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The Gwozdziec Synagogue



Ed Levin

1 Short log wall and base of synagogue roof to be installed with remaining elements and finished interior in 2012 at Warsaw museum.

A Synagogue Roof in Poland

THE roots of the Gwozdziec Synagogue roof project, undertaken in earnest this summer in Poland (Fig. 1), go back to the efforts of Marek Baranski, of Warsaw, who introduced the idea of reproducing the lost synagogue at Zabłudow to the Guild's 2003 TTRAG Symposium in Shepherdstown, West Virginia. Later that year, Baranski organized a conference in Bialystok, not far from Zabłudow, on the lost legacy of wooden synagogues. Numerous Guild members attended the Bialystok conference.

As time would prove, the most inspired were Rick and Laura Brown, artists and entrepreneurs at Handhouse Studio in Norwell, Massachusetts, and professors at the Massachusetts College of Art and Design (or MassArt). Handhouse had recently organized the building of a large 18th-century French builders crane at Norwell, working from original documents, and shown themselves adept at making a large reconstruction "a time machine for learning," as Rick Brown put it (see TF 64).

Handhouse took a deep interest in the subject of lost wooden synagogues and returned to Poland the next year leading a group of MassArt students, touring widely and looking at wooden vernacular architecture, making an extended stay in the village of Narew to document the Catholic and Orthodox churches there (see TF 70 and 75).

The Narew trip, the first of many such educational expeditions, workshops, courses and research projects focusing on the wooden synagogues of Poland, followed the Handhouse paradigm:

studying history hands-on via existing artifacts and documents, and then using traditional tools and techniques to replicate vital pieces of the past now lost to us.

Out of the 2004 trip, course work at MassArt and later MassArt trips to Poland in successive years, and with the help and collaboration of architectural historian and author Tom Hubka and other scholars, Handhouse put together a traveling exhibition, built initially around 1:12 scale models, first of the Zabłudow Synagogue (Fig. 2), then of another that had stood at Gwozdziec (Figs. 3 and 4), with additions coming to include a full-scale *bimah* (a central, free-standing pavilion with lectern, from which the Torah is read) and log entrance, as well as half-scale paintings reproducing ceiling panels from the Gwozdziec Synagogue.

While the Handhouse crews and classes traveled, observed, recorded and built models, in Poland the Jewish Historical Institute Association was making plans for a new museum to be built in the heart of what had been the Warsaw Ghetto and to chronicle one thousand years of Jewish history in Poland. (The Museum of the History of Polish Jews is scheduled to open in the spring of 2013.) Eventually, Rick and Laura Brown encountered scholar Barbara Kirshenblatt-Gimblett, leader of the team planning the museum's core exhibition, beginning an association that bore fruit in 2011 in the Handhouse project to build and install an 85-percent scale replica of the Gwozdziec Synagogue roof, including elaborate polychrome paintings authentically reproduced on wood, as a permanent exhibit at the museum in Warsaw.

Handhouse Gwozdziec Reconstruction Timeline

- 2003 - Handhouse initial visit to Poland
- 2004 - Zabłudow model, coursework, Handhouse workshop
- 2004 - MassArt student travel documenting historic architecture of Poland
- 2005 - Gwozdziec ceiling painting workshops (first of series)
- 2006 - *Bimah*-building workshop
- 2007 - Student travel documenting historic architecture of Poland
- 2007 - Rick Brown Fulbright research fellowship
- 2007 - Student travel documenting painting
- 2008 - Gwozdziec model, course work, workshop
- 2008 - Student travel documenting painting
- 2009 - Student travel documenting historic architecture of Poland
- 2009 - Student travel documenting painting
- 2011 - Framing workshop in Sanok, painting workshops, with student, professional, Polish and international participation
- 2012 - Museum replica painting workshops (ditto)
- 2012 - Installation of timber frame, cupola and painted ceiling in Museum of the History of Polish Jews in Warsaw
- 2013 - Opening of the Museum and permanent exhibition of Gwozdziec roof



Handhouse



Ed Levin



Alois Breier, Max Eisler and Max Grunwald
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2 At top, first stage of model of Zabłudow Synagogue built at Handhouse Studio in Massachusetts.

3 At middle, model of Gwozdziec Synagogue built at Handhouse, on site in Poland for reference by the builders of the reconstruction.

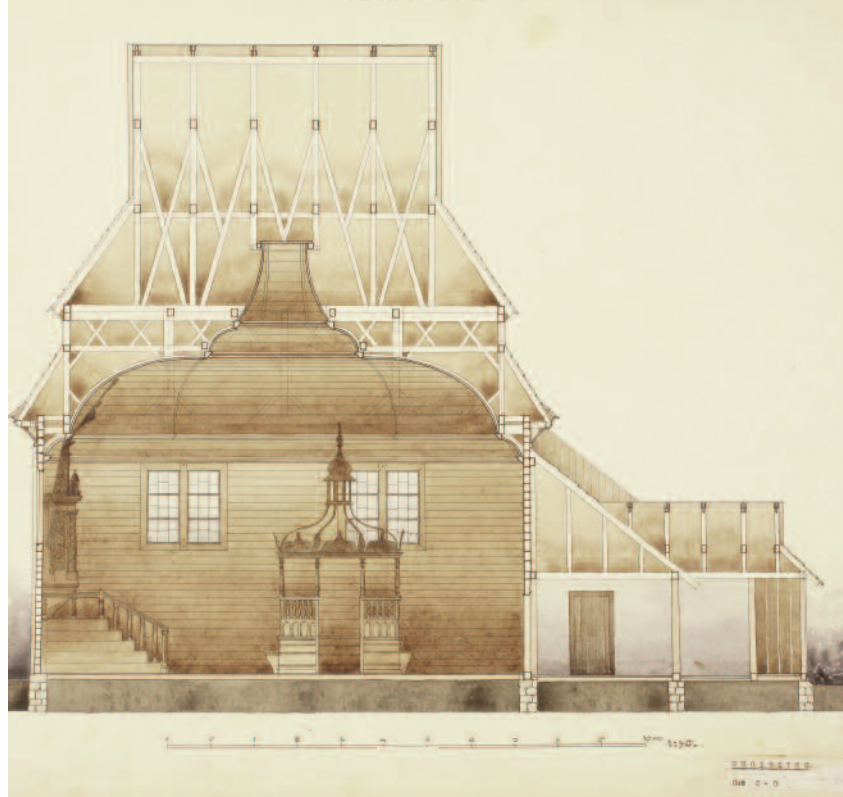
4 Above, photo of Gwozdziec Synagogue, ca. 1913.

Handhouse turned to the Timber Framers Guild as prime contractor for the timber structure. The work was to be done by some 30 professional framers working in tandem with crews of students (including MassArt students) from the US and Poland in a six-week workshop this summer in southeastern Poland. Once the cupola was completed, the structure would be dismantled, the pieces numbered and log walls and timber frame would go into storage pending completion of the museum building in Warsaw. The cupola sheathing boards would be measured, numbered and packed to travel to eight successive painting workshops organized by Handhouse and scheduled over this summer and next, where student painters, including many from Poland, would recreate the polychrome ceiling of the Gwozdziec Synagogue. The timber frame and painted cupola would reunite in the completed museum building in Warsaw in the fall of 2012. The Guild workshop completed the promised woodwork in July and the cupola boards are being painted in the scheduled Handhouse workshops.

History Behind the Gwozdziec reconstruction project, funded by the major gift of Irene Pletka and the Kronhill Pletka Foundation, the history reaches back to the 17th century and beyond. Our contemporary perception of Polish Jewry is typically seen through the lens of the Holocaust, but there is a thousand-year-long history of Jews in Poland. While the reality of anti-Semitism, ghettos and human tragedy cannot be denied, there is much more to the story.

Coming up to World War II, one-third of the population of Poland was Jewish, and Warsaw had the largest Jewish population of any city in the world. Back hundreds of years Poland was known as the *paradisus Iudaeorum* (Jewish paradise), a place renowned for its tolerance and acceptance, particularly through the period of the Polish-Lithuanian Commonwealth from the middle of the 16th century to the end of the 18th century. During extended periods of peace and prosperity, Jewish communities and Jewish culture flourished in Poland, leaving an artistic and architectural legacy. And most notable among the building heritage were wooden synagogues dating from the 17th and 18th centuries.

Wealthy urban congregations built stone synagogues. Village communities with limited but sufficient resources resorted to timber and produced a style of building unlike anything seen else-



Alois Breier, Max Eisler and Max Grunwald. Images used by permission Tel Aviv Museum of Art

5, 6 Breier, Eisler and Grunwald's combination section-elevations of Gwozdziec, from which roof reconstruction dimensions were scaled.

7 Facing page, view of open-air museum in Sanok, Poland, where framing reconstruction took place. Note oil derrick.

where, before or since. These structures featured tall log walls surmounted by elaborate timber frame roofs. To the street they presented more or less ordinary façades, impressive in size, but similar in style to other domestic and modest ecclesiastical buildings. But inside was a very different story. The roof frames supported (and were concealed behind) compound curved domed cupolas, with inside wall and ceiling surfaces throughout covered with brilliant polychrome liturgical paintings and religious texts.

This interweaving of two separate structures into one made the synagogues into hermetic vessels, their plain exteriors concealing interior spaces of extraordinary power and intensity. It's hard to imagine the sudden, enormous and complete transition from the secular street to sacred space experienced by congregants entering the synagogue. Tom Hubka describes the experience in *Resplendent Synagogue* (2003):

For the Gwozdziec congregation, moving from the outside world into the prayer hall's swirling vortex of form and color must have been an intense spatial experience. Their day-to-day lives were set in a muted environment dominated by the dull browns and smoky grays of earthen streets and untreated wooden structures, broken only by points of color and texture. Against this muted backdrop, the prayer hall had visceral intensity that was literally not of their everyday world.

One other element that presumably set these buildings apart was sound. I remember my own experience in 2003 of choral sacred music in a small polygonal wooden church deep in the Polish countryside at Szczyty-Dzieciolowo. As we left the bus and walked toward the green-painted walls of the building, the air suddenly filled with music. It was an Orthodox holy day, and the congregation (mostly women in coats and headscarves) crowded the octagonal nave as their raised voices, counterpointed by the deep tones of the young priest, filled the space inside the church and spilled out into the walled churchyard and beyond. Impossible to describe the sense of wholeness inside this wooden vessel, suddenly and completely made holy by devotion embodied in song.

I have no doubt that to hear the cantor singing and the congregation chanting under the domed ceiling of a wooden synagogue was an equally transformative experience, no less than the pro-

found visual effects of the space.

Documentation Some six dozen wooden synagogues in greater Poland survived into the 20th century. Exact dating is often difficult, given that the buildings and the bulk of the primary documents pertaining to them have since been destroyed. Later 18th-century and 19th-century synagogues might have been built in one go—walls, roof and cupola—while 17th-century examples typically underwent 18th-century retrofits to accept interior cupolas.

Wooden buildings are vulnerable to decay and to destruction by fire (accidental and intentional). Examples of each brought home the fragility of the Jewish architectural patrimony in Poland, and in the 1920s professors and students at the newly formed Institute of Polish Architecture at the Warsaw Polytechnic undertook to document these buildings. Because of their foresight, we have photographs and measured drawings of then-extant wooden synagogues, and books like Hubka's *Resplendent Synagogue* and Maria and Kazimierz Piechotka's *Wooden Synagogues* (1959) are possible.

In addition, we have photographs and measured drawings of the wooden synagogue at Gwozdziec, which had been destroyed in the First World War (Figs. 4–6). Alois Breier, Max Eisler and Max Grunwald documented Gwozdziec (among other synagogues) in 1913, although their work was not published until 1934 as *Holzsynagogen in Polen*. The Tel Aviv Museum of Art provided Handshouse with image scans of the Gwozdziec plates.

The skansen The venue for the synagogue roof build was the open-air museum, or *skansen*, in Sanok, in the southeastern corner of the country (Fig. 7). Set in the foothills of the Carpathian Mountains, with Ukraine about 20 miles to the east and Slovakia 20 miles south, the Muzeum Budownictwa Ludowego (Museum of Folk Architecture) is the largest open-air museum in the country, displaying dozens of relocated buildings representing the four ethnographic groups that inhabited the region.

Our workspace at the *skansen* was a gently sloping field adjacent to the display of early petroleum-extraction equipment (Poland was an oil-drilling pioneer). Spread out on bunks was the material for the frame, over 200 European silver fir (*Abies alba*) logs in lengths up to 40 ft. We had before us two distinct projects, first the timber frame structure of the top of the synagogue, including



John Niningger

shortened walls, and then, fitting neatly inside its roof frame, the cupola, a scaffold to carry boarding in four ascending stages, in effect a compound-curved canvas for reproducing the elaborate polychrome liturgical painting that blanketed the interior of the original prayer hall, walls and ceiling.

The Gwozdziec Synagogue was built over a square plan in three vertical stages. The drawings showed that a base of 20-ft.-tall log walls enclosed the prayer hall, 36 ft. on a side. Next a 32-ft.-square box frame, composed of double sills and plates connected by 16 posts, rose 8 ft. 6 in. above the tops of the logs. Finally, six trusses spanning the box frame plates formed the upper main gable roof, with a pitch of approximately 15:12 and a ridge 23 ft. long, allowing for lean-to roof slopes at either end spanning 4 ft. 6 in.

Echoing the upper roof was a slightly steeper lower roof (17:12), with rafters rising from a flying plate (cantilevered 2 ft. outside the log walls) up to girts set 3 ft. below the top of the box frame. Both lower and upper roofs featured hipped corners. Over time, the prayer hall had been surrounded by supplementary structures yielding yet another band to the cascade of lean-to hip roofs.

In its original 17th-century form, the prayer hall seems to have had a simple shallow barrel vault ceiling, indicated by curved inner surfaces on internal bracing shown in measured drawings done early in the 20th century before the destruction of the building. This curve appears both as a cut surface on the lower scissor braces and a dotted line on the upper scissors rising to the main tie beams. (Fig. 5). By extending and joining these lines we could extrapolate the shape of the original barrel vault.

But by the early 18th century, the space had been remodeled and the interior of the roof frame adapted to the four-stage compound cupola (the cupola ceiling painting has been dated to 1729).

The organization of the Guild framing crew echoed the vertical order of the building and a disposition of special talents. John Niningger, a skilled log builder, was in charge of the log walls. Gerald David, a trained *Zimmermann* experienced in historic framing, took charge of the box frame. Bob Smith, veteran of international framing expeditions and all problems that arise, took on the roof frame. The cupola with its multiple curves was the province of millwright and boatbuilder Jim Kricker.

Overseeing the operation were lead carpenter Mikkel Johansen, who took a “vacation” from his timber framing business in Denmark, and Guild project manager Alicia Spence, along with the overall project managers Rick and Laura Brown of

Handhouse. Barbara Czoch, of the UK Carpenters’ Fellowship and fluent in Polish, was our invaluable minister without portfolio, splitting her time among logistics, translation and pitsawing, of which she was the master. *Skansen* architect Arek Kryda, an expert in Carpathian log building and a vital pillar of the project since well before our arrival in Sanok, quickly made himself indispensable. For crew, in keeping with the nature of the project, we had an international team of framers and students hailing from North America, Belgium, Denmark, England and Wales, Estonia, France, Germany, Japan and, of course, Poland.

Hewing and pitsawing Before we could begin to lay up the log walls or start chopping joints for box frame or roof trusses, we needed hewn beam and post stock. I can testify from direct experience of historic replication work that the choice is typically made to take the low road in timber conversion—to use machine-sawn timber and subject it to some kind of fakery to produce hewn surfaces, a procedure that satisfies neither aesthetically nor philosophically. So it was thrilling to learn that project manager Spence was determined to keep to the high road and hew the timber directly from the log. And scantlings (smaller stock) for braces, common rafters and the like would be gotten out by dividing hewn baulks into two or four smaller sticks with a pitsaw. (The one exception would be the 3x10 stock for the 24 dome ribs, to be supplied by a sawmill.) Alicia had done the paperwork and the spreadsheets, and the project charts indicated that it could be done. But frankly it took some serious chutzpah in the face of limited time and the daunting job at hand: over 200 logs to be converted into 450 timbers—some 16,000 bd. ft. with 10,000 sq. ft. of surface area—by a crew of inexperienced hewers. And of course, that little task done, it would remain merely to scribe, cut and raise the log and timber walls and two-stage hipped roof, cut the compound four-stage curved cupola and fit the cupola to the frame.

Another challenge in store for the hewers was the timber itself. The winter-cut silver fir logs may have been handsome but, by the time we got to it, the wood was on the dry side, stringy with small tough knots. Not terrific hewing material and certainly nothing like hewing green pine or oak. There was also the matter of the relatively small sections of our timbers. The largest on the list were 6x8s and 7x9s and could be hewn out of logs with 10–12 in. dia. inside the bark. But many of our logs were actually 15 in. dia., and some larger, so there was a great deal of material to be removed,



Ed Levin

8–11 Clockwise from top left, deep-scoring oversize logs, joggling large chips, hewing to the line quad-teaming fashion and, at left, turning to another trade, trestle-sawing to get out smaller stuff from hewn baulks.

vastly increasing the work of scoring and joggling (removing the first large chips). With significantly oversized logs, the hewers resorted to deep scoring with two-man saws rather than felling axes (Fig. 8).

Lead carpenter Johansen had cut a deal with Gränsfors Bruks, the Swedish axe-manufacturer, for a mass purchase of felling and hewing axes at substantial discount. So we were well equipped. The crew set aside their usual framing kits, shared safety and technique briefings, picked up their axes and set to work (Figs. 9, 10).

Not knowing the numbers, I can't say that the Gantt production schedule charts were wrong. But I'm pretty sure the time and energy investment in hewing and pitsawing substantially exceeded the tabulated estimates. But then so did the rewards of doing the right thing. I can say with conviction that for this crew of framers and students, it was among the great work adventures of their lives.

For the first two weeks on the ground in Sanok, pretty much the whole enterprise was devoted to hewing. But on the other conversion front, Barbara Czoch and Leon Buckwalter put heads and hands together to make a trestle for swivel-sawing. Once enough large timbers had been hewn, the saw went into action under Barbara's direction, producing braces and common rafters (Fig. 11).

With the beam pile growing, the joinery began. Where the evolved default joint in Western European framing is the pegged

mortise and tenon, in Eastern European carpentry it is the lap dovetail and its close cousin the half-lap crossing. Blind mortise and tenon joints are found only occasionally, as at the meeting of major posts and beams. Taking advantage of the larger log sizes, John Nininger was able to reduce the number of courses in the short log walls from six or seven down to five. He chose the dove-tailed corner, full-scribe log method (Fig. 1), a choice supported by local historical evidence. After scribing in place, longitudinal log joints were hollowed with the so-called Harley-Davidson drawknives (handlebars the reference) to ensure tight fits at the surfaces (Fig. 12).

To keep the bulk of the joinery close to the ground where it was easily accessed and worked on, John prescribed that the short log walls be laid up *inverted*. The layer including wall plates and lower box frame sills went down first, then the remaining courses were scribed on one by one—the entire construction stood on its head. Meanwhile, the same trick was employed on the framed walls, with the box frame plates going down first then posts, girts and X-braces scribed upside down.

Once the log walls were complete and the box frame establishment taken as far as possible, both assemblies were pulled apart then quickly re-erected right side up with the box frame in place



Ed Levin

12 John Nininger, with drawknife, explains hollowing the underside of a squared log to fit neatly over the one below in a full-scribe hewn log wall. From left, Museum of the History of Polish Jews director Agnieszka Rudzińska and Gwozdziec project co-director Rick Brown.

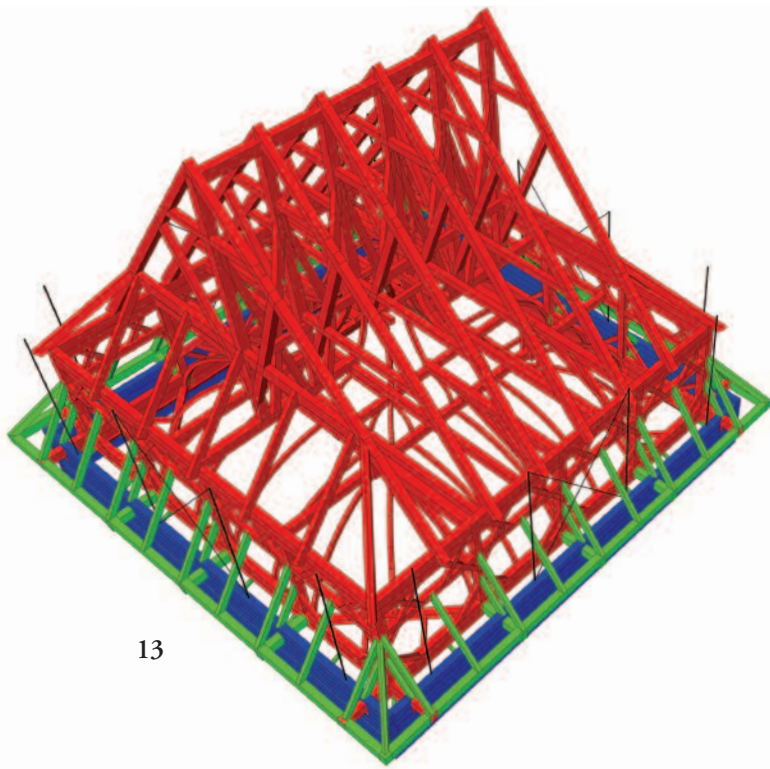
atop the log walls. Post feet were married to the box frame sills and lower braces scribed in, and flying plates were added to the outer ends of the hammer-beams to allow fitting of the lower roof.

While the intricate dance of log walls, box frame and roof proceeded, Jim Kricker's crew hewed away at the 80-odd curved ribs that carry the cupola boards. Working from the cupola profile drawings, they lofted and cut full-size Masonite patterns and used them to select and lay out the stock. Each of the major ribs of the dome was made in two parts from sawmilled, sistered 3x10s, half-lapped in the length at midspan to make up the full length of the curve of the dome and pendentives. Remaining shorter ribs for the cove, zodiac and lantern were one piece, hewn from a mixture of sawn lumber and naturally curved sticks taken directly from the nearby forest.

It was not unusual to see Jim walking off into the woods to hunt for stock, or heading out in a truck with Arek Kryda to explore a new woodlot. The results—a firewood pile to the uninitiated—were then picked over by the cupola builders, patterns in hand, and their axes and hatchets maintained a steady rhythm under the tent adjacent to the office hewing cupola curves. As a sign of progress, mockups of partial cupola stages would periodically invade the office to be checked for conformity with the plans.

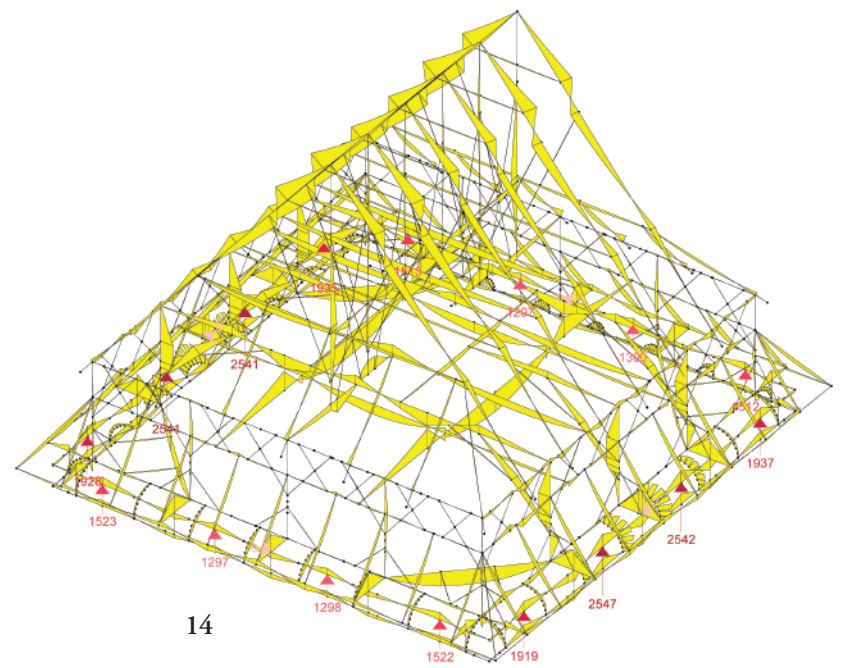
Design Prime source material for recreating the frame, cupola and decoration of the Gwozdziec Synagogue was the work of Breier, Eisler and Grunwald, who had documented the synagogue in photos and drawings a few years before its destruction in the First World War. Their black-and-white photos were the primary basis for Handhouse reproductions of the Gwozdziec paintings, and their measured drawings included sections and elevations of the prayer hall taken in both directions, as well as framing plans. There are no dimensions, but all three drawings have on-board scales, a 5m scale on the plan drawing and the gable section (east elevation), a 10m scale on the ridge section (south elevation). Both scales are graduated with 1m hash marks (Figs. 5 and 6).

By bringing these drawings into a computer-aided design (CAD) drawing at scale and in correct orientation, I could trace frame elements over the original layout and create a full three-dimensional model of the timber frame and cupola, an accurate representation of the structure according to Breier *et al.* The process was not completely straightforward as there are some minor discrepancies between the individual source drawings, and not all frame members are shown. Some pieces are simply absent (cupola ribs, for instance), others appear only in one or two views, and there are dimensional differences from section to plan.



13

13 Load displacement drawing shows how core of structure does not sit directly over log walls that ultimately support it. Core elements in red, log walls in blue, connecting and ancillary parts in green. Slender suspension rods (black) lead up to concrete museum ceiling (not shown), from which entire 64,000-lb. timber structure will be hung.

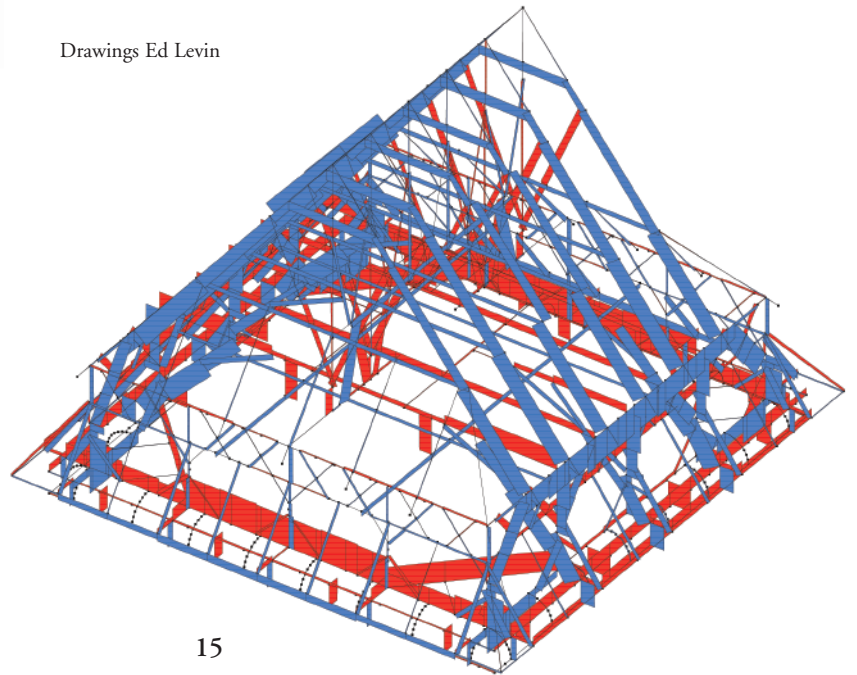


14

14 At right above, diagram of bending stresses, timber by timber. Width of yellow band is proportional to magnitude of stress. Support rod locations shown by red arrows, reactions in kilograms. Principal bending loads are found in long members crossing ceiling, tasked with supporting cupola over full span of prayer hall.

Drawings Ed Levin

15 At right, axial loads represented graphically, compression force in blue, tension in red. Major tension loads are found in the box frame sills, octagon braces and the portion of the hammer-beams connecting out to the log walls. Significant compression forces follow main roof load path to stiff log walls.



15

The drawing process for the Gwozdziec frame replica differed in several notable respects from earlier drawings I had made for the model-building at the Handshouse workshops in Massachusetts. For one thing, authentic joinery was now a prime consideration. We weren't building a miniature this time, and it wouldn't go together with hot melt glue and the occasional brad. Along the same lines, there were engineering considerations to be taken into account. As a museum exhibit in a gallery setting, the replicated roof would not have to bear snow or wind load, but it would have to support itself plus the dead load of roofing, cupola and siding, plus the live load of workmen during installation and maintenance, and it would have to comply with modern Polish building codes.

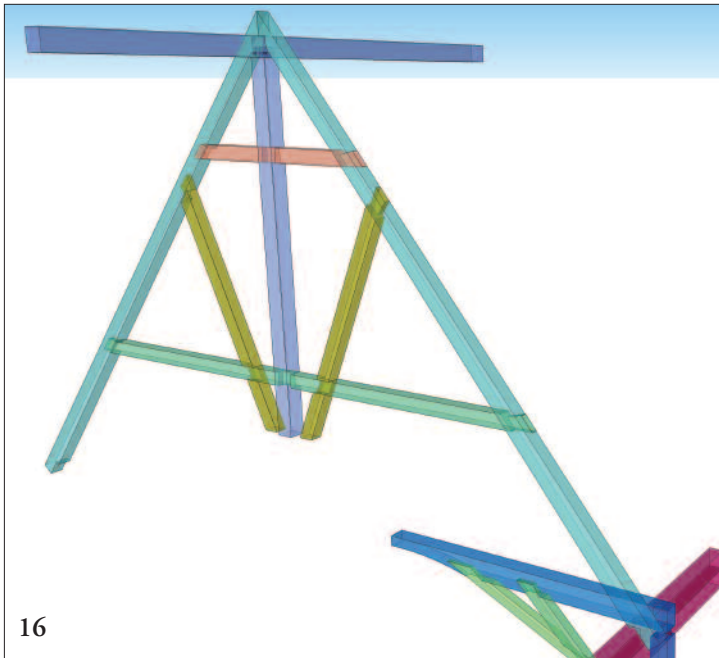
By modern standards, the original structure was notoriously lightly framed and its roof structure had been significantly compromised by the major early-18th-century cupola remodel. As seen in photographs, it is apparent that the roof frame was less than robust and that gravity had taken a toll.

Issues engendered by units and scale led to additional bends in the path from source material to construction documents. With historic joinery taken into account, working at 85 percent of the original to meet the museum's size requirements was not a simple matter of pressing a 15 percent reduction button. Given the Eastern European standard of side-lap joinery, and the fact that lap

joins were not typically framed with the members set flush with one another (save for the sheathed surfaces of floors and walls), changing member sizes affected relative member positions. Thus minor size adjustments could ripple through and have significant effects on the overall configuration of the frame.

Before engineering review of the frame, I ran the timber lists by the leadership of the Guild building crew. Looking at sections of 5x7 and 5x5 equivalents (and sometimes smaller) in 32-ft. to 36-ft. lengths, the professional framers nixed any reduction in timber section. So it was back to the drawing board. In the final frame drawings, lengths were scaled down 15 percent. Where the outside footprint of the log wall base had measured 37 ft., for instance, it now scaled at 31 ft. 6 in. But all timber sections and thus most joint dimensions remained unreduced.

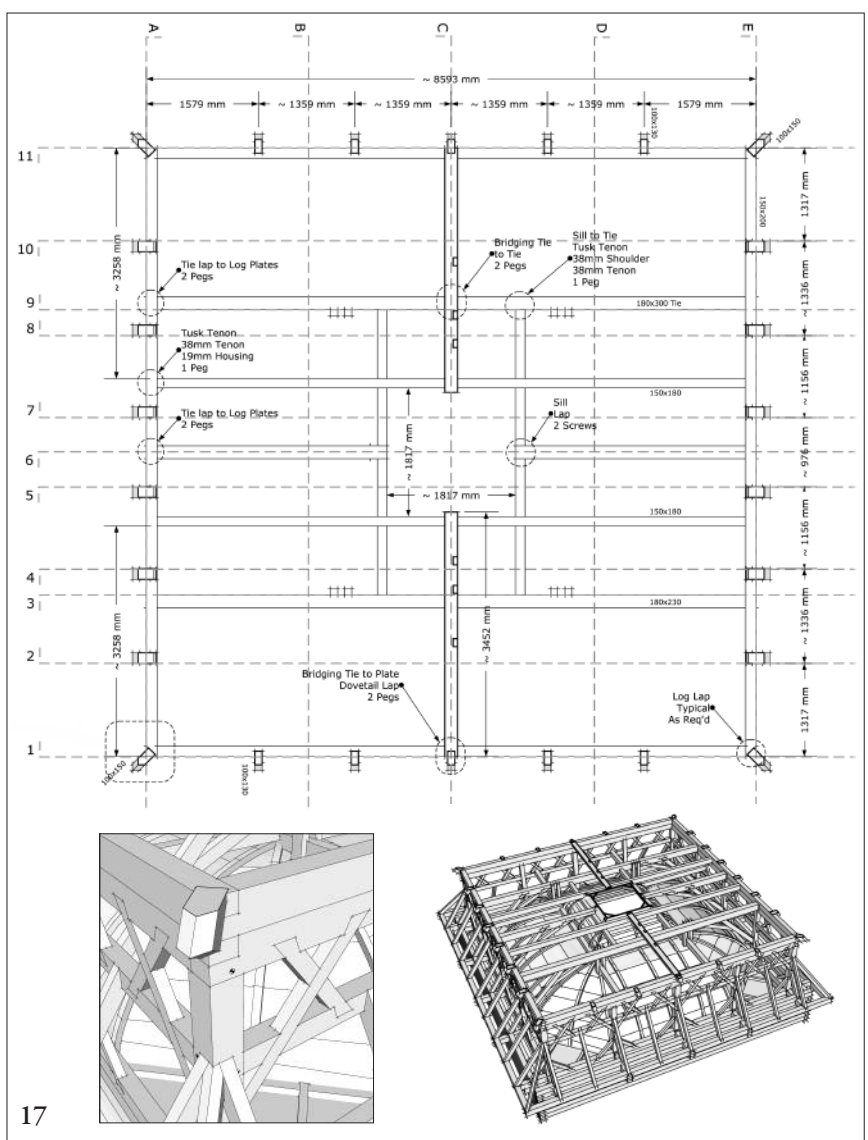
Engineering As specified under the design and engineering agreement for the Gwozdziec frame replica, framing plans would be prepared in the US and analyzed here for compliance with Polish building codes. The plans and structural analysis would then be submitted for review and approval by the Museum's project engineer. The American structural engineer was Ben Brungraber of Fire Tower Engineered Timber (Providence, Rhode Island), the Polish engineer Arkadiusz Łozinski of ARBO Projekt in Warsaw.



Ed Levin

16 Rendering showing roof truss joinery in Gwozdziec framework, mostly half-dovetail laps at ends and halvings at crossing joints, with an occasional mortise-and-tenon joint and notched joints at rafter ends. Wall log corner joints not shown.

17 At left, typical shop drawing (elements rearranged for publication) by Mike Beganyi, who brought the AutoCad frame model into SketchUp and, using LayOut, created a handsome set of shop drawings keying each dimensioned bent and wall section to cutaway 3D frame models, with connections highlighted in bubbles. Area inside dotted line at lower left corner of plan view is rendered in shaded perspective, entire assembly in line drawing.



Mike Beganyi

The timber frame CAD model (Fig. 13) was ported over to a finite element analysis (FEA) engine for review of resultant deflections, stresses and connection loads. No surprise, the Gwozdziec frame presented some unusual modeling challenges. A particular engineering concern regarding the frame was the horizontal displacement of major loads from major support mechanisms. Specifically, the weight of the main roof and the timber frame superstructure was channeled down along the perimeter of the box frame, which sits 2 ft. inside of the log walls. Thus the entire weight of the roof and box frame sits well inside its principal means of support.

Four load paths present themselves as possible channels to get this load to ground:

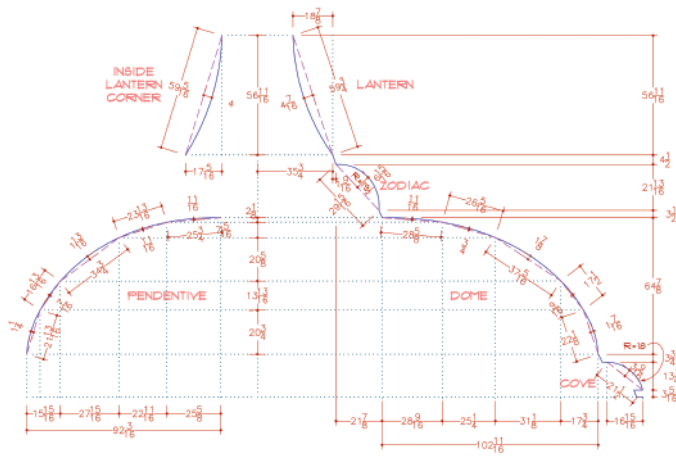
1. Some or all of the load can follow the box frame sills outward to the log walls. However the eight beams that comprise the double sills cross one another at the corners of the box frame where they are substantially weakened by half-lap joints.
2. A portion of the load can flow out along the hammer-beams that span between box frame sills and flying plates, with the log walls as a fulcrum between.
3. Load coming down the box frame posts can divert outward via the frequent 4x5 struts down to the log walls.
4. Finally, it's conceivable that some of the load finds its way down into the log walls via the ribs and boarding that form the cove, the lowest stage of the cupola.

Reviewing the axial forces in the roof struts and cove ribs, and the shear forces in the hammer-beams and box frame sills, the gravity load of the core of the building—the box frame, roof above and almost all the cupola load—is indeed shared between the available mechanisms, with about half the force taken by the roof struts, a quarter by the hammer-beams, a fifth via the box frame sills and about a twentieth by the cove ribs (sheathing effect ignored).

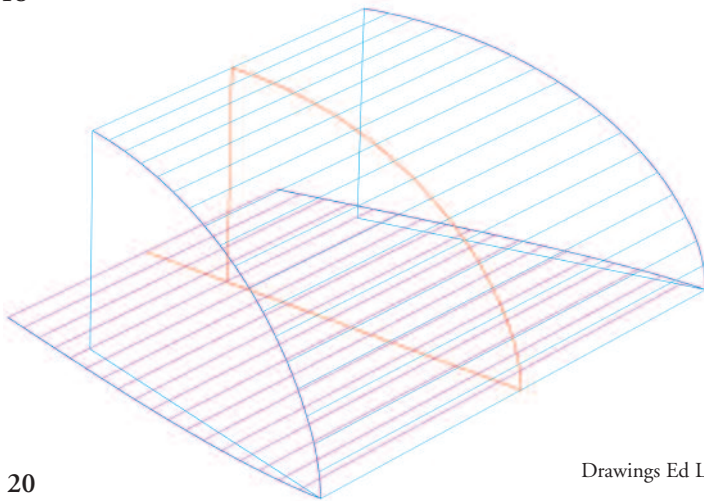
Collectively, these four load paths carry close to 40,000 pounds, approximately two-thirds of the total combined load of the entire structure. The results of the analysis were a bit of an anticlimax, which is to say they were what we were hoping for. Deflections were well within acceptable ranges, as were resultant axial, shear and bending stresses in the frame members, even under our unrealistic maximum load (Figs. 14 and 15).

The balance of the structural assessment was to review connection capacities under predicted loads. Joints (Fig. 16) were secured with wooden pegs, allowing 400 lbs. capacity per peg in single shear (lap joints) and 800 lbs. in double shear (mortise-and-tenon joints). Where pegging was not practical, timber screws were substituted with a working capacity of 300 lbs. per screw in single shear and 600 lbs. in double shear. Shop drawings were now in order (Fig. 17).

Suspension Since we would not carry the synagogue's log walls down to the ground, the structure must be designed to hang from the ceiling of the museum building. Our ultimate solution was to suspend the frame with a total of 16 vertical 24mm-dia. steel rods (four per side) on 8-ft. centers (visible in Fig. 13). The rods would run down through the centers of the log walls to washers and nuts at the bottoms of the walls. This system was adopted by the Polish engineers with the addition of X-rod sway bracing in the center panels. Given the small rod size, the suspension system was unobtrusive, and it could be used also to install the completed frame and cupola by rigging grip hoists to half the suspension points, allowing the timber structure to be winched up into place and the balance of the rods installed. By the same means the whole rig could be lowered at later times as needed, for maintenance of the frame or clearance to work on mechanicals in the museum ceiling.



18



20

Drawings Ed Levin

18 At top, dimensioned drawing shows profile of various ribs that carry cupola sheathing and was used to make full-size patterns for those ribs.

19 Above right, photo of cupola lantern is sole photograph we have of Gwozdziec Synagogue framing.

20 Above, sheathed surface of dome section with individual boards indicated by cyan lines. At base of 3D figure, surface is developed or laid flat, with edge joints shown in magenta.

21 At right, this surface shown with boards numbered and dimensioned theoretically on left (taken off the frame and cupola drawings) and on right by actual measurements off completed structure.



19

Alois Breier, Max Eisler and Max Grunwald
Image used by permission Tel Aviv Museum of Art

	117 ¹ / ₄	2 ¹ / ₈	113 13/16	19
	18 121 ⁷ / ₃₂	7 ¹ / ₈	114 3/4	18
	17 125 ³ / ₁₆	7 ¹ / ₈	118 3/8	17
	16 129 ¹ / ₈	7 ¹ / ₈	121 3/4	16
	15 133 ¹ / ₁₆	7 ¹ / ₈	125	15
	14 136 ⁵ / ₁₆	7 ¹ / ₈	128 1/4	14
	13 140 ²⁵ / ₃₂	7 ¹ / ₈	131 7/8	13
	12 144 ¹⁷ / ₃₂	7 ¹ / ₈	135 7/8	12
	11 148 ¹ / ₁₆	7 ¹ / ₈	139 1/8	11
	10 151 ¹ / ₂	7 ¹ / ₈	142 5/8	10
	9 155 ⁵ / ₃₂	7 ¹ / ₈	146 1/8	9
	8 158 ³ / ₁₆	7 ¹ / ₈	149 1/2	8
	7 161 ⁷ / ₁₆	7 ¹ / ₈	152 1/4	7
	6 164 ¹ / ₂	7 ¹ / ₈	154 7/8	6
	5 166 ³ / ₂	7 ¹ / ₈	157	5
	4 168 ⁵ / ₈	7 ¹ / ₈	158 5/8	4
	3 170 ³ / ₈	7 ¹ / ₈	159	3
	2 172 ¹ / ₈	7 ¹ / ₈	161 1/8	2
	1 172 ⁵ / ₈	7 ¹ / ₈	163 1/8	1
		7 ¹ / ₈	165 1/8	

21

AS DESIGNED

AS BUILT

Cupola In addition to the frame drawings, a second set of drawings documented the plans and profiles of the various cupola surfaces. The master CAD model included the cupola ribs and sheathing (Fig. 18). A set of beams expressly installed for the purpose (presumably in the 18th century) defined each cupola stage.

The cupola sill at the base of the cove was cleated to the inside of the log wall. The beam at the next stage—top of the cove, base of the dome—was attached to the underside of the box frame sills. Above that level, a gridwork of new timbers had been threaded through into the frame to carry the upper cupola stages: four long beams crossing tic-tac-toe fashion at the dome peak—zodiac base, with their ends framed in to the box frame girts; similar arrangements at the zodiac peak—lantern base (joined into the box frame plates and main tie beams of the original frame); and finally a quadrant of cupola top plates at the lantern peak, hung from truncated braces and kingposts in the roof frame.

A series of hewn curved ribs stepped upward and inward between these five levels of cupola foundation timbers: three dozen 2-ft. cove ribs, two dozen 11-ft. dome and pendentive ribs (each sistered together in two parts), sixteen 3-ft. zodiac ribs, and finally

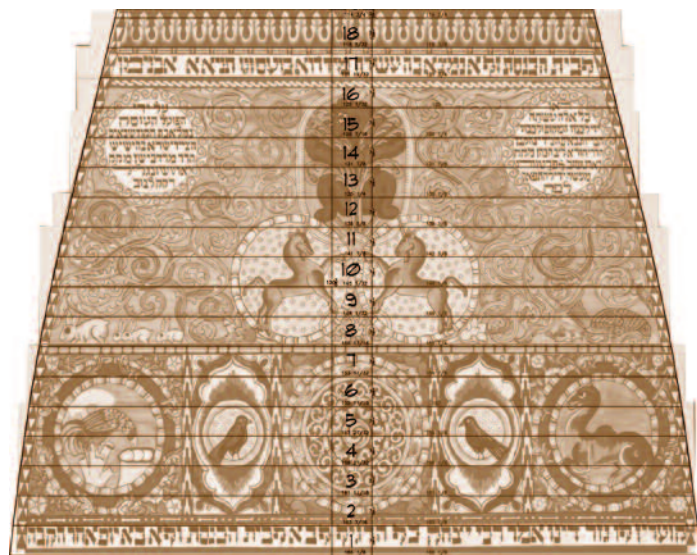
eight 6-ft. lantern ribs. By the evidence of the one surviving photo of the roof frame (Fig. 19), these sticks were hewn out of natural curves straight from the tree, and cupola team captain Kricker largely followed this precedent, save for the dome ribs, which, in deference to our limited time schedule, were taken out of machine-sawn stock (Figs. 22, 23). Likewise the cupola sheathing, which would be silver fir boards, milled, kiln-dried and planed to 1 in.

The critical interface was the curve that defined the inside of the ribs and the outside of the boards. The cupola drawings needed to supply the cupola framing team with the plan layout of ribs and boards and the curved inner profile for each of the ribs. Simple dimensioned 2D rib and board profile sections met most of the framers' needs. These could be taken directly from the CAD model. The painters, on the other hand, would need to know the numbers of boards per ceiling section, and their widths and lengths. Painting would be done section by section with the boards laid on horses (painting two or three boards at a time, limited by the reach of the painters).

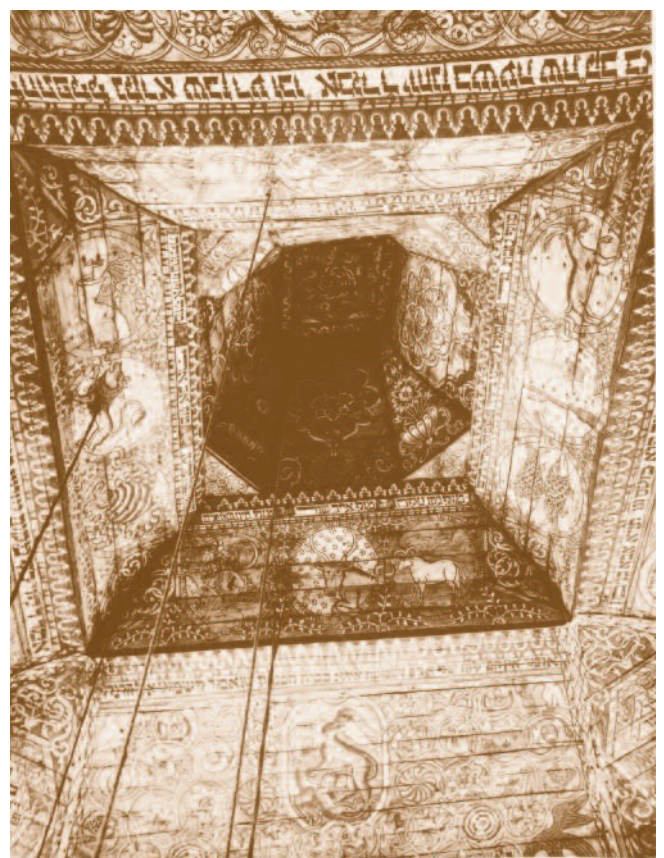
To generate this data, the curved surfaces of each ceiling section needed to be developed (laid out flat), a plan drawing made



Photos Ed Levin



Ed Levin and Handhouse



Alois Breier, Max Eisler and Max Grunwald
Image used by permission Tel Aviv Museum of Art

22, 23 At top, framer Mark Surnoskie shaves a fair curve on lower surface of dome rib, and dome ribs spring from box frame sills.

24 Above, ceiling painting applied over as-built board layout. To fit painting to wood, MassArt student Cailigh MacDonal, member of framing and painting workshops alike, carefully reshaped painted image in Photoshop without distorting internal geometry.

25 At right, detail of historic monochrome photograph used by Handhouse as basis for replication of Gwozdziec ceiling.

and the numbers, widths and lengths of the boards established (Figs. 20, 21). As far as possible, the numbers of boards per section should duplicate the original building's, a count that could be determined by close examination of photographs of the ceiling taken before the destruction of the building (Fig. 25).

These developed drawings were used to rough-in the sheathing. But since actual frame dimensions differed at least slightly from the framing plans, nor were actual board widths identical to those in the drawings, members of the painting crew went back and took as-built dimensions and the board plans were redrawn

(Figs. 21, 22). Finally the image of the painting was overlaid on the as-built board plan and tweaked carefully (so as not to distort images and geometry) until aligned (Fig. 24). —ED LEVIN

For more on the Poland project, visit mcnorlander@wordpress.com (the framing blog) and gwozdziecpainting.blogspot.com (the painting blog). For the history and philosophy of the project and much more (including a 120-page pamphlet for download), go to handhouse.org. For information on the Museum of the History of Polish Jews, go to jewishmuseum.org.pl/en/cms/home-page. To explore the skansen in Sanok, Poland, go to skansen.mblsanok.pl/a/stronaa.php?id=stronaa.