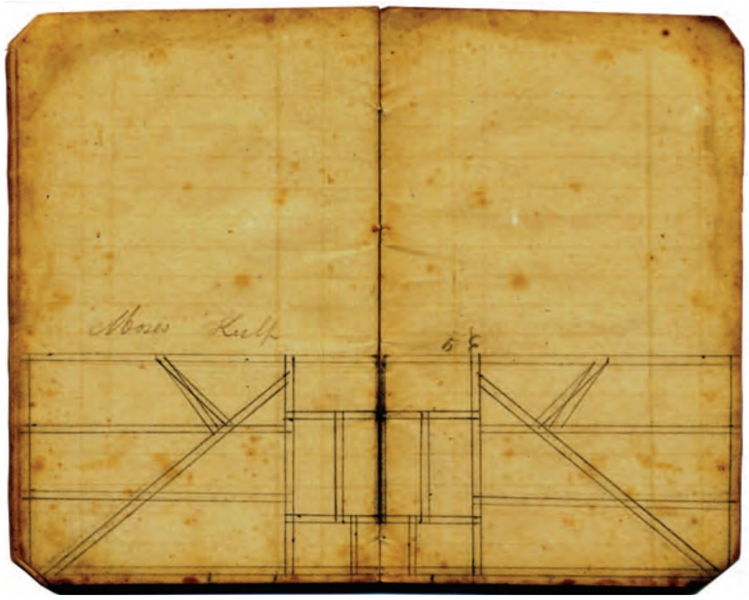
5 Henrich gable end, three aisles 14,16,14 total 43 ft. (somehow).



6 Basement plan for Henrich (here Hendrich), showing stable layout with feed aisle and *Peilereck* closures at forebay ends.



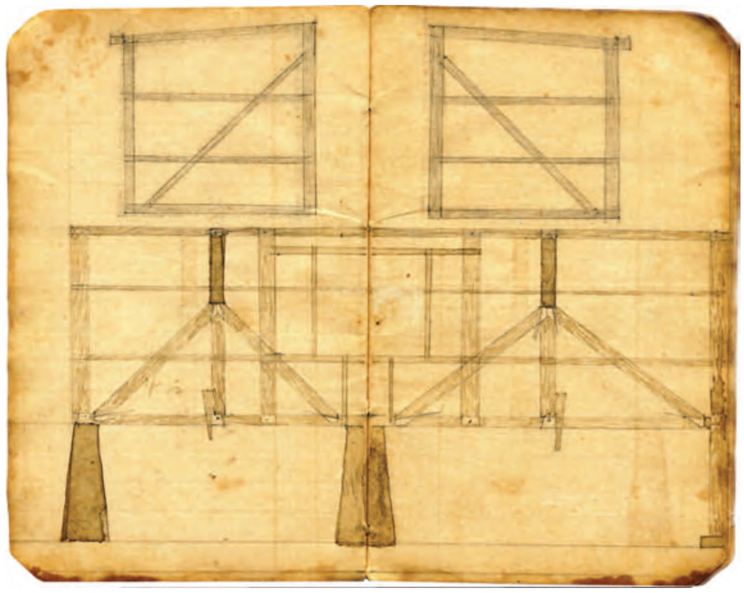
7 Moses Kulp barn, 40 ft. across gable end, lapped braces, canted purlin posts with struts and decorative rafter tails.



8 Moses Kulp 56-ft. forebay wall elevation with low-angle long braces and possible stiffeners. Winnowing doors at center.

Jeffrey L. Marshall

9 English Lake District–style barn, Hilltown Township, Bucks County, Pa., about 60x38 ft., dated 1846, with characteristic pent roof instead of framed forebay as on "standard" Pennsylvania barn.



10 Kingpost trusses without client attribution. Wedges for half-dovetail tension connections drawn comically large. Mirror-imaged pair of frames in upper half could be end views.

after stone barns in the English Lake District and omitted the forebay, instead providing a pent roof over the stable yard (Fig. 9).

Fig. 10 presents a pair of kingpost trusses. The drawings of the wedges at the post-to-chord connections are quite dramatic. Perhaps Overholt was trying to make clear to a prospective client, just how the trusses would work. Or was he really into overcompensating with his wedges? Certainly the transparent views of the half-dovetail tenons and the diminished shoulder connections at the kingpost and in the lower chords, as well as the careful woodgraining of the timbers and the shading of the piers and other details, suggest a different purpose here from Overholt's usual one. The pair of drawings above the kingpost trusses may represent the sides of the forebay. Or, neglecting the pitched top members, they perhaps show what a queenpost option might look like instead.

The drawing for P. Gross (Fig. 11) has sparked debate. Is the elevation to the left an eaves wall or a forebay wall? Given that the bents are identical, did Overholt draw the bent on the left first, realize that he didn't have enough room to draw the roof system, and then proceed to try it again by hugging the margin at the right? (And, even so, the roof peak spills onto the facing page.)

Many of Overholt's drawings are floor plans of the lower level of two-level Pennsylvania bank barns, laid out to meet the individual needs of the farmer. They show feed aisles entered from the gable end of the barn and from the barnyard. The plan of the John L. Myers barn from 1865 (Fig. 12) shows a bank barn with the foundation of the bank (top of plan) and the pillar-corners of the closed forebay support system (bottom of plan). The depth of a *Peilereck* varied widely, from the 2 or 3 ft. represented here to almost 6 ft. The larger alcoves often had a door enclosing a closet, or a door in the exterior wall to exit the barnyard. Smaller niches had pegs to hang harness or shelves.

The P. Moyer barn drawing (Fig. 13) does not indicate the bank or projecting forebay defining a two-level barn with Pennsylvania German influences, perhaps because the superstructure of this barn was completely of wood frame construction. It also shows a more simplified plan than the Myers barn. There is increasing documentation that a large number of Pennsylvania barns were constructed without a forebay, which strikes at common nomenclature describing barns as English or German. What it probably shows is acculturation and the blending of building traditions and the influence of English Lake District–style barns (Fig. 9) built without forebays on 19th-century Bucks County builders; but this is still under study.

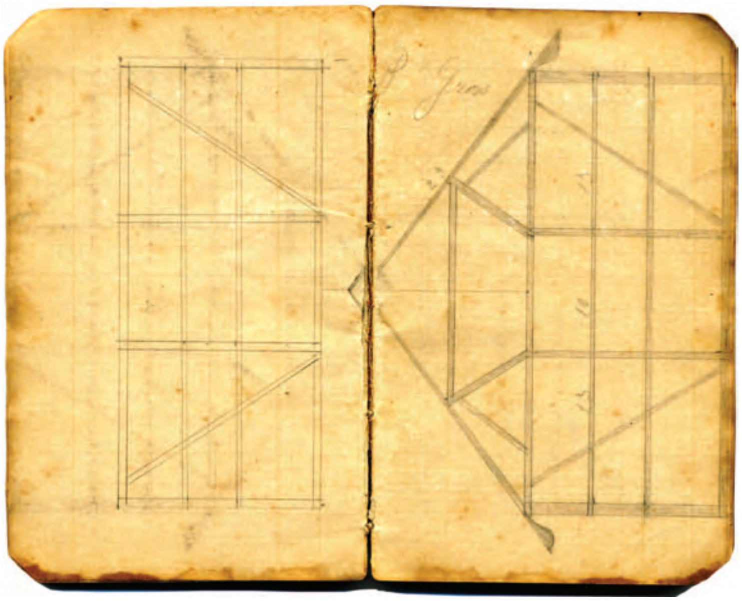
Fig. 14 shows a queenpost truss–like long wall with the legend, "Abraham D. Overholt a straw shed 50 by 18 and 12 high." Today, the term *straw shed* is typically associated with a shed built with the main barn or a later addition used to store the straw produced in large quantities after the introduction of mechanical threshing in the late 19th century. The section to the right of the drawing presumably represents the 18-ft. end wall. Overholt seems to have constructed a number of forebay or straw shed additions, suggesting that these features may have been routinely added to older barns.

Fig. 15, labeled "Barn front" on one leaf and "D" and "M" on the other, may be purely speculative. The dimensions shown on the lefthand leaf cannot be reconciled.

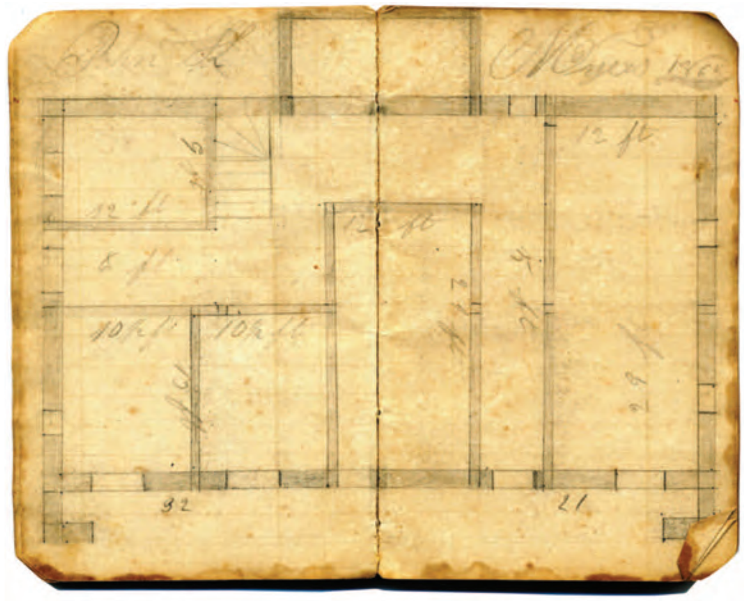
In the drawing of the David Fretz barn (Fig. 16), it would seem that Overholt was experimenting with roof pitches (as well as bracing and other questions). Perhaps he started with the lower pitch and then adjusted as necessary. The peak of the lower pitch nearly fits an equilateral triangle based at the bottom of the stone wall, a standard local method for proportioning, but the resulting pitch is very shallow, not quite 6:12. The meaning of the 27½ written in the upper corner of the drawing is unknown. The batter on the foundation wall at left may indicate the bank side of the barn.

—Jeffrey L. Marshall

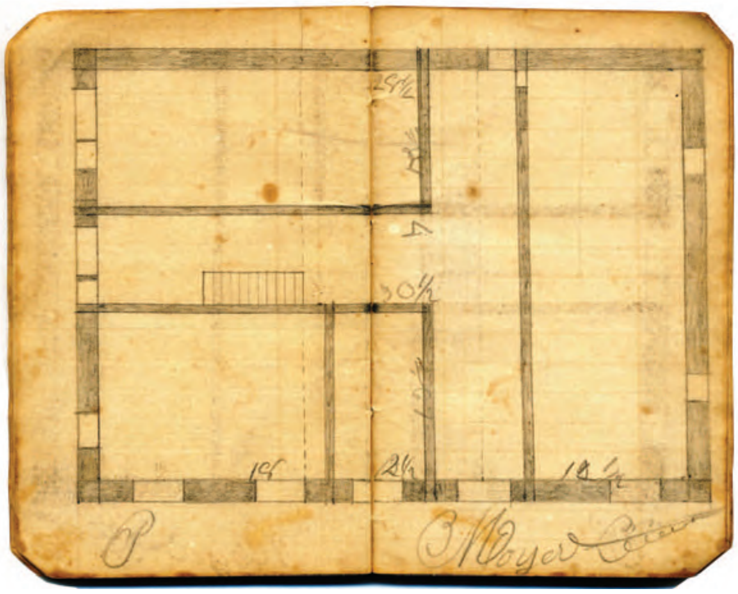
Jeffrey L. Marshall (jmarshall@heritageconservancy.org) is president of Heritage Conservancy and of the Historic Barn and Farm Foundation of Pennsylvania. He has been researching historic buildings in Bucks County for more than 30 years. *Michael J. Cuba assisted materially in the preparation of this article. Some biographical information was drawn from "The Joseph G. Overholt Workbook: A Barn Dating Project," by Maureen F. Victoria, a 2011 student project for Bucks County Community College.*



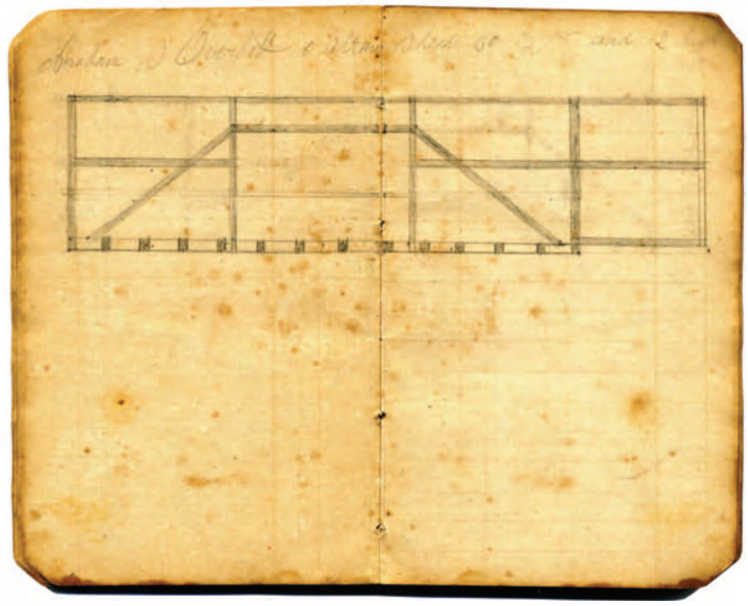
11 Identical bents, one with roof frame and elaborate rafter tails for P. Gross.



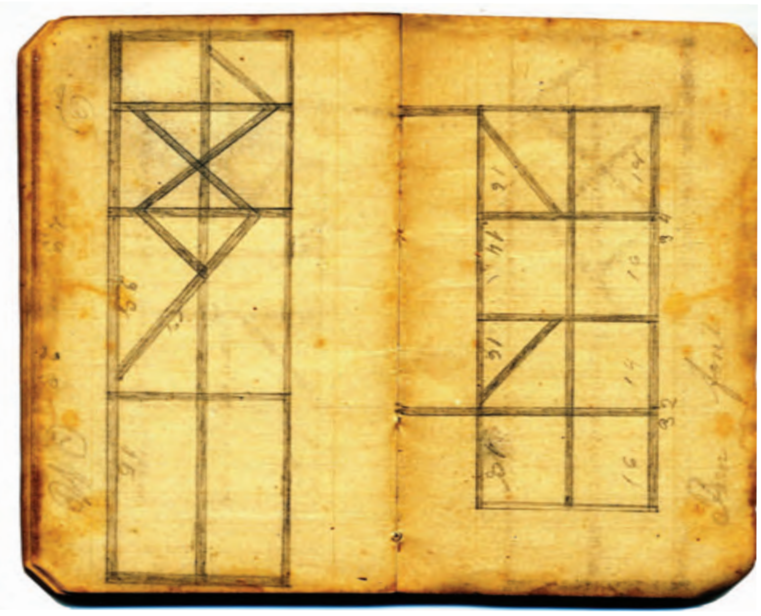
12 Basement plan for John L. Myers dated 1865 showing bank foundation (top of plan), *Peilereck* supports for closed forebay.



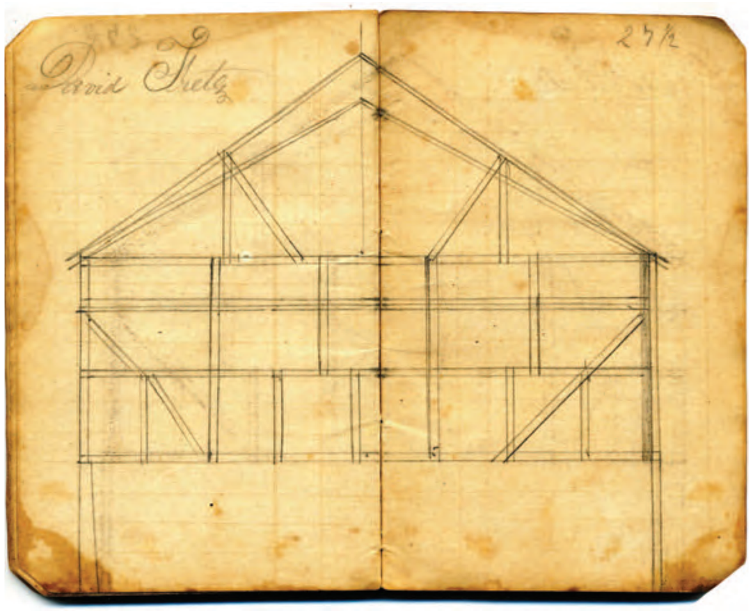
13 Basement plan for P. Moyer without bank or forebay foundation, suggesting an English Lake District–style barn.



14 Straw shed for Abraham D. Overholt, 50x18, with presumed end wall depicted at right of long wall.



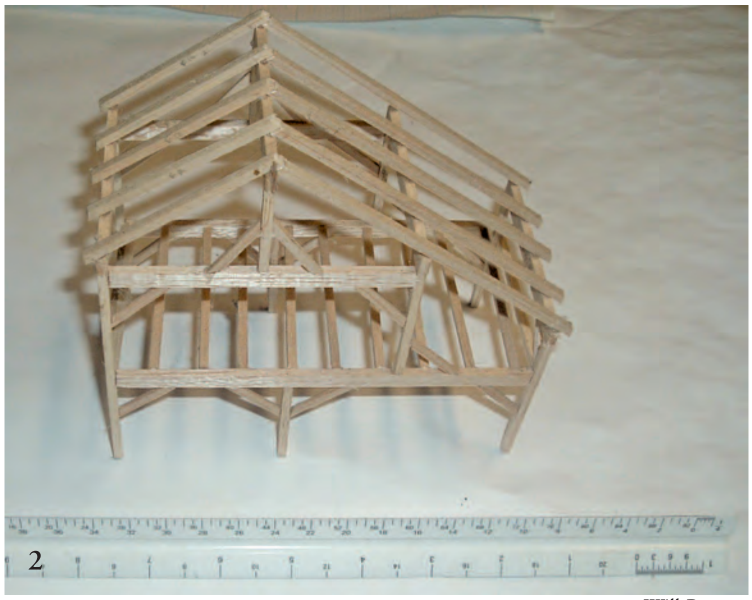
15 Lefthand leaf, "Barn front" with bracing scenarios and irreconcilable dimensions. Righthand, long wall, mystery bracing.



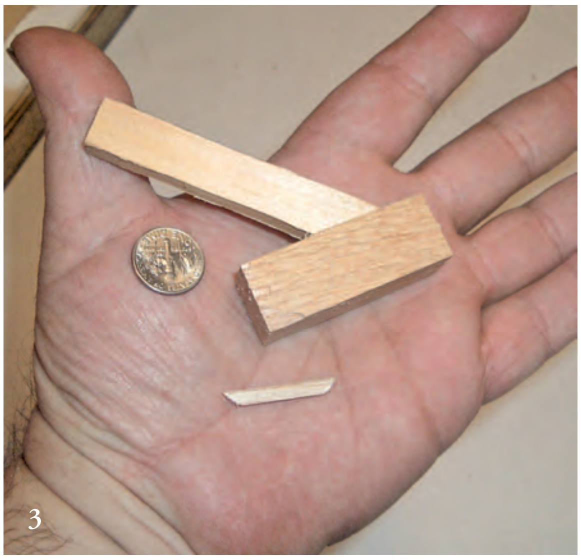
16 Gable end view including foundation, with experimental roof pitches and bracing, for David Fretz.

Building a Timber Frame Model

Tim Beal



Will Beemer



Jim Rogers

Jim Derby

1 Pine construction model in 1:24 scale by Tim Beal, Whiting, Maine. Note annotations on beams.

2 Balsawood construction model in 1:48 scale by Heartwood School, Washington, Mass.

3 Brace and beam fragment in 1:12 scale, brace in 1:48 scale.

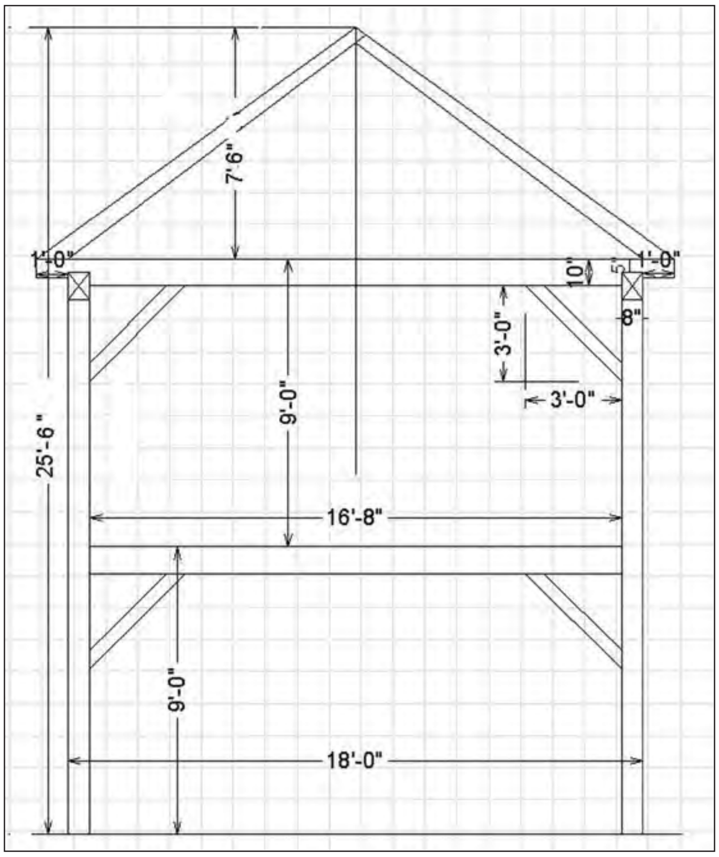
4 Spruce working model in 1:5 scale of existing three-bay barn, 30 ft. 6 in. by 36 ft., built by Jim Derby in Waldoboro, Maine.

THE first thing we need to decide when building a timber frame model is the scale, which might depend on our purposes. For example, if we choose a scale of 1 in. equals 1 ft. (1:12) for a real structure 18 ft. wide and 36 ft. long (such as the frame we will model in this article), our model will be 18 in. wide and 36 in. long, fairly convenient to build and handle, but big enough to show design features.

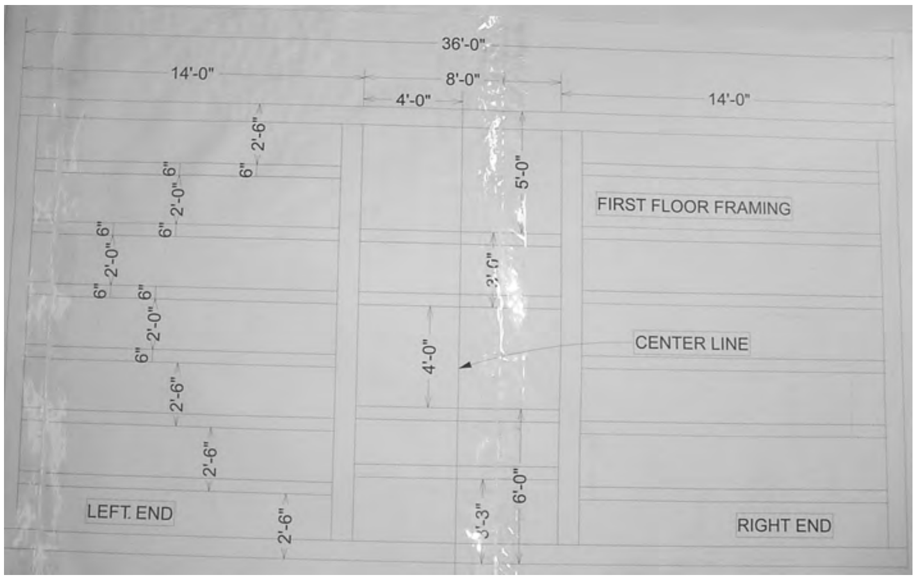
But if the actual frame will be, say, 88 ft. long, then our model at this scale would be over 7 ft. long, large for a model and possibly somewhat difficult to transport. In that case we may prefer to use a scale of ½ in. equals 1 ft. (1:24), thereby making your model 44 in. long. Fig. 1 shows a model in that scale, still large enough to assemble with small screws—and to annotate.

We could even make a model with the scale ¼ in. equals 1 ft. (1:48) as seen in Fig. 2. This size is easy to draw on letter-size graph paper, and some materials are ready-made since that scale is used for model railroading, but its smaller pieces can sometimes be difficult to assemble (Fig. 3). On the other hand, if we intend the model to demonstrate joinery and other construction features, or perhaps to serve as a playhouse, then we would choose a very large scale such as for the model in Fig. 4.

We are going to work, then, in 1:12, the scale I prefer, to model the 18x36-ft. project frame for the New England hall-and-parlor house described in Jack Sobon's *Build a Classic Timber-Framed House.* The first step is to make 1:12 scale drawings of the assemblies, whether drafting by hand or with a CAD program (Figs. 5 and 6). The drawings should include floor-timber plans and bent elevations. Wall elevation drawings are not necessary for this model's construction, nor are roof-frame drawings, as we have a common-rafter roof. After completing the drawings, develop a cutting list of the pieces using full-size dimensions (Fig. 7) and convert this list to a list of model timbers using scaled dimensions (Fig. 8). I round to the nearest English system fraction (Fig. 9).



5 Drawings at model scale later provide position and length for all members by direct transfer of measurement.



6 First-floor deck layout.

Scale for Models of 1" = 1'		
1"	=	3/32"
2"	=	3/16"
3"	=	1/4"
4"	=	3/8"
5"	=	7/16"
6"	=	1/2"
7"	=	19/32"
8"	=	11/16"
9"	=	3/4"
10"	=	27/32"
11"	=	15/16"
12"	=	1"

9 Dimensions do not scale exactly to familiar fractions in 1:12 (as they do in 1:4, 1:8, 1:16 scales), so are rounded for convenience.

Lumber needed for Jack's House Short and Long Timbers						
		timbers	Made	10/12/2007		Grand
Thickness" x	Width" x	Length"	= BDFT ea.	x count =	Total	Total
joists					0.00	
6	7	14	49.00	12.00	588.00	588.00
joists					0.00	588.00
6	7	10	35.00	4.00	140.00	728.00
prick posts					0.00	728.00
8	8	10	53.33	2.00	106.67	834.67
girts					0.00	834.67
4.5	7	14	36.75	4.00	147.00	981.67
girts					0.00	981.67
4.5	7	10	26.25	2.00	52.50	1034.17
joists					0.00	1034.17
5	7	14	40.83	12.00	490.00	1524.17
joists					0.00	1524.17
5	7	10	29.17	5.00	145.83	1670.00
braces					0.00	1670.00
3.5	5	10	14.58	16.00	233.33	1903.33
attic joists					0.00	1903.33
2	10	10	16.67	3.00	50.00	1953.33
raising plates					0.00	1953.33
2	12	14	28.00	4.00	112.00	2065.33
raising plates					0.00	2065.33
2	12	10	20.00	2.00	40.00	2105.33
rafters					0.00	2105.33
4.5	7	14	36.75	28.00	1029.00	3134.33
sill girters					0.00	3134.33
8	10	18	120.00	2.00	240.00	3374.33
sill ends					0.00	3374.33
8	9	18	108.00	2.00	216.00	3590.33
sills long					0.00	3590.33
8	9	20	120.00	4.00	480.00	4070.33
posts, oak					0.00	4070.33
8	8	18	96.00	8.00	768.00	4838.33
girting beams					0.00	4838.33
8	10	18	120.00	4.00	480.00	5318.33
plates					0.00	5318.33
8	10	20	133.33	4.00	533.33	5851.67
tie beams					0.00	5851.67
8	10	20	133.33	4.00	533.33	6385.00
attic joists					0.00	6385.00
2	10	20	33.33	22.00	733.33	7118.33
	Total Number of Pieces			103.00	Total Bdft	7118.33

7 List of scantlings for actual house frame.

Lumber needed for Jack's House Model Short and Long Timbers						
		timbers	Made	9/15/2007		Grand
Thickness" x	Width" x	Length"	= BDFT ea.	x count =	Total	Total
joists					0.00	
1/2	19/32	14	0.03	12.00	0.35	0.35
joists					0.00	0.35
1/2	19/32	10	0.02	4.00	0.08	0.43
prick posts					0.00	0.43
11/16	11/16	10	0.03	2.00	0.07	0.49
girts					0.00	0.49
27/64	19/32	14	0.02	4.00	0.10	0.59
girts					0.00	0.59
27/64	19/32	10	0.02	2.00	0.03	0.63
joists					0.00	0.63
7/16	19/32	14	0.03	12.00	0.30	0.93
joists					0.00	0.93
7/16	19/32	10	0.02	5.00	0.09	1.02
braces					0.00	1.02
9/32	7/16	10	0.01	16.00	0.14	1.16
attic joists					0.00	1.16
3/16	27/32	10	0.01	3.00	0.03	1.19
raising plates					0.00	1.19
3/16	1	14	0.02	4.00	0.07	1.26
raising plates					0.00	1.26
3/16	1	10	0.01	2.00	0.03	1.29
rafters					0.00	1.29
27/64	19/32	14	0.02	28.00	0.68	1.97
sill girters					0.00	1.97
11/16	27/32	18	0.07	2.00	0.15	2.12
sill ends					0.00	2.12
11/16	3/4	18	0.06	2.00	0.13	2.24
sills long					0.00	2.24
11/16	3/4	20	0.07	4.00	0.29	2.53
posts, oak					0.00	2.53
11/16	11/16	18	0.06	8.00	0.52	3.05
girting beams					0.00	3.05
11/16	27/32	18	0.07	4.00	0.29	3.34
plates					0.00	3.34
11/16	27/32	20	0.08	4.00	0.32	3.66
tie beams					0.00	3.66
11/16	27/32	20	0.08	4.00	0.32	3.98
attic joists					0.00	3.98
3/16	27/32	20	0.02	22.00	0.48	4.46
	Total Number of Pieces			103.00	Total Bdft	4.46

8 List of scantlings for model frame.

Next, gather the materials needed to build the model, including a piece of plywood large enough for model base. Stock to be made into scale timbers can be planed to appropriate scaled thicknesses and then ripped to the scaled widths of the timbers. To fasten, we will use wire brads (16 to 18 gauge) as well as hot glue, woodworking glue and wood screws of different sizes and lengths (Figs. 10 and 11).

Another option is to purchase the stock for your model ready-made from a hobby shop, although this will naturally limit your model timber sections to those available from the store (Fig. 12).

Make sure to obtain or cut model timbers long enough for each scale length on your list, with an extra piece or two of each size in case of errors (Fig. 13). Extra stock may be needed also if you're still in the design phase and you make changes, thus requiring alteration of the model. Taking a scale model apart to try a different design may require additional or replacement model timbers.

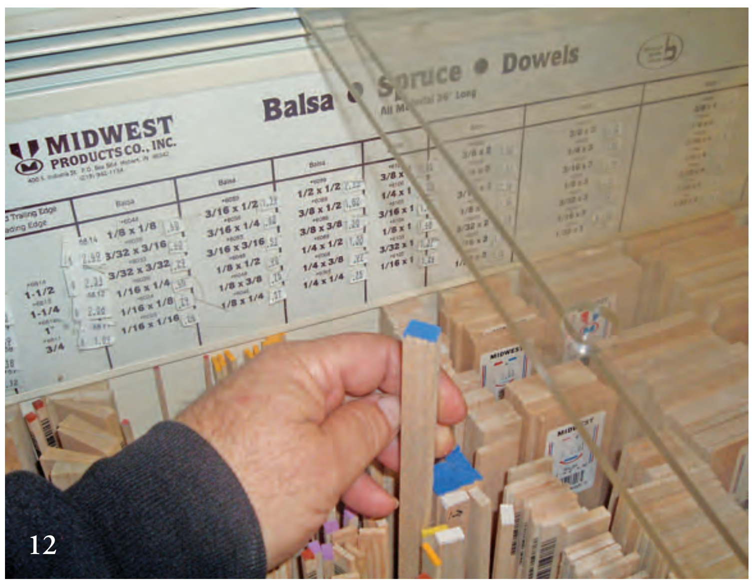
Many hand tools are useful for cutting and assembly: miter box, brad pusher, hammer, hot glue gun, clamps, tape measure, ruler, speed square, combination square, 8x12 framing square, finish- nail gun, needle-nose pliers and wire (brad) cutters (Fig. 14).

Once you have gathered all your tools and cut stock to the width and thickness needed, gather pieces for one bent. Using your drawing as a template, lay each piece onto the drawing and transfer the lengths to the pieces (Fig. 15).

Cut braces in a mini-miter box, lining up the mark carefully with the saw kerf if laid out individually (Fig. 16).

Now that all the timbers for a bent have been cut to length, we can begin assembling it. Start by marking each joint location lightly with a pencil (Fig. 17).

Attach braces to beams using a small brad or two in a brad pusher, which has an interior magnet to hold the brad and a plunger to send it into the joint (Fig. 18). Sometimes a spot of hot glue helps to temporarily hold pieces while assembling units (Fig. 19). Fasten a larger connection such as a post to a beam with a finish-nail gun (Fig. 20).



10 Materials (here white pine) and fasteners for model building.

11 Ripping model timbers on table saw.

12 Certain model timber sections can be found ready-made.

13 Model timbers, with extras, stacked and ready for end cuts.

14 Tools useful for cutting, fastening and raising model.

15 Laying timbers on bent drawing for direct transfer of lengths.

16 Cutting brace to length in mini-miter box.

17 Marking joint position for assembly.

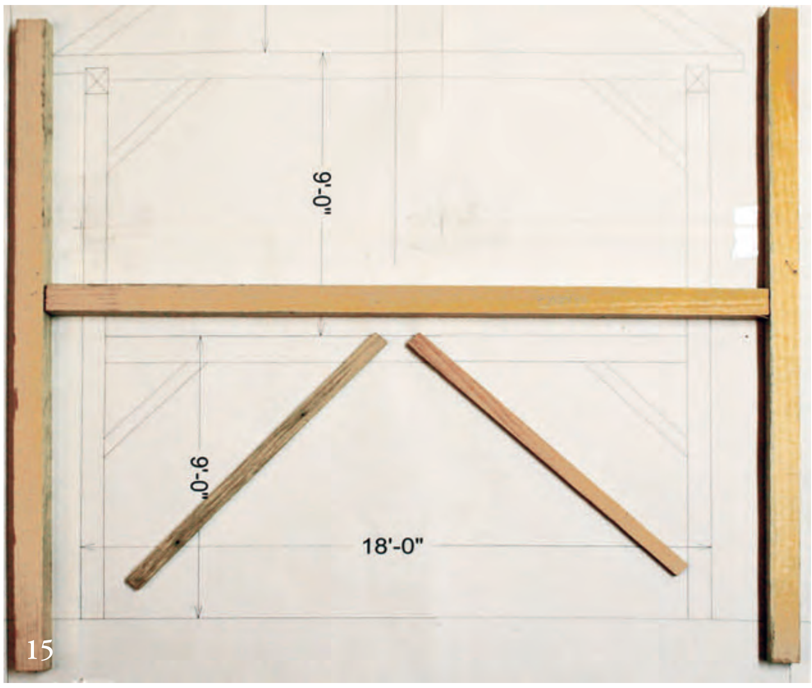
18 Brad pusher holds and drives fastener simultaneously.

19 Spot of glue aids positioning before fastening.

20 Finish-nail gun fastens major connections.


13


14



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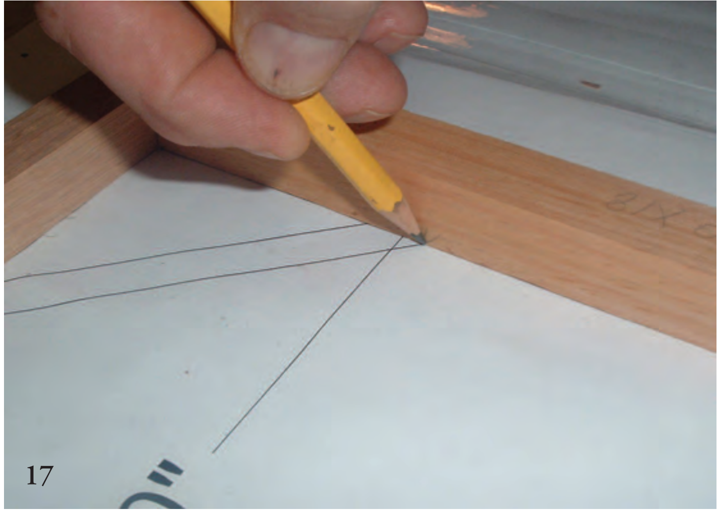
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19


20

To transport the finished model later, provide a piece of plywood large enough to represent the foundation plus a little area around. Attach the floor plan to the plywood to guide the positioning of sills and posts. Then attach first floor timber sills and floor joists (Figs. 21 and 22). If the building will have no proper timber deck, then the model posts fasten directly to the plywood.

To raise the model frame, start as you would a real bent-style raising: raise one bent and brace it off (Fig. 23).

Posts can be secured to the sills with brads, or ultimately to the deck by providing screw holes up through the plywood for small screws to reach the base of the post (Fig. 22). Pre-drilling ensures correct alignment and prevents the posts from splitting.

As bents are raised, secure them by adding connecting girts (interties) and wall braces (Figs. 24 and 25).

Lay second-floor joists according to the timber plan (Fig. 26).

Set plates, upper tie beams and their braces (Figs. 27 and 28).

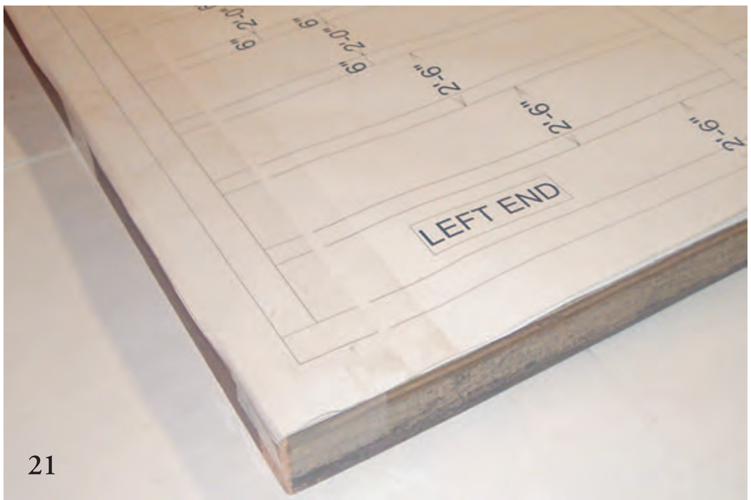
Lay attic joists (Fig. 29).

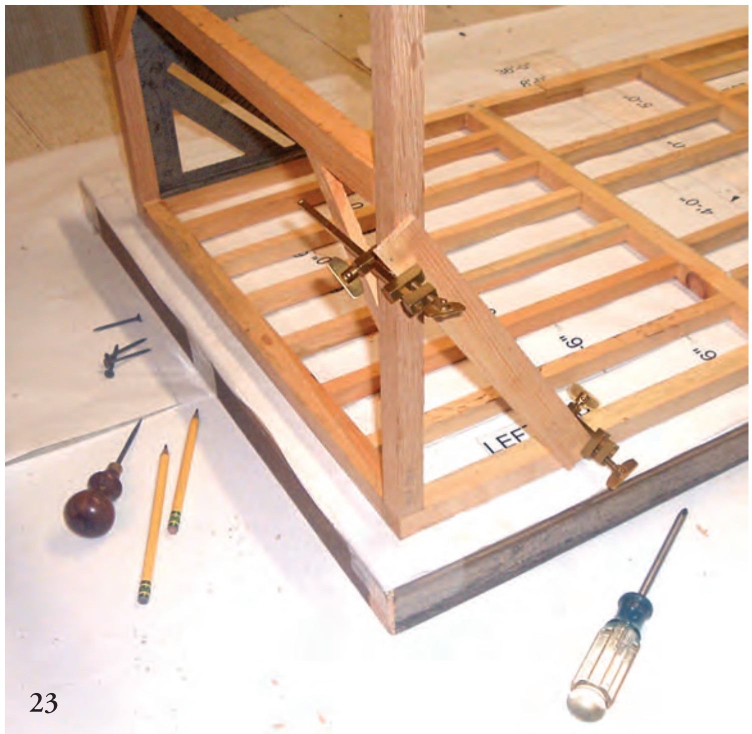
Common rafters are seated first on the tie beams (Fig. 30), and then on a raising plate (not yet in place), a wide plank that lies over the cantilevered ends of the attic floor joists.

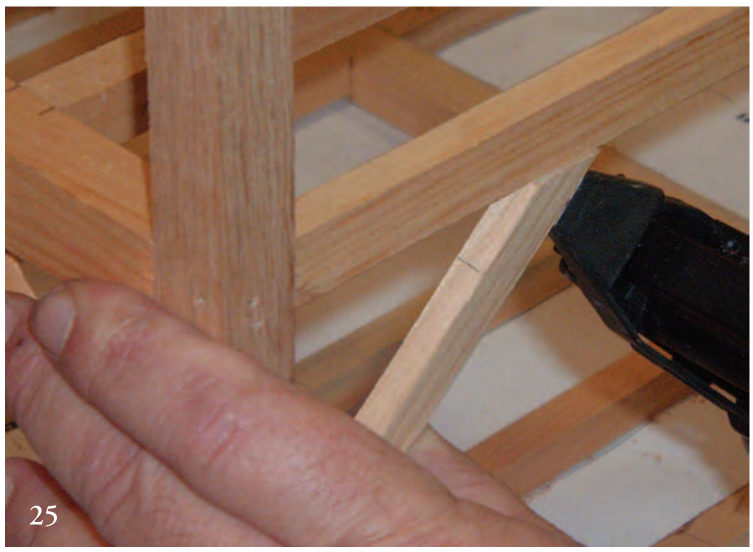
Add the wetting bush, and the model is complete (Fig. 31).

—Jim Rogers

Jim Rogers (jrsawmill@verizon.net) operates Jim Rogers Timber Designs, Vintage Tools New England, and Jim Rogers Sawmill in Georgetown, Massachusetts. This material is drawn from a manual provided as part of his model-building workshop at the 2014 Manchester, N. H., Guild conference.







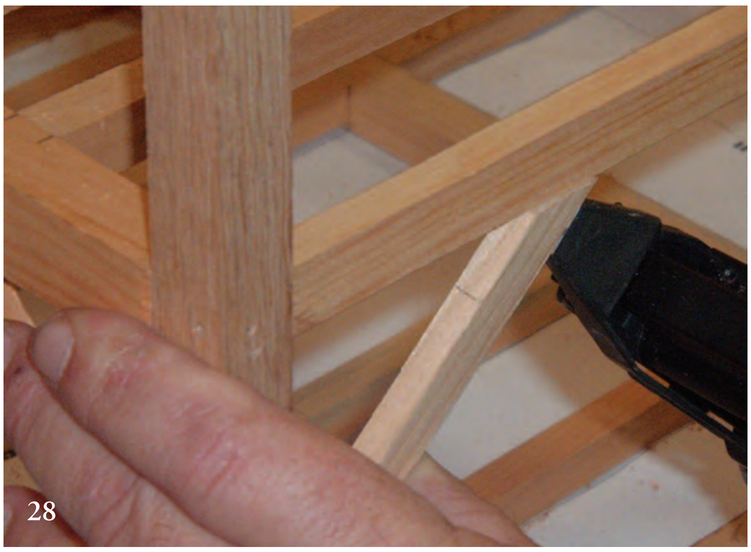
21 Timber deck plan attached to plywood base for deck layout and raising of bents.

22 Laying sills and first floor joists. Hole in sill at girder joint will clear screw from underside of base up into wall post.

23 Raising first bent and bracing plumb, held here with clamps.

24 Setting connecting girt with finish-nail gun.

25 Adding long wall braces.



26 Laying and fastening second floor joists.

27 Setting plates.

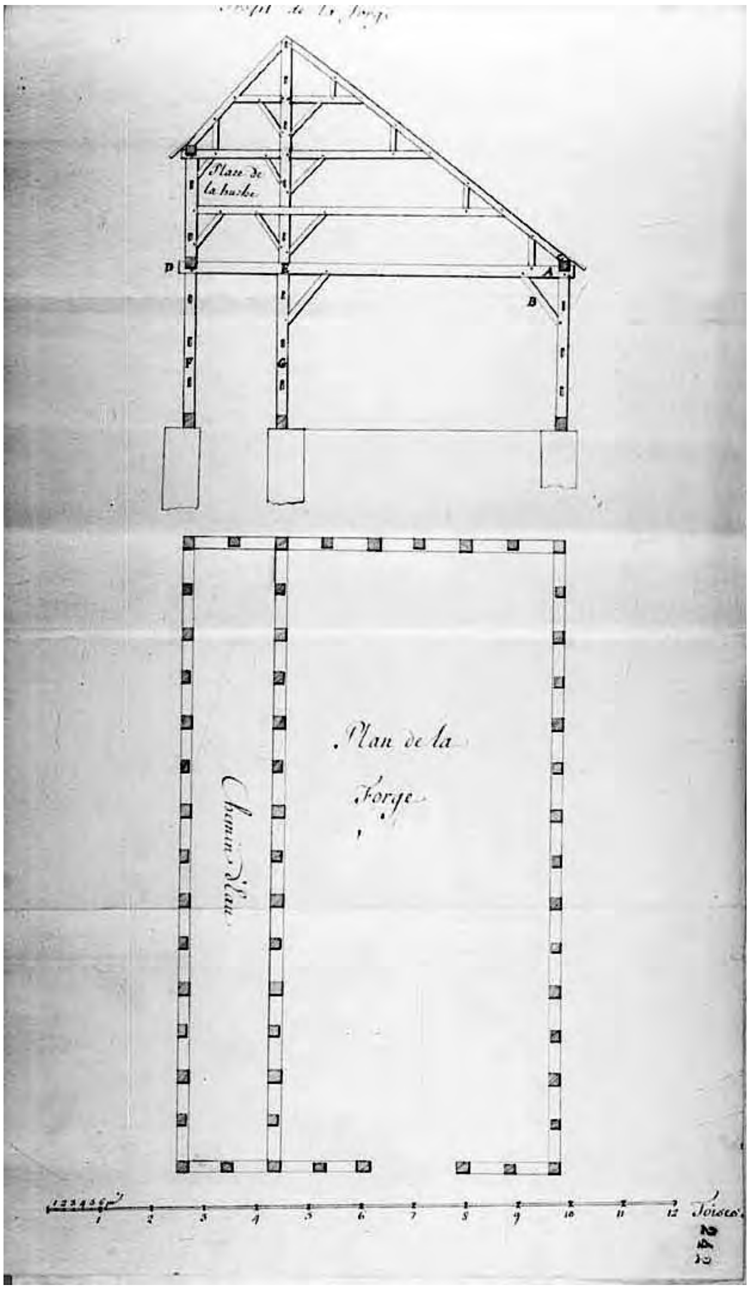
28 Setting tie beams and their braces.

29 Laying attic floor joists.

30 Setting a common rafter. Remaining commons will seat on raising plate laid over cantilevered ends of attic joists and visible in Fig. 31.

31 Finished model.

What Was Chaussegros de Léry Worried About?



Archives Canada

Memorandum

For the frame of the forge to be well constructed, one must place the beams in a manner which caps the posts. This is to say that one makes a tenon at the top of the posts, and in the beams, a mortise. It will be seen that the beam A extends to the outside 3 or 4 inches beyond the posts. It then bears upon the posts placed inside of the area marked B. The plate C bears on the beams and is notched at each beam to a depth of 3 or 4 inches across the width of the plate, and at the plate C [make] another notch of 3 inches across the width of the [each] beam. By this means the roof frame can never spread beyond the ground plan of the building. If the beams are not found long enough, they are scarfed at the end marked DE.

As regards the wall in place of the posts F and G, it's work that will cost close to 3000 pounds and, since there is no material amassed on site and it must be brought in during the months of May and June, it will take all that one can do to carry out this work in those two months—supposing that the weather is fine.

That will cause a delay of at least two months or perhaps three where one could make ten to 12,000 pounds of iron, without counting the cost of the wall, which could be done in another year. If judged appropriate, one could erect it on the foundations, removing the posts as one proceeded, or else enclose them in the walls. The work would be the more solid thereby. It's up to the interested parties to reflect upon and consider, and not to spend money uselessly.

—Translation by Jan Lewandoski and Ken Rower

1 At left, *Plan* (or *Projet*) *de la Forge*, ca.-1738 drawing of frame for new forge structure at Saint-Maurice ironworks near Trois Rivières in eastern French Canada, attributed to Gaspard-Joseph Chaussegros de Léry (1682–1756). *C* marks end of righthand wall plate. Under short side of roof, *Place de la huche* probably indicates location of penstock to bring water to overshot wheels in *Chemin d'Eau* labeled in plan view. A *toise* measured 6 ft. 5 in.

2 Above, translation of document attributed to Chaussegros de Léry, in which he explains roof framing of new structure, then discusses what might be others' proposals to build masonry walls in place of posts, which he does not favor. A pound (*livre*) in money was equivalent to about $12 today, in weight to about 17 oz.

SIX years ago I found myself online examining over 650 documents pertaining to the activities of the Royal Chief Engineer for New France from 1719 to 1756, Gaspard-Joseph Chaussegros de Léry (1682–1756). My purpose was to research 18th-century wooden framing in Québec, relative to my discovery of anomalous relict framing in the Lower Champlain Valley of Vermont near the site of Fort Saint-Frédéric (now Crown Point, New York, originally Pointe à la Chevelure, meaning "scalp point"). Fort Saint-Frédéric and the approximately 200 French wooden houses, churches and barns surrounding it on both sides of the lake were destroyed in 1759, toward the end of what we call the French and Indian War.

Occasionally in this archive (archivescanada.ca, with most original documents in the Archives of the Departement d'Outre-Mer in France) I would find an elevation drawing of a frame, or an account of construction quantities and costs or of where desirable wood species were to be found, but the most interesting document I found was the Plan de la Forge (Fig. 1), which Archives Canada identifies as the work of Chaussegros de Léry for the Saint-Maurice Ironworks near Trois-Rivières in Québec, Canada's first major industrial operation and a National Historic Site today. The document itseis undated, but the archivists put it at ca. 1738, when Chaussegros de Léry was known to be at work on this very project. Even more remarkable is that the drawing, an elevation of a bent and a plan of the footprint of the frame, is accompanied by a *mémoire* (Figs. 2 and 3), in the sense of a memorandum of facts and ideas, in which the designer of this frame specifies some elements of joinery that will alleviate certain concerns he has with the structure. Historic framers are archaeologists of a kind and we usually have only the artifact, an existing old structure, and find ourselves arguing over the intent of the framer's choices. Here we have the intent, although the artifact no longer exists except on paper.

What is Chaussegros de Léry concerned about in this account? One of the things framers have been concerned about through history: how to maximize open space inside a structure while maintaining stability, particularly without allowing the effects of dead and live loads to depress the roof system and spread the eaves beyond the walls or push the walls out of plumb. In the worst cases this sequence can flatten the building. The Royal Engineer's answer is to lock the plate (*sablière*) *C* tightly to the tie beam *A* as well as to other transverse beams, by deep notching into each other, so that the plate will resist being pushed or rolled by rafter thrust.

On first looking at the elevation of the bent, there appears to be plenty of framing in the roof system to make it rigid in itself. A closer look shows why Chaussegros de Léry might be worried. The forge is actually a saltbox, platform framed on the tall side over the *Chemin d'Eau* or water channel, with a hinge point at *D*. That roof is short, however, and the slope is steep (12:12) and so perhaps of less concern, but the rectangular portion of the forge building under the longer roof on the right is about 35 ft. wide with some 43 ft. of rafter length, without intermediate posts and with relatively short bracing. These dimensions are converted from the French *pied* (foot) of the 18th century, which was about 6.6 percent longer than the contemporary US foot. In use the *pied* was subdivided into 12 *pouces* (thumbs) and aggregated into *toises* (fathoms) of six *pieds*. The scale at the bottom of Fig. 1 is in these units.

The major bents of the projected forge, which include principal rafters, are a little over 10 ft. on center, and we don't know if there are common rafters. No notches, mortises or cleats for purlins are indicated on the rafters, but with this bent spacing there likely would be small purlins or common rafters, and perhaps both. While there remain very few all-wooden frames from 18th-century Québec or France, there are plenty of timber-framed roof systems on top of masonry walls, and the rafter spacing varies typically from 3 to 6 ft., with small purlins for vertical boarding or the closer spacing of rafters for horizontal boarding.

In the case of the forge, the same triple-collared roof frame might occur even over the minor wall posts that subdivide the longitudinal spaces between the major bents, since 10 ft. is long for the sort of small-section purlins called *pannes*, and few persons would stretch a 43-ft. rafter unstiffened over a 35-ft. span at the given pitch of around 8:12. The mortises in the column that rises to the ridge are characteristic of longitudinal bracing systems typical of French and Québecois construction at the time, usually integrated into a structural ridge.

What mode of failure is Chaussegros de Léry hoping to avoid? Snow and wind loading, and possibly the weight of slate roofing on the long slope are already mitigated by the configuration of tall posts *G* and a structural (if segmented) ridge tenoned into them. At the long slope's 8:12 pitch, this may remove somewhat less than half the load delivered by the rafters to the plate, and somewhat more than half this residual load will be trying to push the plate horizontally outward. The three collar levels by their bracing and struts produce triangulation that stiffens the rafter and, with whatever tension capacity the collar-to-rafter joints have, restrain rafter thrust by an unknowable amount. At the lowest strut that drops to the big tie beam above a brace (at the extreme right on the drawing), some compressive load transfer that diminishes thrust against the plate is gained, but not as much as a short canted strut would effect.

The greater danger to the goodness of the frame is probably foundation settling or undercutting of foundation walls under post lines *F* and *G* along the water channel. Were *G* wall to settle, the entire roof system would drop, pressing outward on both of the wall plates, turning the virtues of the tall posts and structural ridge into a vice, since their weight and that of everything attached to them, would now be pulling down on the rafter system. For Chaussegros de Léry's lock-in plate joinery to succeed in this event, it would have to suspend the unsupported tall posts, turning them from compression members to tension members. Since the entire foundation under wall *G* may not have fallen away at the same time, it is possible that the surplus capacity of several of the eight (or possibly more) principal-raftered frames, combined with a very stiff joint at the outside wall *F* would keep the forge square and true. I actually suspect that the hinge and similar foundation (with similar problems) under the *F* wall might be as weak a link, although its failure would have a lesser, gradually detrimental, effect of pulling the 35-ft. space, the workrooms of the forge, out of plumb.

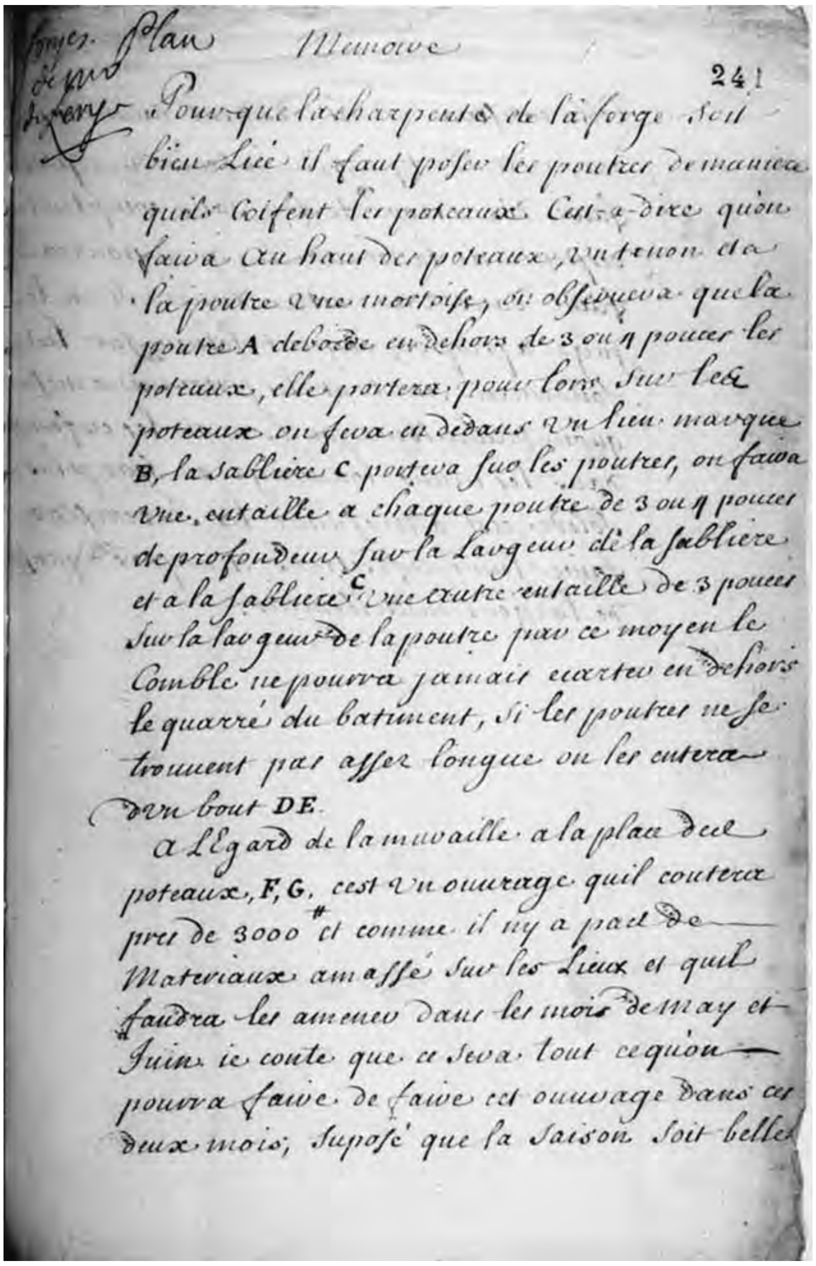
The third section of the memo is the most difficult to understand because it deals less with construction details than with hypotheticals concerning not having time or money to get stone walls erected in place of or including the tall posts *F* and *G*, and suggesting that it would be better to go ahead and make iron anyhow. The last passage of the text is a somewhat pointed comment concerning the interested parties making their own reflections and not spending money uselessly. This sentence provides a clue to some of what the Chief Engineer is worried about, and can be illuminated by an account of events at the forges in the years immediately before "the engineer Chaussegros de Léry had to step in and rectify the system," as Roch Samson remarks in his excellent 1998 book *The Forges du Saint-Maurice: The Beginnings of the Iron and Steel Industry in Canada, 1730–1883*, a joint enterprise with Parks Canada. A chronology drawn from Samson's narrative applies to our question.

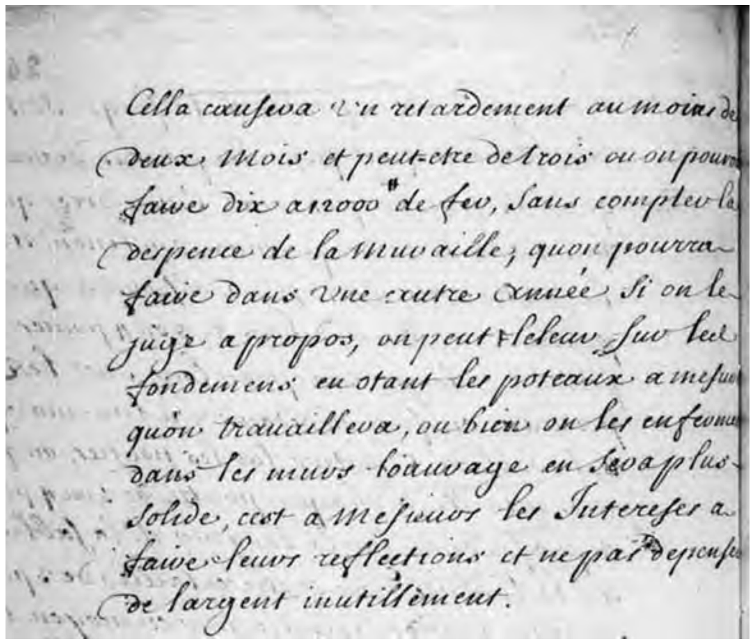
1734: The seigneur and Montreal merchant François Poulin de Francheville, with government encouragement, builds a forge on the St.-Maurice River but fails to make iron profitably. In addition, the spring thaw reveals how unstable the forge's machinery is. Operations are suspended after a few months.

1735: The French Ministry of the Marine takes over and sends an experienced ironmaster from France, Pierre-François Olivier de Vézin, who finds the winter climate in New France difficult and that the effects of freezing and thawing in particular put foundations and structures to a severe test.

1736: The St.-Maurice River, swollen in the spring from snowmelt, delays the important job of quarrying limestone on its banks upriver in nearby Gabelle. The limestone was to be used both for the foundations of the forge structures and as flux in the ironmaking process. Vézin has stone brought at great expense from Québec to Trois-Rivières along the St.-Laurent (St. Lawrence) and upstream on the St.-Maurice to the site, but then does not use it as when the St.-Maurice subsides transport is restored from Gabelle and local quarrying resumes.

1737: A large charcoal house is constructed at the blast furnace. A 1737 letter in the archives claims that the forge has 6000 cords of cut wood on site. Burning charcoal both melted the iron and added carbon to make it harder. At the time, hardwood charcoal was preferred for smelting at the blast furnace and softwood charcoal for later refining of the iron. Both are available in huge quan-





Archives Canada

3 Chaussegros de Léry's *Memoire* (dated 1739 by Samson), above and above right, with tranlators' transcription at right. Doubtful words flagged by question marks in transcription. For translation see Fig. 2.

Memoire

Pourque la charpente de la forge soit bien Liée il faut poser les poutres de maniere quils Coifent les poteaux. Ceci-a-dire qu'on faira au haut des poteaux un tenon et a la poutre une mortoise, on observera que la poutre A deborde en dehors de 3 ou 4 pouces les poteaux, elle portera pour lors sur les poteaux on fera en dedans un lieu marque B, la Sabliere C portera sur les poutres, on faira une entaille a chaque poutre de 3 ou 4 pouces de profondeur sur la largeur de la Sabliere et a la Sabliere C une autre entaille de 3 pouces sur la largeur de la poutre. Par ce moyen le Comble ne pourra jamais ecarter en dehors le quarré de batiment, Si les poutres ne se trouvent pas assez longue on les entera d'un bout DE.

A L Egard de la muraille a la place des poteaux, F,G, c'est un ouvrage quil coutera pres de 3000# et comme il ny a pas de Materiaux amassé sur les lieux et quil faudra les amener dans les mois de May et Juin ie [il?] conte que ce sera tout ce qu'on pourra faire de faire cet ouvrage dans ces deux mois, suposé que la saison soit belle.

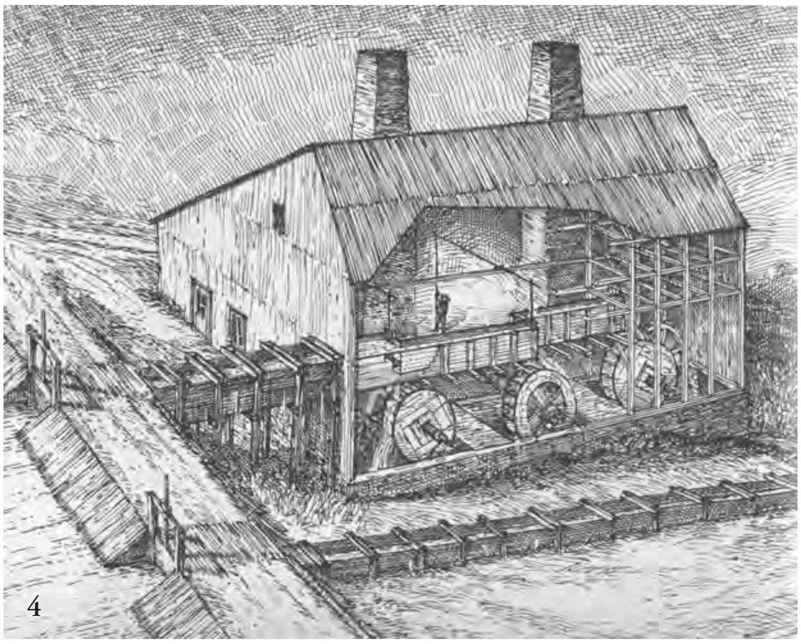
Cella causera un retardement au moins de deux mois et peut-etre de trois ou on pourra faire dix a 12000 # de fer, sans compter la despence de la Muraille, qu on pourra faire dans une autre année. Si on le juge a propos, on peut l'elever [?] Sur les fondemens en otant les poteaux a mesure qu on travaillera, ou bien on les enferment dans les murs l'ouvrage en Sera plus solide, cest a Mesieurs les Intereses a faire leurs reflections et ne pas depenser de l'argent inutillement.

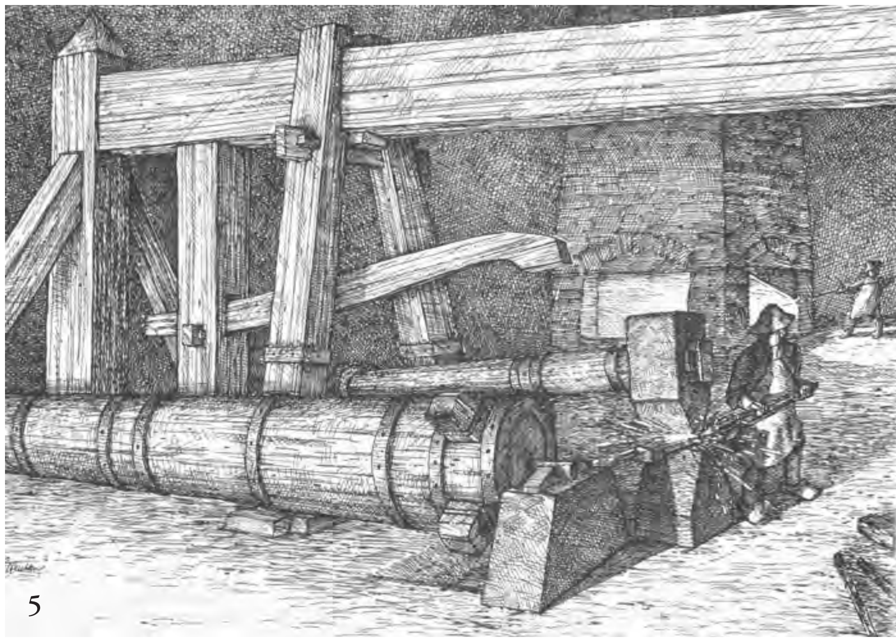
tities in the roughly 300,000-acre land reserve granted to the enterprise. The builder of the charcoal house, as well as a forge and other buildings that prove problematic in use, is a carpenter from Québec town named Charléry, hired carelessly by one of the business partners in the enterprise.

1738: The new charcoal house collapses under the weight of snow on April 1. The Royal Engineer Chaussegros de Léry, already in New France to work on fortifications, is called upon to rectify the operations. Most of his work here has to do with hydraulic engineering and water-powered machinery, but also includes design and perhaps construction of a second forge (to be called the upper forge) based upon the frame illustrated in the Plan de la Forge (which Samson dates at 1739). The new structure will contain three 10-ft.-dia. water wheels in the water channel as well as a triphammer and other forge machinery, two large chimneys and charcoal storage (Figs. 4 and 5).

IN this period timber framers were often called upon to construct wooden machinery like the hammer in Fig. 5, often very heavily built. Here we may have an explanation why a memo was written on the restraint of rafter thrust. Chaussegros de Léry was presented with the collapse of the charcoal house under snow load and asked not to let such an event happen again. Thus he specifies joinery for a plate that is difficult to roll, which is what often happens when snow load depresses a roof system.

But Vézin had also called in Chaussegros de Léry to deal with the problem of excessive water in his foundations. The engineer probably knows that foundation problems are as great a threat to the forge as weak joinery and he would prefer the stonework and drainage well done. However, he is likely under pressure from a management that wants to make iron soon, and thus he avoids responsibility for stonework and suggests that the interested parties make their own reflections, throwing in the admonition about spending money uselessly. These are not generic comments but have the particular context of the events in 1736 when, in an atmosphere of haste to make iron and recoup the large investment, Vézin and the partners purchased stone from quarries along the St.-Laurent, had it transported to Trois-Rivières and brought up the St.-Maurice to the forge, at great expense. By the time this stone arrived, the river had gone down, their own stone became





From Roch Samson, *The Forges du Saint-Maurice,* published by Parks Canada and Les Presses de l'Université Laval (1998), drawings Bernard Duchesne

4 Conjectural drawing of Upper Forge developed from 1739 frame drawing and inventory of 1741, showing overshot 10-ft. waterwheels, penstock (*la huche* in Fig. 1) to power them as well as penstock leading downhill from stream to power lower forge.

5 Massive timber frame accommodating triphammer with banded helve raised by slow-turning, waterwheel-driven banded camshaft (about 3 ft. in dia.) with inserted cams. Curved element suspended above helve would spring-return hammer to anvil but is shown posed too high to be effective. Blast furnace in background.

6 Map of area showing location of Forges du Saint-Maurice, a few miles up St.-Maurice from Trois-Rivières, the latter town New France's second settlement (1634) after Québec (1608), and so named because of two islands dividing the St.-Maurice into three mouths where it joins the St. Laurent. Oak timbers for massive purposes such as hammer frame came from Chambly, on the Richelieu River a little north of St. Jean-sur-Richelieu.

Google Map adapted by Michael Cuba

available and they used that, leaving the costly imported stone lying on the ground. This incident, somewhere between unfortunate and a scandalous waste of public funds, is probably the inspiration for Chaussegros de Léry's admonition.

Was the forge as drawn ever built? Samson thinks so and has some evidence in the 1741 inventory of the premises that has the upper forge almost identical in size to the specifications on the drawing: 70 *pieds* long by 44.5 *pieds* wide, with a wall height of 17.5 *pieds*, or about 75 by 47 ft., 19 ft. 8 in. high. We would like to know wood species but they are unspecified. The choices were great and they may be many and mixed.

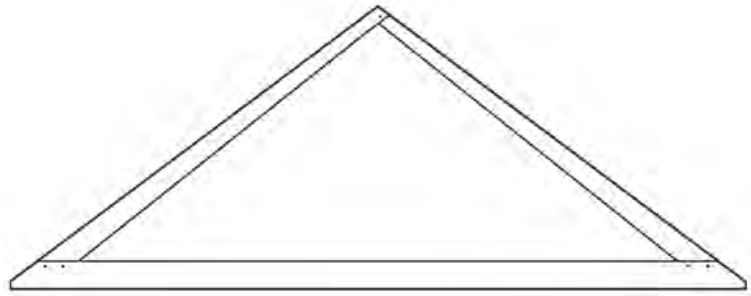
A question of interest to framers is how large are the timbers in use. Using the scale of *toises* (six *pieds*) at the bottom of the plan, the major posts and the lowest tie beam appear to be 18x18 in. While it is possible that Chaussegros de Léry drew the timbers oversized to allow room to display joinery and identification, mills with their vibrating machinery generally were the most heavily built of 18th-century frames other than long-span trusses, uncommon at the time. In his memo, Chaussegros de Léry seems to despair of acquiring 48-ft. 18x18 tie beams and suggests scarfing where tension was lowest, this in spite of Vézin's 1736 report that he had to cut down "monstrous" trees to clear the site for the forge. John Johnson's 1799 lumber list for the multispan bridge across the Richelieu River at St. Jean in Québec began by specifying 231 timbers 16x18 and 53 ft. long (see TF 10), so we know that this sort of material was available nearby and used during this heroic period of timber framing. In an appendix, Samson quotes Chaussegros de Léry's *Estat des bois de chesne nécessaires pour les harnois d'une forge,* that is, a list of the oak timbers necessary for the forge's equipment. Among many large oak members are the 17x17 jambs for the forge hammer assembly and a 38-in.-dia. toothed rotating shaft to raise and drop the hammer (Fig. 5). Samson notes that the only wood brought for the forge from off site is oak (*chesne* or *chaine*, today *chêne*), carried from Chambly just north of St. Jean on the Richelieu River between Montreal and Lake Champlain (see Fig. 6).

Commentary

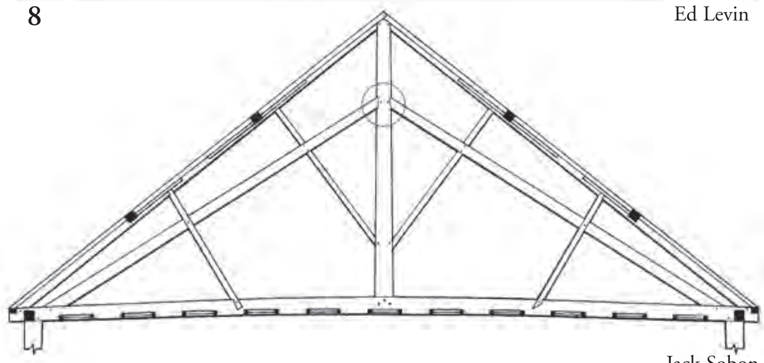
CHAUSSEGROS de Léry was hardly the first and not the last person to contemplate the problem of rafter thrust. In all likelihood, most solutions are ancient and spring from the inventiveness of framers rather than the considerations of engineers or architects. Rafter thrust and spread have a great number of causes, and spread is in fact a visible symptom of almost all the structural problems a frame, or even a masonry building, might have.

If a part of the eaves wall foundation, sill or post fails or rots, this will drop part of the wall, unweight some rafters and put

Will Beemer



8 Ed Levin



Jack Sobon

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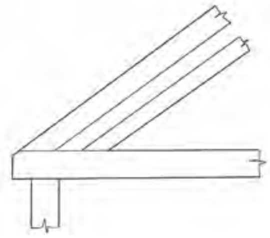

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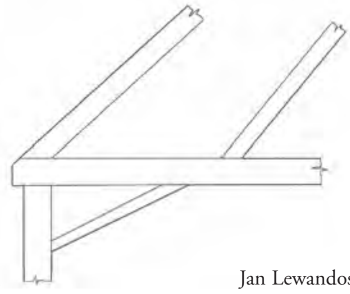


11 Jan Lewandoski

7 Cruck frame, workshop-built in Massachusetts, 2005.

8 Essential base-tied truss.

9 Early double-raftered truss, Strafford (Vt.) Meetinghouse, 1798.

10 Practical spacing for inner rafter of double-raftered truss.

11 Impractical spacing for inner rafter. Brace ineffective.

much more roof load on others that still bear upon a plate, and may overload the last. Failure of tying joints at the top of a wall because of bad design or rot will allow roof loading to push the plate outward, or even the entire wall. Excessive and underestimated loading of a roof system, such as by the presence or addition of cupolas, steeples or chimneys, or a change from wood shingles to slate, can exceed the bending capacity of rafters, plates or tie beams and result in movement.

The failure, or their deliberate removal for convenience, of interior supports such as purlin ties and intermediate posts that comprise integral parts of roof-system stability will result in a dropping of the ridge and consequent spreading at the eaves. To make matters worse, sometimes interior galleries and floors are hung from a roof system after their supporting posts are removed.

How have framers restrained rafter thrust? No person or group of persons has seen or can see in a lifetime enough examples of timber framing in one country, let alone worldwide, to write its history. Also, timber framing, other than the great wooden bridges of the 19th and early 20th centuries, reached its greatest development perhaps 200 to 1000 years ago, and we have no one alive and very little written about it to help us understand its intent and aesthetics. What we have is the physical evidence of the inventiveness, engineering ability and aesthetic sense in the products of craftsman who worked (and we think liked to work) within the physical constraints of natural material.

Cruck frame The cruck frame very successfully takes almost all roof load away from the plate and exterior walls and directs it, often by a drier interior path, to the ground or sometimes a tie beam. The beautiful structures produced required lots of large curved timber, framers and carpenters ready to work close to irregular natural materials and a premodern aesthetic focused on large, riven parts of trees (Fig. 7).

Trussed roof frames Instead of rafters bearing on a plate atop a wall, they tenon or notch into tie beams attached to plates or posts. These trusses may be composed of as few as three members, i.e., two rafters and a tie beam (Fig. 8), or numerous more elements. Ideally there is no thrust on the plate or wall, rather roof loads are converted to axial tension loads in the tie beam, loads that it can bear. In reality, the rafters in this configuration are trying to crush the end of the tie beams, to a degree depending upon the pitch of the roof. Also, while the tie beam in its entirety has adequate capacity to absorb in tension the roof loading, the critical point of failure is the short relish beyond the rafter tenons at the end of the ties. This relish eventually fails in double shear in a large percentage of its applications, particularly since the end of a tie beam is subject to roof leakage and eaves damage, rapid drying, checking and cracking, blowing in of water under the roofing and insect damage, more so than the rest of the beam. Also, in long spans such as those over 24 ft., one end of a single-stick tie beam, originally oriented toward the top of the tree, will display spiral grain, more knots and other such defects. Add to this the framer's tendency to locate mortises for flying purlins or segmental plates and other eaves joinery in this same bearing area, and sometimes complete cantilevering of the tie beam end and rafter to the outside of the plate, and you will see the weakness of the single-raftered truss.

Failure of the single-raftered truss, unless the tie beam itself breaks within the span of the walls, doesn't usually result in walls being pushed out of plumb, but rather the eaves being distorted, the tie beam sagging into the ceiling if it is a king- or queenpost truss, and additional load being thrown to adjacent trusses with possible harmful consequences.

Double-raftered trusses and the *jambe de force* All of these roof frames attempt to take much of the roof load and deliver it by a relatively dry and protected interior path to the same tie beam as the outer rafters, and to a mortise 1 or 2 ft. in from the eaves


12

Chris Drake

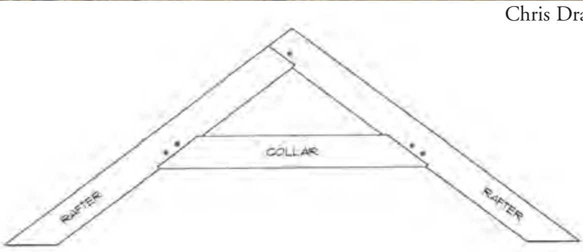

14

Ken Rower

12 *Jambe de force* descends from collar beam to tie beam in white fir frame built by Frameworks Timber, Fort Collins, Co., 2012.

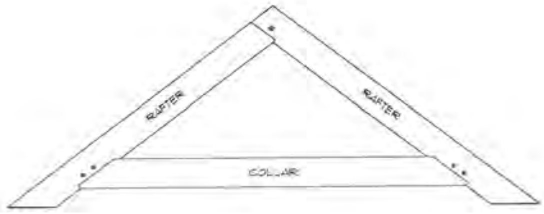
13 Gallows frame and end supports for barn ridge, Guild project, Brownington, Vt., 2014.

14 Collar beam in compression (a) and tension (b) according to height.



14a

Ed Levin



14b

rather than 3 or 4 in. in as in the single-raftered truss. If the outer rafter starts service life with more load, and then crushes into a rotting tie beam end, then more load is naturally shifted to the inner rafter (Figs. 9 and 10).

These are very successful trusses, but they must be designed correctly. In a building with relatively thin walls, such as a wooden frame, the inner rafter will bear on an unsupported section of tie beam (or bottom chord) inboard of the wall. Some localized bending will occur but not serious distress, unless the inner rafter is brought too far inside as in Fig. 11.

Some roof trusses and many wooden bridge trusses contain a short strut let into a main post or rafter not far above its bearing on the bottom chord. This strut in a roof truss is at a steeper pitch than the rafter and lands inboard of the end of the tie beam, bringing the load more nearly toward the ground and taking pressure off the short relish at the end of the tie beam or chord. This is much the same idea as the schemes mentioned above (Fig. 12).

Interior support: purlin systems and the structural ridge One can remove much weight and thrust from an exterior plate and wall by propping rafters on a structural ridge, on one or more lines of principal purlins in the span, or on very tall columns that reach from strong interior positions to the roof frame. Chaussegros de Léry's frame has just such tall columns supporting the principal rafters, with perhaps a structural ridge for other undelineated rafters. Two articles in TF 114 dealt with this method. In Don Perkins's "Ship's Knees of Maine," we saw very large natural knees, well capable of resisting overturning because of their form and large bearing areas, both prop up and tenon into principal rafters in the bent, thus resisting outward movement in these two ways. And David Bähler's fascinating "Structural-Ridge Swiss Roofs" showed how a structural ridge and multiple purlins can remove thrust and load from the plate and exterior wall. Chinese framing (see "Chinese Traditional Framing," TF 16, 17 and 20) typically has featured a large number of tall interior columns rising to lines of purlins carrying small rafters with short spans without a hierarchically larger plate at all, just eaves purlins.

Recognizing the accompanying burden of having many interior posts to support structural ridges or purlins, Bähler calls the method "a thoroughly practical approach that effectively avoids (rather than solves) difficult challenges in timber framing." He is correct in suggesting that there is no defeating gravity in the long run. Purlin systems are good at reducing the bending in rafters, but unless the rafters are joined into the purlins as they pass, they can slip across the purlins and still cause eaves and walls to spread.

The five-sided mortised ridge (five-sided to accommodate normal rafter connections at roof pitches other than 12:12), common in early frames in parts of New England and New York and often 30 to 50 ft. long as a single stick, serves merely to link the common rafters at their peak and act as an aid during raising. Pierced by many mortises, it tends to bend or break when rafters sag. The addition of a gallows frame, a pair of posts rising from points along the ridgeline of the frame to the ridge, usually joined by a braced beam, can turn the five-sided ridge into a structural ridge quite effectively (Fig. 13).

Collars and raised tie beams Somewhat similar to base-tying rafters, but simpler and less effective, is the introduction of collars to rafter pairs. If collars are located above the lower third of the rafters (Fig. 14a), generally they are in compression (unless the rafters are so large and stiff as to be unaffected) and bending is still possible in the part of the rafters below the collar. If collars are placed lower, they become longer and need to become larger, otherwise they will buckle when compression occurs. But at some point in the descent they reverse function to become tension members (Fig. 14b), and also obstruct the usable space under the roof. At this point they might as well be called raised tie beams and will need tension joinery to connect them to the rafters. While this

15

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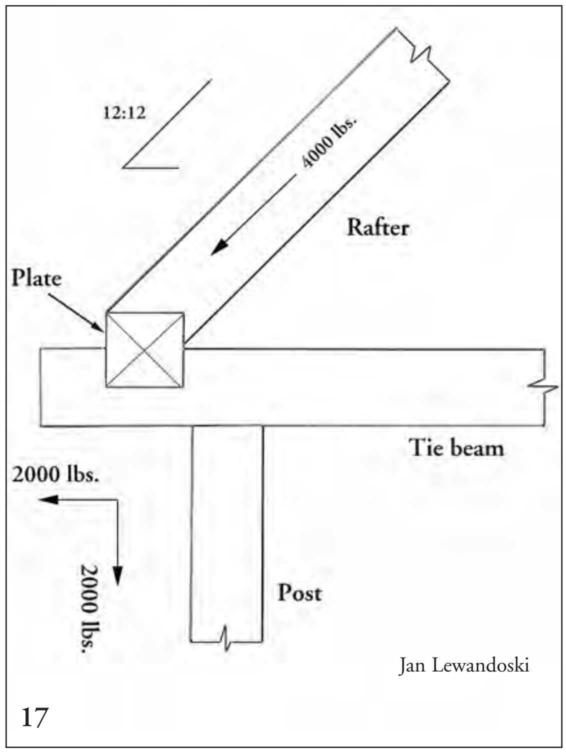
Jan Lewandoski



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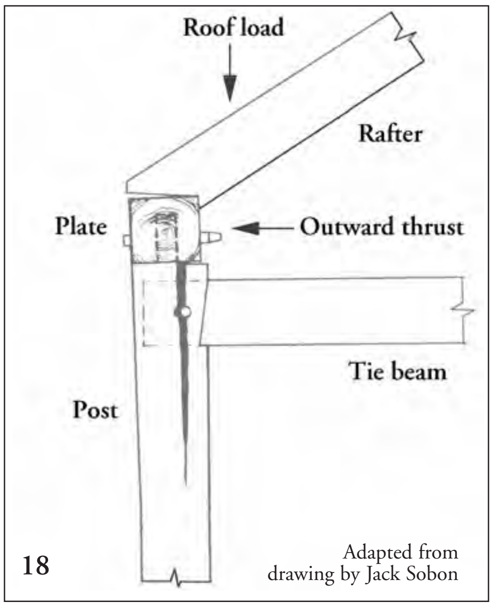

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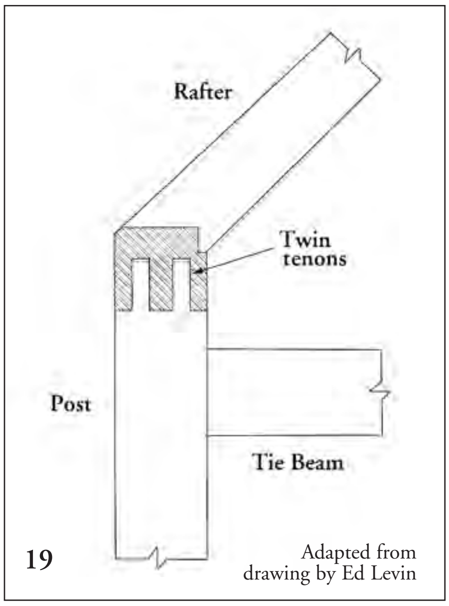

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15 Sag in roof of meetinghouse, South Reading, Vt., 1844, resulting from lost section at rafter connection with collar beam.

16 Buttressed walls at St. Andrews church, St. Johnsbury, Vt., 1861. Steeply canted timbers inside boxes are restrained at lower end by extended floor beams.

17 At 12:12 pitch, axial rafter load resolves into equal vertical and horizontal components. At steeper angles, horizontal thrust grows proportionately smaller.

18 Excessive rafter thrust can split wall post restrained by tie beam when post is weakened by decay or checking.

19 Displacing the post tenon inward or cutting twin tenons can better resist such action.

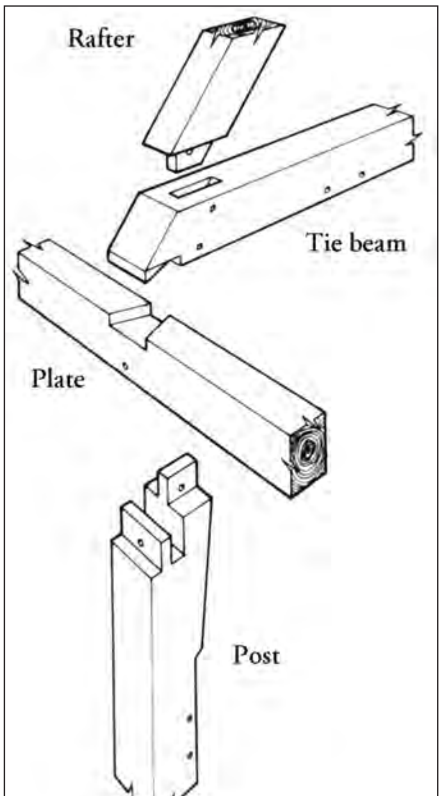
joinery is needed for tension capacity, it also removes section from the rafter. The visible sag in many church roof becomes located at just this point (Fig. 15).

Buttressing Outside the perimeter of the walls, buttressing is located periodically at points of high stress. This technique is of course well known in stone-built Gothic style churches but is also used in 19th-century wooden Gothic Revival churches. While sometimes wooden buttresses are simply false, with the form of a buttress but containing nothing inside an empty decorative box, they might in fact contain a steeply canted timber buttressing a wall post, such as at St. Andrews, St. Johnsbury, Vermont, 1861, where extended floor timbers actually anchor the canted timbers (Fig. 16). But even so these steeply pitched braces arriving short of the top of a slender wall column are of little effectiveness.

Steepening the roof pitch A steeper roof pitch will change the proportions of vertical and horizontal load at the plate. A pitch of 12:12 will produce as much vertical load on the plate as horizontal thrust, and more vertical load than horizontal thrust will result for pitches greater than 12:12, as well as snow sliding off more readily (Fig. 17). The price paid is a relatively tall roof with increased wind pressure and long rafters covering marginally usable space. The tradeoff is worthwhile in areas of very heavy snow loading (in the East, northern New England, New York and Québec), but in the 18th and 19th centuries the Classical Revival in its various forms on the contrary emphasized an escape from medieval forms and the adoption of low pitches such as 6:12 and 7:12 in imitation of ancient Mediterranean monuments, in spite of the dramatically different climate.

Common rafters bearing on the plate Where modest-dimension common rafters steplap into the middle or outer half of the top of the plate, the result is a tendency toward overturning or rolling the plate. This tendency can be countered by birdsmouthing or lapping the rafters against the inside of the plate. But such positioning on the plate requires a deep rafter to bring the roof plane out to the eaves, deeper than needed to carry the roof load. Furthermore, if the rafters are heavy (as in Fig. 17), the timber bill increases and erection is more difficult.

If rafter thrust toward the outside of the plate doesn't overturn or tear the plate off, it occasionally splits one or more posts supporting the plate. The thrust uses the post tenon, usually located 1½ or 2 in. from the post's outside face, as a lever to split the post



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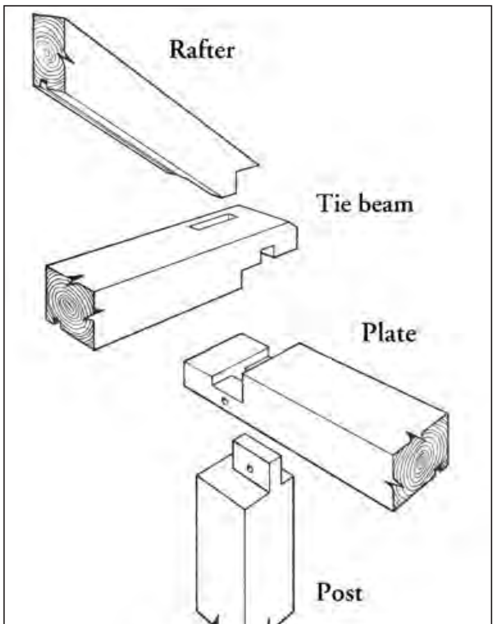

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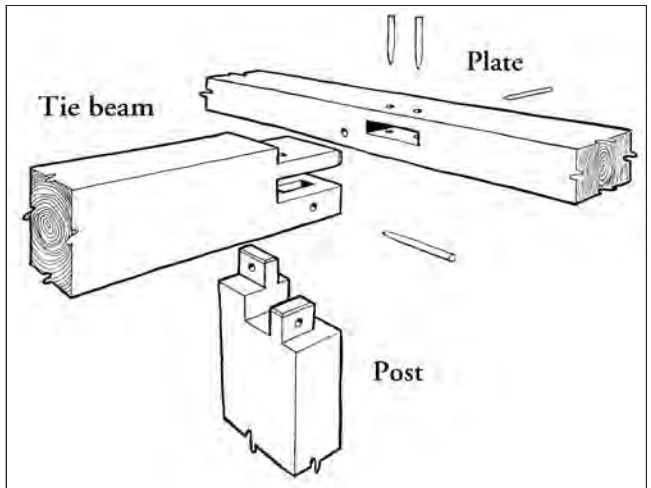

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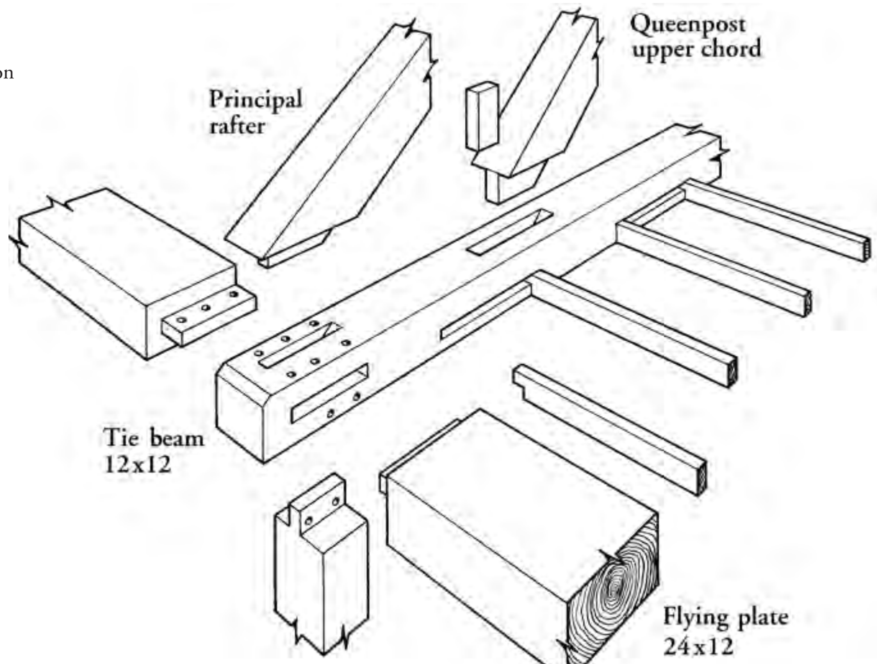
Drawings Jack Sobon



23

20 Typical English tying joint midwall, exploded view showing jowled post with wall plate tenon and tie beam (teazle) tenon, plate with lap dovetail recess in upper face for tie beam, tie beam with mortise for rafter seat, and tenoned rafter.

21 Unusual corner tying joint, Kents Corners, Vt., before 1810, with cogged connection between tie beam and plate provided by extension of post tenon into underside of tie. Grooves in underside of end rafter and plate accept tops of sheathing boards.

22 Triple bypass joint, Richmond, Mass., before 1810. Jowled post is rotated 90 degrees from position in English tying joint, teazle tenon then enters plate not tie beam. Tie is tenoned firmly to plate and mortised over remaining tenon on post.

23 Truss seat joint at flying plate, Rindge, N. H., 1797.

along a check, particularly if weakened by water infiltration and rot (Fig. 18). Inflection points at level changes in the top of flared or gunstocked posts, such as in Fig. 20, can likewise be vulnerable.

In a ca.-1820 barn in Montgomery, Vermont, the framer had abandoned typical reference face joinery and moved the tenons at the top of the 10x10 posts to 2 in. from the *inside* face, thinking, I believe, to better resist roll and cracking. Running taller post tenons right through the plate to better resist roll is likely never done as it would subject tenon end grain to moisture entry at the eaves (and the possibility of merely bending or breaking a longer tenon), but a twin tenon at the top of the post would well resist roll and twist of the plate (Fig. 19).

Locking in the plate Much as Chaussegros de Léry suggested, one can try to make it difficult for the plate to be forced outward or rolled by the rafters by locking it to the tie beams, in his case even though the plate sits atop the ties. The English tying joint commonly uses a half dovetail lap where the tie beam crosses over the plate, as well as a tenon rising into the plate from the post (Fig. 20). While useful, any dovetail is subject to shrinkage and side grain compression, and even horizontal shear, and thus some slippage is inevitable. English tying joints are sometimes cogged at this crossing, but the cog is necessarily small and half in the tie beam near the end, where shear and crushing are dangers (Fig. 21).

The triple bypass joint rests the plate on a tie beam lap, a tenon enters it from the tie, and another from the post as well, and although perforated by joinery, this configuration is pretty good as long as it doesn't get wet (Fig. 22).

While these arrangements help retain the plate at the bents, resistance to the thrust of common rafters depends upon the size, stiffness and connections of the plate between the bents. Often enough in large historic structures, common rafters bear upon a flying plate tenoned into the tie beam ends, rather than bearing upon the wall plate itself. At the 1797 Meetinghouse at Rindge, New Hampshire, with its original roof pitch of around 7:12, the flatwise 24x12 segmented flying plate may show some understanding of the need for stiffness, but in truth it may have been just another means of providing cornice framing at this time of great timber abundance (Fig. 23). The disconcerting fact that this immense plate merely tenons into mortises near the ends of the tie beams, and with short relish, is indicative of the problems we face when we have only the artifact, but no account of the framers intent. —Jan Lewandoski

Ann McGarrell and Marie-Dominique Corbière helped materially with transcription and translation of Chaussegros de Léry's mémoire.

Axe Culture

IN its simplicity the axe is an ingenious tool. An extension of the woodworker's arm, it serves multiple purposes, and provides the user's soft hand with the ability to cut and shape harder materials. The axe, the first woodworking implement and for a long time the only one, continues as a highly appreciated and purposeful tool in handwork, and demonstrates its close connection with the person as a potent maker, able to transform one's immediate surroundings with just two actions: cutting and hitting.

Though the form of the axe has undergone modifications since its initial appearance in the prehistoric era, its construction is still straightforward. The predecessor of the metal axe with wooden handle as we know it today was a heavy sharpened stone held in the hand. The more efficient arrangement of mounting the blade to a handle was followed by the arrival of metallurgy and the discovery that stone (ore) can be turned into metal and then into tools.

The axe evolved not only in the details of its design and fabrication techniques but also in cultural circumstances. The history of this tool is thus not a linear progression. Geography and society affected the process. The axe is not only a tool of labor. Its properties as a product of craftsmanship and its place in armory yield symbolic meanings and sacred significance in different cultures. It appears as a woodworking tool, a weapon or a ceremonial item in almost every corner of the world.

One of the most important symbols of Minoan civilization is the double-bitted axe (Fig. 1). Minoan culture prospered in the Bronze Age on the Greek island of Crete. (The Middle Minoan period, considered the age of glory, lasted ca. 2000–1500 BCE.) Discovered in modern times by British archaeologist Arthur Evans, Minoan Crete is thought to be the location of the mythological labyrinth, right next to the Palace of Knossos. Historical and etymological investigations lead to a conclusion that the word *labyrinth* is strictly related to the word for axe, *labrys*, in Lydian, an ancient Anatolian language.

The cultures of the Greek and Turkish peninsulas continually overlapped. In this case, Anatolian neighbors brought to Crete new metallurgic skills along with the cult of their *labrys*. Inside the Minoan palaces schematic representations of an axe were observed, and likewise in the labyrinth itself (Fig. 2). The tool had been given a religious importance.

One could question the presence of a generic forestry tool on an island that today is associated with dry soil and cultivated olive groves, but in fact Crete used to be covered in coniferous and deciduous trees. Historical documentation indicates fir, pine, oak, ash, maple and possibly cedar in addition to olive. Abundant wood was the main engine of success for some 500 years, with two solid bases for Minoan prosperity, naval entrepreneurship and bronze fabrication, both requiring massive wood consumption. The common fuel in early metallurgy was charcoal (ideal because of its high burning temperature, ca. 2500°F), obtained by evaporating all the fluid components from wood by slow burning in a limited air supply. Together with accelerated shipbuilding to export timber and bronze, the practice caused permanent deforestation. Cretan economical potential decreased so much that in 1450 BCE it was easily conquered by the next mighty civilization, the Mycenaean—a good lesson from the past about how important it is to temper the exploitation of natural resources.

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Nikater

C. Messier

1 Cast bronze *labrys*, 1400–1200 BCE. Thin blade implies ceremonial application.

2 Symbol of double-bitted axe carved in stone at Palace of Malia, Crete, similar to those on walls of labyrinth at Knossos.

3 Arkalochori Axe, cast bronze double-bitted votive axe, 1700–1450 BCE, excavated in Crete 1934.

Luigi Zanasi

Clark or Darius Kinsey

4 Double-bitted steel felling axe, 20th century, probably US made.

5 Felling a spruce with double-bitted axes and crosscut saw, probably early 20th century, Washington State.

6 North American woodworking tomahawk with stone head.

The double-bitted axe may be a mythic symbol of Minoan power and independence. While historical sources don't provide specific information about its meaning and application, anthropologists believe that the *labrys* had sacred connotations from the very beginning: perfectly symmetrical, derived from the earth (ore), allowing for transformation and re-creation. The double-edged design certainly can be explained on a practical level but may be also seen as an incorporation of metaphorical values. The symmetry is associated with Asherah, Anatolian goddess of birth and fertility (always depicted in a perfectly balanced position) and sometimes with the form of butterfly, an ancient Greek symbol of the human soul (Fig. 3). From the woodcutter's point of view, the balanced load at the end of the handle is indeed a big advantage, making the tool much easier to swing. The duplicated form also guarantees more durability—when one of the edges becomes blunt, the other is still usable. Sharpening is handy, as the user can just strike into a log to block the axe, hone one edge, then reverse.

The Minoan double-bitted axe was cast in bronze, a very hard material in its era. Axes with cutting edges almost decoratively curved were probably dedicated to ceremonial purposes and possibly for battle (use as a weapon is not confirmed but very likely). If the blade was elongated and the edge was straight or nearly so, almost certainly the axe was meant specifically for forestry. Some contemporary makers still produce woodworking axes with steel heads that are very similar to the ancient *labrys*.

Millennia later, the double-bitted axe had another significant role in the service of a different civilization, when European settlers brought it to North America. The philosopher Ronald Jager discusses the role of this tool in US and Canadian societies in "Tool and Symbol: The Success of the Double-Bitted Axe in North America" (*Technology and Culture*, Vol. 40, Oct. 1999). Acknowledging the three advantageous features of the double-bitted axe—balance (head symmetry), aerodynamics (long handle) and versatility (double edge)—Jager describes the evolution of the felling axe after it was introduced by the invaders, reporting that the axes brought by settlers came to be viewed by them as too heavy and inefficient. North American smiths began to forge shorter heads after it was noticed that bits worn down by repeated grinding worked more efficiently. The symmetrical shape began to be seen newly as a performance feature. Only one edge was regularly honed and used for cutting while the other was left a bit blunt and used for rough jobs like clearing knots (Fig. 4).

The development of blacksmithing techniques was also significant: wrought-iron axe heads often had inserted steel cutting edges, and solid steel heads were eventually introduced. The massive demands of the 19th-century North American wood industry resulted in factory production, with highest product quality the ultimate goal. Jager cites data from *Scientific American* showing that 81 patents related to axes were issued in the years 1830–1873. What lies behind a set of dry facts about the economy in North America in the 18th and 19th centuries is the human factor leading to the glorification of the felling axe in the hands of a worker and its meaning in the construction of a new country. The double-bitted axe became the symbol of a secular cult related to the myth of American woodsman (Fig. 5).

ANOTHER type of axe is closely linked to autocthonous North America. The tomahawk is an ancient woodworking tool and a noble object of cult. The name applies to different implements. Early English settlers like John Smith (*Map of Virginia*, 1612) or William Strachey (*The Historie of Travaile into Virginia Britannia*, ca. 1616) indicate that *tomahawk* is connected with the Algonquin expression *tämähakeu* ("he uses for cutting"), and associated with *tomahack* (axe), *tockahack* (pickaxe) and *monacooke* (sword), though it should be remembered that many words of indigenous origin are transliterated using English phonetics. The word may refer to an early North American hatchet with a wooden handle and a grooved, sharpened stone head lashed to it with rawhide or an evolved version with the stone fitted through a mortise in the handle (Fig. 6). The woodworking tomahawk with stone head was used for felling trees by first burning part of the tree, later clearing the charred section and then repeating the sequence until the trunk fell. It's not clear whether the tomahawk was actually used for battle, but it is known

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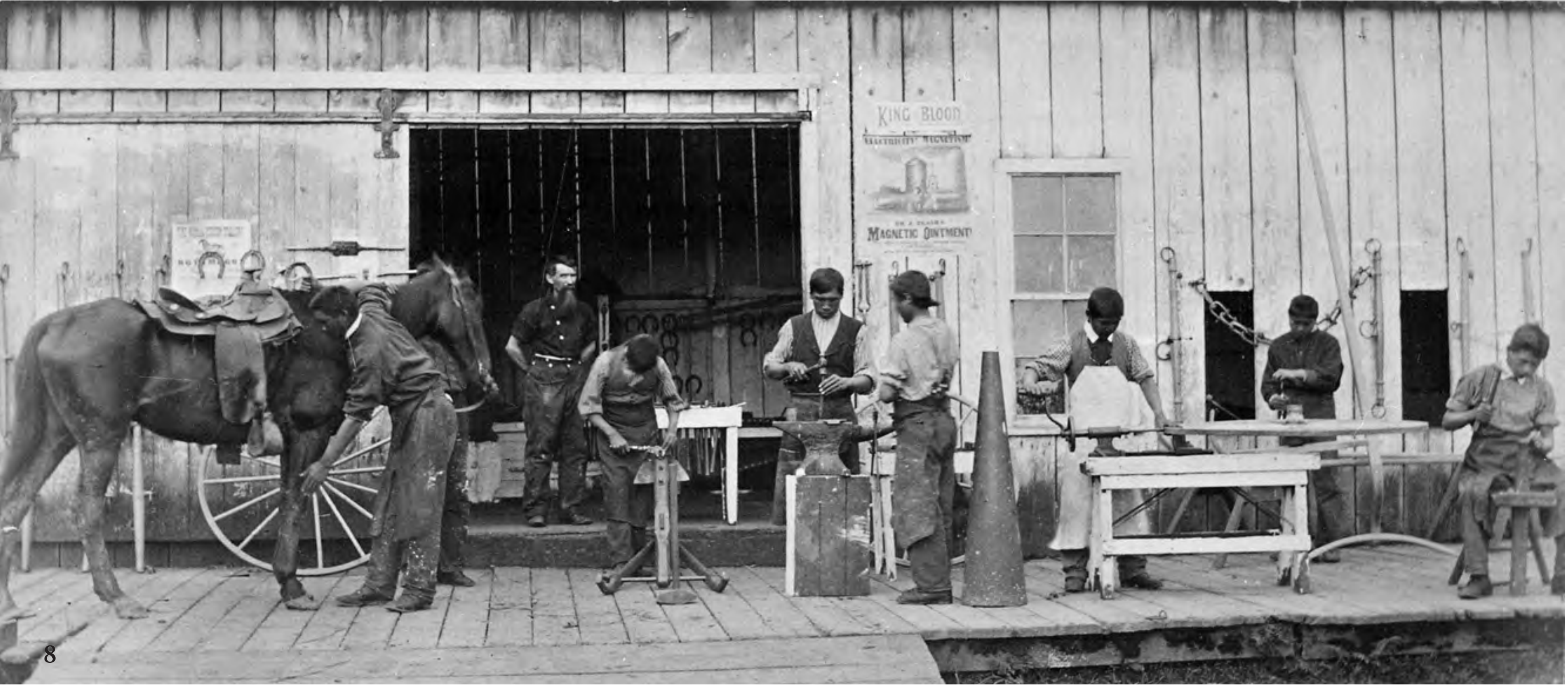

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US National Archives and Records Administration

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William Henry Jackson, NAA

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National Anthropological Archives, Smithsonian Institution

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US National Archives and Records Administration

7 **Below left, North American war club.**

8 **Forest Grove Training School, Oregon, alumni practicing smithing ca. 1882.**

9 **Below right, iron-headed tomahawk**

10 **Pawnee chief Te-Low-A-Lut-La-Sha (Sky Chief) with iron-headed tomahawk, 1868.**

11 **Kiowa chief Gui-Pah-Go (Lone Wolf) with ceremonial iron pipe tomahawk, 1870.**

12 **Chippewa Way John smoking pipe tomahawk, Red Lake band, Minnesota, 1923.**

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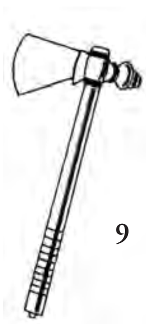
that bows and arrows or war clubs were used for fighting an enemy. The war club was made out of dense wood in the form of a slightly curved shaft with a ball or other massive element mounted on one end (Fig. 7). This item was used for striking or, more likely, for throwing. Some historic sources indicate that this weapon was sometimes simplified and designated as an emblem of war (to bury it means peace) but its name was confused with one used strictly as a mechanical tool. Metallurgy was introduced to native tribes along with European tools and weapons. Having demonstrated a certain admiration for metal inventions, Native Americans were lavished with hatchets, axes and knives imported from the old continent, and later were taught blacksmithing techniques (Fig. 8). This interaction resulted in an object of a new kind, another version of a tomahawk, adding another element to the nomenclature investigation (Figs. 9 and 10). A reshaped axe with wrought-iron head served equally as woodworking tool and weapon. It cut more efficiently than stone and, when in the hands of a warrior already proficient at tossing the war club, the metal tomahawk naturally took on the role of a throwing axe in a battle.



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John Atherton

Brooklyn Museum

Honolulu Museum of Art

Brooklyn Museum

13 Wrought-iron axe, West Africa, hand-shaved shaft with mortised metal head. Blackened head probably caused by mud soak.

14 Songye ceremonial axe, 19th or 20th century. Wrought-iron mortised head, wooden handle decorated with metal sheath.

15 Songye ceremonial axe, 19th or 20th century, Democratic Republic of Congo.

16 Songye ceremonial axe. Elaboration of blacksmith's art reached exceptional levels in territories of Angola, Congo and Zambia.

This invention later was transformed into the so-called *pipe tomahawk* (believed to have been introduced in the first half of the 18th century) combining a ritual pipe and a hatchet. Inspiration for this object might have come from the fact that colonists used ash saplings for axe handles while the natives used it for pipes, hollowing the sapling by burning out the heart with a hot wire. The head of the pipe tomahawk meanwhile offered a long slim edge, with the pipe's bowl fixed on the other end of the shaft (the poll). (Figs. 11 and 12). Pipe tomahawks, whether ornate (both the wooden and iron parts) or modestly decorated, were always manufactured with great care for detail, which demonstrates special status for the artifact, a polymorphic object with various meanings in a moment of intercultural encounter: an offering, a propitious spirit, an item of pride and defense.

THE characteristic axe of West Africa has a handle carved in hardwood to a cylindrical shape, with both ends rounded, and a long, slim iron head resembling a splitting wedge pierces the swelling at the top of the hardwood handle, which perhaps also adds a little weight. The long, slim tang is held in place by friction, renewed by an occasional soak in mud. Such an axe is used for felling, farming, construction work, splitting and woodworking, and allows for pulling, dragging or even rolling a timber or log.

Eugenia W. Herbert suggests in *Iron, Gender and Power: Rituals of Transformation in African Societies* (1993) that knowledge of metallurgy in a given society was never shared with a wide group to preserve control by a few, especially in religious and political matters. Smithing in numerous societies is considered elite or even sacred. It has always been particularly meaningful in Africa, where the Iron Age supposedly began earlier than in Europe (in Africa evidence has been found of functioning furnaces dated 1300 BCE). The process of turning stone (metallic ore) into metal is perceived as metaphysical. Metalworkers, Herbert observes, used to live outside of society, believed to be mediating between earthly and divine realms. Elaborate and richly decorated ceremonial axes and beautifully shaped throwing knives are the fruit of African blacksmithing craftsmanship. The most prominent examples come from Chokwe, Lwena and Songye peoples in territories of Angola, Congo and Zambia (Figs. 14–16).

NOT only among African tribes were professional smiths thought to hold supernatural powers. Nordic cultures also associated metalwork with spiritual activity. Vikings believed that mythic dwarves could make weapons and tools for both humans and gods. The actual status of a metalworker in this civilization likely changed between common and elite according to social and political con-

Christer Åhlin and Iris Tiitto, Statens Historiska Museum, Stockholm

Inciatus

The National Museum of Denmark

Gränsfors Bruk

17 Mythical smith Weyland depicted on medieval Viking runestone. Figure suggests supernatural position of metalworker.

18 Mammen axe, 10th century, Denmark, with motifs equally understood by pagan and Christian interpreters.

19 Viking bearded axe head (*skeggøx*), ca. 1000. Designed to serve as woodworking tool, later also implemented in battle.

20 Viking-style bearded axe head, ca. 2015, a popular form with artist-blacksmiths worldwide.

ditions. The pragmatic isolation of the smithy in a remote site because of its disturbing heat, fumes and noise at the same time engendered particular mystery in the sounds of hammering and dark smoke escaping, and stories about secluded metalworkers can be easily mythologized (Fig. 17) .

Despite the soot and smoky atmosphere, the pagan practice was acknowledged as spiritual by introduced monotheistic religion. Archaeological excavations sometimes reveal the proximity of smithies and Christian chapels, which can be interpreted as a practical arrangement as the churches were often equipped with forged cult objects, but also can be seen as evidence of overlapping religious contexts. Olle Heimer, describing these excavations in *The Mythical Forge and the Holy Chapel* (2010), also refers to former smithies that were turned into chapels.

The Mammen axe (Fig. 18), found in a grave in the Jutland peninsula of Denmark and dated 10th century, is a tangible expression of the dualism of Viking beliefs at a certain historical moment. Art historians have named a particular style of decoration after the location of the tomb, and objects representing Mammen style are often interpreted as vessels for simultaneous pagan and Christian symbolism. A single theme can be associated either with the old or the new religion. Floral decoration on one of the axe faces is often read as the biblical Tree of Life or as an important element of Viking mythology, the eternally green ash tree called Yggdrasil. A birdlike creature depicted on the other face is thought to represent the pagan rooster Gullinkambi, waking warriors for the ultimate confrontation, but also to represent the Christian phoenix associated with the resurrection of Christ. In both pagan and Christian tradition, the axe carries symbols of rebirth or awakening. This iron axe head is richly embellished with silver inlay. Elaborate fabrication and ornamentation imply the high status of this particular object, never put to use but engaged in the burial ritual of a wealthy man. That the axe is imbued with metaphorical rebirth, thus creation (this belief aligns with the symbolic attribution of the Minoan *labrys*), may relate to the making of the tool and what the tool in turn can make.

Viking culture contributed significantly in the development of axe technology. Learning from experience, they invented lightweight battle axes and perfected woodworking tools. Lovisa Brånby in "Ancient Northern European Axes" (2006), a 17-page monograph written for the Swedish makers Gränsfors Bruk and downloadable in PDF at docdatabase.net, reports that in the 7th century visible adjustments were made to axe design: "ears" firmly positioning the axe head on the handle, and an oval shape (rather than cylindrical) for the shaft, which provides a better grip and is less likely to twist in the axe eye. By this time the bearded axe (Norse *skeggox*) had been invented, a perfected woodworking tool suitable for cutting or flattening that continues to be made today (Figs. 19 and 20). Blacksmithing was widespread over the Scandinavian territories, apparent not only in the scope of archaeological finds but also with respected contemporary axe manufacturers still in Sweden and Denmark, as well as in adjacent Finland.

This brief voyage through the world of axes—entirely omitting the broadaxe, its own world—reveals the object not only as a tool or weapon but also as a bearer of beliefs in making, in transformation of the environment, and in human ability, whose practical application induces special admiration. A tool in action is animated, acquiring potency and effectiveness. If today's technology comprises mostly internally powered tools, the axe remains vital in the hands of a craftsperson. —Olga Micińska

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